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Literature review of pain and welfare impacts associated with on-farm cattle husbandry procedures

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Abstract

This project was conducted to provide the cattle industry with information needed to negotiate the development of new cattle welfare standards. The project reviewed the welfare science on five beef cattle husbandry practices: castration, spaying, dehorning, branding and ear marking. It also examined Australian and international standards for the conduct of these practices, including those of a selection of animal welfare groups. There is a considerable body of science on castration and dehorning in particular. Regimes for effective anaesthesia and/or analgesia have been developed for various methods of castration and dehorning and certain methods are preferable to others from a welfare perspective. There is less information available on the other practices. A review of pain management in other species reinforced the potential effectiveness of local anaesthesia and nonsteroidal anti-inflammatory drugs. Current Australian welfare standards for cattle and sheep are generally in line with those of New Zealand and less restrictive than those of European countries.

This review attempts only to present the science of cattle welfare with some consideration of a range of standards. Industry must make judgements about appropriate levels of animal welfare that also take into account practicality, cost, public perception, market acceptability and other factors. A series of recommendations is made to assist the industry deal with the possible medium- and long-term evolution of animal welfare expectations and legislation.

Executive Summary

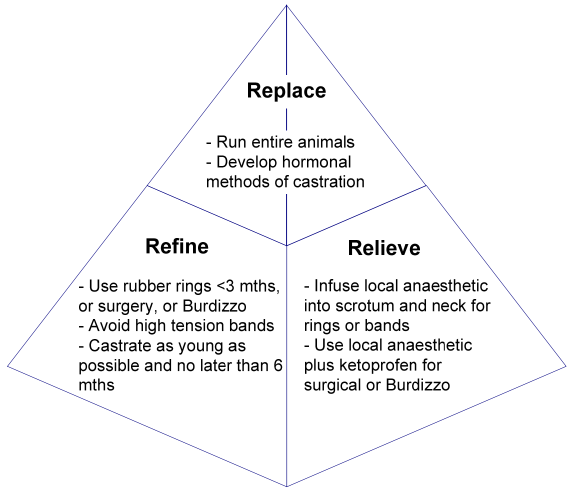
The aim of this project was to provide the information needed by the Australian cattle industry to respond to the imminent transition from national 'model' codes of practice for livestock welfare to legislated national standards and guidelines. Science is expected to be a critical element in establishing these standards. The cattle industry, including MLA, seeks to understand how current industry practices compare with scientific understanding and with international standards of animal welfare.

The project focused on five husbandry procedures commonly used on cattle in Australia: castration, spaying, horn removal, branding and ear marking. The methodology involved a review and analysis of the animal welfare science behind these procedures and any protocols for the relief of pain associated with them. New ideas for pain management were sought from the scientific literature and from pain experts in the medical and broader veterinary fields. In addition, official and unofficial standards for cattle welfare from Australia and around the world were collated and compared to allow an understanding of Australia's relative positioning. A total of more than 600 scientific articles, legislative instruments, codes of practice, standards and policies are cited.

There is a very considerable body of literature on castration and dehorning in particular, including many papers on the control of pain associated with these practices. Less work has been done on branding and spaying, the latter because it is less commonly practised overseas than in Australia. Ear marking has received very little attention.

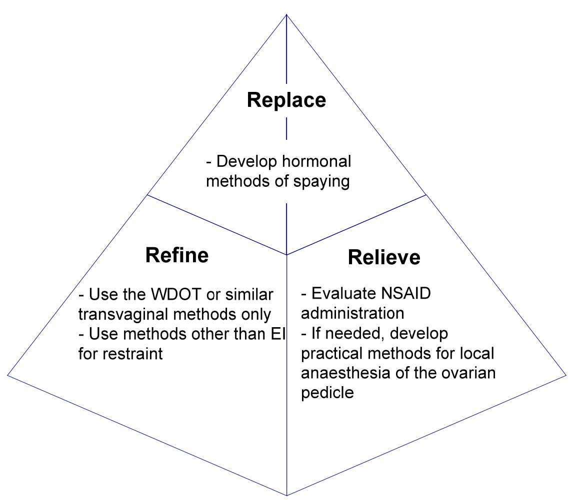
There is substantial evidence that castration using any technique causes acute (up to 12 hours) and possibly chronic (several days) pain. However, there is no clearly preferred method. Pain may increase with age at castration but there is no clear age beyond which castration is unacceptably painful. Analgesic regimes to reduce the acute pain of all methods of castration have been identified. The nonsteroidal anti-inflammatory drug ketoprofen, used in conjunction with local anaesthesia, appears to almost eliminate the pain of surgical or Burdizzo castration, while local anaesthetic alone is effective in reducing the pain of rubber rings or bands.

A model of the options for minimising the pain of castration was developed using '3Rs': refine (use the best technique possible in the right way on the right animals), relieve (provide pain relief), and replace (with a non-painful procedure). The model is represented as follows:

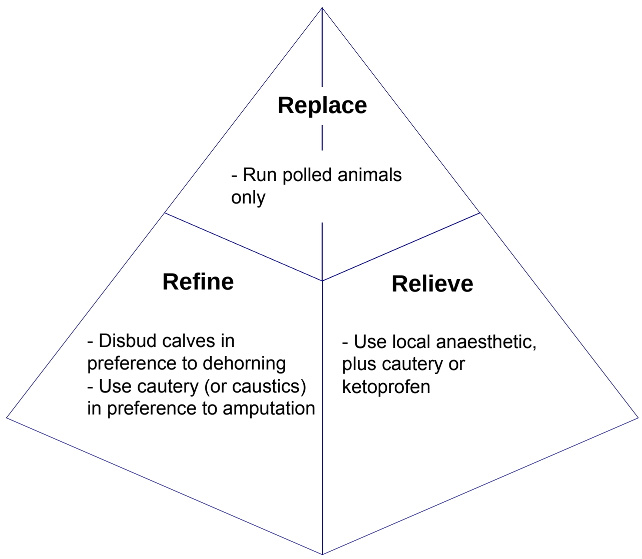


Australian standards for castration of cattle are generally in line with those of New Zealand but less restrictive than those of most welfare agencies which require anaesthesia over 12 weeks. The UK and EU have the tightest standards, with Switzerland for example permitting surgical castration only with anaesthetic at any age. The new Australian standards for castration are unlikely to differ significantly from the provisions of the Model Code except possibly to mandate an upper age limit of 4-6 months. This would place Australia on a similar level with New Zealand, between EU countries which require anaesthesia for castration at any age, and North America with fewer restrictions.

Spaying of cattle has been subject to relatively little attention from the international scientific community and indeed from regulators. The limited evidence suggests that the Willis dropped ovary technique (WDOT) delivers a better welfare outcome than flank spaying. Work is needed to identify possible pain relief options for the WDOT. Flank spaying without anaesthesia is considered unacceptable worldwide and is very likely to be banned in Australia. A 3R model for spaying of cattle is shown below.



Horn disbudding using cautery (heat), or possibly caustic agents (although widely rejected), is considerably less noxious than amputation disbudding or dehorning. The method of amputation dehorning does not make a significant difference to the pain response. Protocols for minimising the pain of dehorning have been developed and they involve local anaesthesia, analgesic (e.g. ketoprofen) and/or heat cautery of the wound. Australian has relatively lenient provisions on dehorning of cattle, but the new standards are unlikely to have much impact on currently permitted procedures except to mandate an upper age limit for dehorning cattle – possibly 6-12 months, depending how the practicalities of the pastoral zone are accommodated. There is a good argument for industry to move towards polled cattle as the most welfare-friendly approach to dehorning. A 3R model for horn removal is shown below.



Branding causes significant pain. Administration of an analgesic may provide a benefit but this has not been studied. There are few if any practical options to replace branding with a less aversive procedure. Some welfare groups advocate freeze branding over fire branding but the science indicates only a small welfare benefit if any. Ear notching and marking undoubtedly causes some discomfort but the extent of pain is not understood. There may be options to reduce the need to cut ears using other forms of identification.

An extensive review of pain management in other species, including humans, did not reveal any particularly promising opportunities for pain relief in cattle that have not already been identified in the literature. The major constraint to widespread use of pain relief drugs is their vet-only scheduling. The Australian National Deer Velveting Accreditation Scheme offers a possible model by which cattle producers might obtain more affordable access to veterinary drugs for use during husbandry procedures. However, a similar scheme for the cattle industry would be much larger and would require the cooperation of a large number of professional and regulatory bodies and a significant initial investment in design before implementation and likely significant ongoing management and auditing costs.

The information presented in this review should allow the cattle industry to argue for scientifically sensible standards for cattle welfare. It is important to recognise that this review attempts only to present the science of cattle welfare, with some consideration of the standards of a range of government and non-government bodies, in relation to the practices examined. It cannot provide 'right' or 'wrong' answers to what constitutes an appropriate level of animal welfare. Industry must make these judgements taking into account practicality, cost, public perception, market acceptability and other factors.

With this disclaimer in mind, a series of recommendations has been made to improve the industry's long-term position in dealing with animal welfare:

1. MLA commissions a comprehensive survey of castration, dehorning and branding practices across Australia, so that solid data are available to guide R&D, extension and policy. There is some information on the uptake of different practices but it is limited and this makes it difficult to judge the impact of possible changes in standards.

2. MLA commissions a study of the use of ketoprofen under field conditions to manage the pain associated with castration, dehorning, ear marking, branding and other procedures undertaken concurrently. At least two production systems should be included: a southern system involving *Bos taurus* breeds, and a northern system with *Bos indicus* cattle, the ages of which should be determined in consultation with an industry reference group. The study should quantify the costs and benefits of ketoprofen use for each system. It should be conducted in complete confidence and the results retained for future reference.

3. MLA commissions a feasibility and cost study for a scheme to license lay people to administer local anaesthesia for castration and dehorning in calves. The study would be preceded by a discussion between MLA and APVMA on the likelihood of success for such a scheme. This study would include the identification of shielded-needle, needleless and possibly other technologies that could be used to deliver local anaesthetic with reasonable operator safety as well as the regulatory changes that would be required to permit the use of local anaesthetics, and also non-steroidal anti-inflammatory drugs, by lay people. As with the recommended ketoprofen study, this study should be conducted in complete confidence and the results retained for future reference.

4. If castration using high-tension bands (as distinct from rubber rings) is shown to be a widespread practice in Australia, MLA considers research to clarify the welfare implications of this method. New Zealand may already be undertaking or planning such research in which case Australia may be able to benefit from the results. Alternatively, a collaboration on such research with Meat & Wool New Zealand may be appropriate.

5. MLA continues to support research into hormonal technologies for suppression of fertility in female cattle.

6. MLA commissions research on pain relief options for WDOT spaying. A preliminary study might focus on the welfare benefit of an NSAID such as ketoprofen administered shortly after spaying using the WDOT. If there is evidence that local anaesthesia will be required, surgical instrument engineers might be approached to develop a modification to the Willis instrument that allows the injection or spray of a local anaesthetic into or onto the ovarian pedicle at the time it is transected. A mucoadhesive formulation of lignocaine is another option for consideration.

7. MLA uses the findings from AHW.094 to promote the uptake of polled breeds of cattle. It is recognised, however, that there are negative perceptions about polled cattle in some parts of industry and that these may need to be addressed first.

8. MLA maintains a watching brief on the development and uptake of newer identification management systems with a view to identifying opportunities for branding to be dispensed with as a management tool. Alternatively, MLA could take a proactive stance on R&D to develop new identification systems, although branding is a lower welfare priority than other procedures.

9. MLA considers conducting research to quantify the welfare impacts of ear tagging and notching given the dearth of information currently available. This is a relatively low priority, however, as ear tagging and notching are second-order welfare issues compared with castration, spaying and dehorning.

10. MLA reviews the potential of NLIS to take over the role of identifying HGP-treated and spayed animals and thereby obviate the need for ear notches in these circumstances. This is a lower priority given the relative unimportance of ear notching as a welfare issue.

Further details about each recommendation are provided in the report. The recommendations seek to strike a balance between short-term welfare improvement measures and longer-term, but more uncertain, replacement technologies. In overview:

- Recommendation 1 seeks to bolster the cattle industry's understanding of its exposure to changing animal welfare standards;

- Recommendations 2, 3 and 6 are made as defensive strategies for the cattle industry, given that the welfare benefits of local anaesthesia and/or systemic analgesia have been clearly demonstrated for certain painful procedures and there are growing international expectations that pain relief should be used when it is available;

- Recommendations 4 and 9 are concerned with filling knowledge gaps about welfare impacts; and

- Recommendations 5, 7, 8 and 10 promote the development of technologies that replace painful procedures.

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1 Background

The Australian system of nationally agreed but inconsistently adopted 'model' codes of practice for livestock welfare is currently being reviewed, with a view to establishing national standards and guidelines with the standards intended to become legislation. This process was recommended by Geoff Neumann & Associates (2005) who recognised that science must be a critical element in establishing standards for animal welfare.

MLA and others had identified that the science and understanding of pain during on-farm husbandry procedures is often disjointed and incomplete and that the extensive references needed bringing together in a thorough review. To assist with the process of identifying priorities for research investment and the development of national standards and guidelines for cattle, a comprehensive review of the existing science relating to pain responses during on-farm procedures for cattle was commissioned.

This project provides a review of the scientific literature on indicators of the levels of acute and sub-acute (first 96 hours post-treatment) pain associated with the on-farm procedures of castration, spaying, earmarking and ear notching, dehorning, disbudding, tipping and branding (both fire and freeze) in cattle. The relative benefits of pain relief and the practical constraints to its use are also discussed. The report includes a targeted review of potential pain relief solutions in other species including other livestock, companion animals and humans to help identify future development options. In addition, for both sheep and cattle, standards and requirements in Australia and a selection of other countries are considered in this review to help identify where Australia fits in relation to accepted on-farm practice, scientific understanding and legal requirements internationally.

This information will be used by industry to develop informed policy and position statements which are supported by science and political developments.

2 Project objectives

The objectives of the project were to:

1. Provide physiological, behavioural and production related data on the levels of acute and sub-acute pain (first 96 hours post treatment) experienced by cattle as a consequence of the following procedures:

   i. Castration,
   ii. Spaying,
   iii. Disbudding, dehorning and tipping,
   iv. Branding (freeze and hot iron),
   v. Ear marking and ear notching.

   The comprehensive review was to include data and its examination including consideration of the following factors:
   - All known surgical and non-surgical procedures as carried out under Australian intensive (farm and feedlot) and extensive (range) situations;
   - Genetic variation, i.e. both *Bos indicus* and *Bos taurus* based breeds of cattle;
   - Age of animals, i.e. from young to mature animals;

- As many of the existing codes of practice refer to procedures performed in feral cattle, any data referring to feral cattle; and
- Where possible, a summary of the likely production impacts of procedures particularly at different ages.

2. Provide meaningful comparisons between procedures based on the level of acute and sub-acute pain.

3. Identify the gaps and inconsistencies in data where conclusions are difficult to draw and further research is required.

4. Identify similar pain profiles in other species (animal and human) and present a summary of potential analgesic solutions including a brief description of the pharmacology, which may have relevance to pain relief during the acute and sub-acute stages of the above cattle husbandry procedures; identify potential solutions for pain relief/analgesia in cattle spaying for both flank spaying and the Willis dropped ovary technique; consider the approach to control of pain in deer velveting in New Zealand as a possible model and critically evaluate this model for its relevance.

5. Determine the implications of the available pain data on Australian on-farm husbandry procedures as described above and place it in context against other research; compare this research with standards both in Australia and other countries; compare Australian standards and those of other countries for both sheep and cattle to determine where Australia is positioned relative to international standards; assess how this information can be used to most effectively prioritise research investments and assist in the development of national standards and guidelines. Direct reference is made to the requirements in the following animal welfare codes of practice:
    - *Model Code of Practice for the Welfare of Animals: Cattle*
    - *Model Code of Practice for the Welfare of Animals: The Sheep*
    - *Model Code of Practice for the Welfare of Animals: Feral Livestock Animals*
    - *National Guidelines for Beef Cattle Feedlots in Australia.*

3 Methodology

3.1 Review of scientific literature

A review of the scientific literature was initially undertaken using CAB Abstracts®, MEDLINE®, PubMed® and Agricola®. Search terms included combinations of:

- Cattle, bovine, calf;
- Synonyms for each of the procedures under review (e.g. spay, ovariectomy);
- Stress, pain, welfare; and
- Analgesia, anaesthesia.

The reference lists of papers obtained from these searches (especially review papers) were then cross-checked to identify other papers not found initially; this process continued until no new references appeared. The 'related articles' facilities of PubMed® and other databases were also used. Further searches of the databases and of Google™ Scholar using specific terms were then undertaken as required (e.g. 'Kimberling Rupp' for the spay device). This has provided a comprehensive review of the scientific literature relating to pain response in cattle.

Copies of the papers themselves were obtained from the library of the Victorian Department of Primary Industries, Werribee, and also from online journals where available. Some references were ordered from the publisher.

The papers were reviewed and assessed for scientific rigour and for relevance to Australian conditions. Very few papers were excluded on the basis of either criterion. Some of the references obtained were not published scientific studies but letters, opinions (e.g. material on Temple Grandin's web site), unpublished studies, or copies of presentations. If sufficiently relevant and reliable, such material was used in the review subject to an acknowledgment of its limitations. Animal welfare is an emotive issue and will not be adequately characterised purely by science.

Other reports used in the review were obtained from MLA, including:

- Geoff Neumann and Associates (2005);
- Project report AHW.120 *Review of literature on the relief of pain in livestock undergoing husbandry procedures* (Crowe 2006); and
- Project report AHW.143 *Evaluation of the impact on animal welfare of various manipulative and surgical procedures performed on the reproductive tract of female cattle in the northern beef industry* (McCosker 2007).

Over 500 scientific articles were cited.

In a few cases, e-mail or telephone contact was made with research groups whose work was not available in the literature or needed clarification. The nature of the current project was not revealed to the individuals contacted.

3.2 Review of Australian and international animal welfare standards

Australian legislation and codes of practice relevant to the procedures under review were obtained from the web sites of the applicable government departments of each State and Territory. The legislation reviewed included acts and regulations concerned with 'animal welfare', 'prevention of cruelty to animals', and 'veterinary surgeons' / 'veterinary practice'.

The web sites themselves also provided, to a greater or lesser degree of usefulness, a guide to each State or Territory's animal welfare statutes and Codes. Broader web searches yielded other relevant documents such as reviews of Acts or Regulatory Impact Statements on proposed legislative amendments.

International animal welfare standards were found by searching the web using Google. A useful central reference on international animal welfare law, including copies of the relevant statutes, was the Michigan State University College of Law[1], while another was the Georgetown University Law Center[2], both in the USA. These sites were particularly useful for English translations of some foreign statutes and also for discussion papers on cattle law in the US and other countries.

[1] www.animallaw.info
[2] www.ll.georgetown.edu/intl/guides/InternationalAnimalLaw.cfm

Every effort was made to obtain standards from New Zealand, the European Union and some of its member countries, the US, Canada, and a cross-section of other countries including those of eastern Europe and South America, the latter because of its large and growing cattle industry. Statutes, ‘official’ Codes of Practice, voluntary industry codes, and reviews or position papers of government welfare advisory groups were also obtained to try to identify where international legislation might head in the future.

It should be noted that the authors of this report are not legally trained and can only provide personal assessments of the content pertaining to animal welfare legal provisions. There may be details that are technically incorrect. However, any conclusions reached were checked against other sources as far as possible (for example, several of the scientific papers refer to legislative provisions of various countries). The authors are confident there are no errors that would substantively change the recommendations of the report.

Cattle welfare standards, or policy / position statements published by various animal welfare interest groups were also obtained and examined for this review. These included publications from various Societies for the Prevention of Cruelty to Animals, accrediting bodies for ethical or organic production systems, and veterinary professional bodies.

Web sites and publications by animal rights groups such as Animals Australia, Voiceless, People for the Ethical Treatment of Animals (PETA) and others were also perused to give a sense of the major husbandry ‘targets’ for these groups. Neither specific issues (apart from general condemnation of farming practices) nor any constructive opinions were identified.

3.3 Development of ‘3R’ models

As a way of summarising the findings of the science and the various welfare standards, a model was developed to show a hierarchy of preferred strategies to manage the welfare implications of particular practices. The purpose of the model is to simplify decision making on-farm and at policy level by allowing a graphic conceptualisation of the various strategies, including their relative preferability.

The model proposed in this report is an adaptation of a ‘3R’ model used in addressing the use of animals in scientific experimentation (Russell & Burch 1959, USDA undated). This original model has three components: Refine, Reduce, Replace. ‘Refine’ refers to using techniques and procedures that minimise distress; ‘Reduce’ refers to using fewer animals; and ‘Replace’ refers to the substitution of animal models with non-animals or lower-order organisms. The three components seem to be presented as non-hierarchical, i.e. none is better than any other, but emphasis will be placed on one or more of them in a particular situation.

Having three categories seems to work for painful husbandry procedures in farm animals, but with some modifications to the original model:

- ‘Refine’ means applying the least stressful method in the least stressful way (i.e. quick, expert application, using least stressful handling approach in the youngest animals that management practices allow) and ensuring the most appropriate environment available (hygienic, dust free, comfortable temperature etc).

- ‘Relieve’ means using pain relief. There may be a range of analgesia options available offering varying degrees of relief (e.g. local anaesthesia, systemic analgesia).

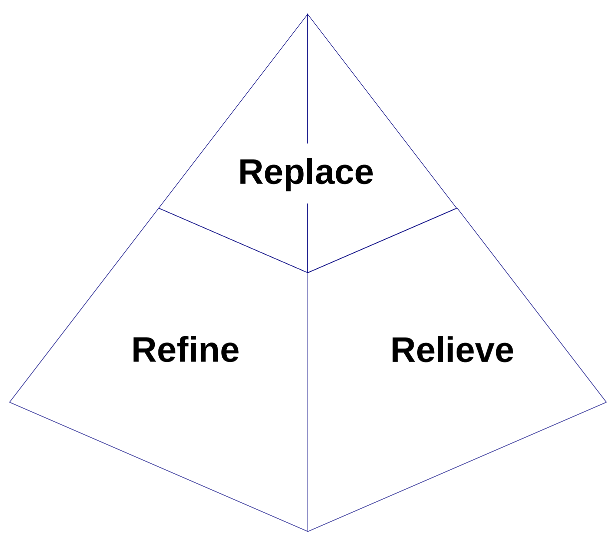
- ‘Replace’ means replacing the stressful procedure with a non-invasive, preferably stress-free procedure. Where possible, use no procedure at all (e.g. leave males intact if turned off at an early age or replace horned with polled stock).

It seems for the present purpose that ‘Replace’ is conceptually superior to ‘Refine’ and ‘Relieve’, as the latter two ameliorate stress rather than abolish it. It might be argued that some procedure / analgesia combinations do almost abolish any suffering, and that even some ‘stress-free’ replacements – e.g. castration by injection – are not without some degree of stress, if only handling. On balance, however, ‘Replace’ seems to be a superior and longer term option.

‘Refine’ and ‘Relieve’ are more difficult to separate. A procedure that is well-chosen and carried out efficiently (e.g. sharp instruments, well-trained operator) might be preferable even without analgesia to a poor procedure where analgesia is provided. For example, Stafford & Mellor (2005b) rank amputation dehorning following regional nerve block as more stressful than cautery disbudding without anaesthetic.

Thus, the 3R model for painful husbandry procedures in farm animals is represented as a pyramid, as shown in Figure 1.

Figure 1 Generic 3R model for welfare management of painful husbandry procedures



A 3R model was produced for each of castration, spaying and horn removal. There was insufficient information to create models for branding or ear marking.

3.4 Review of pain management across species

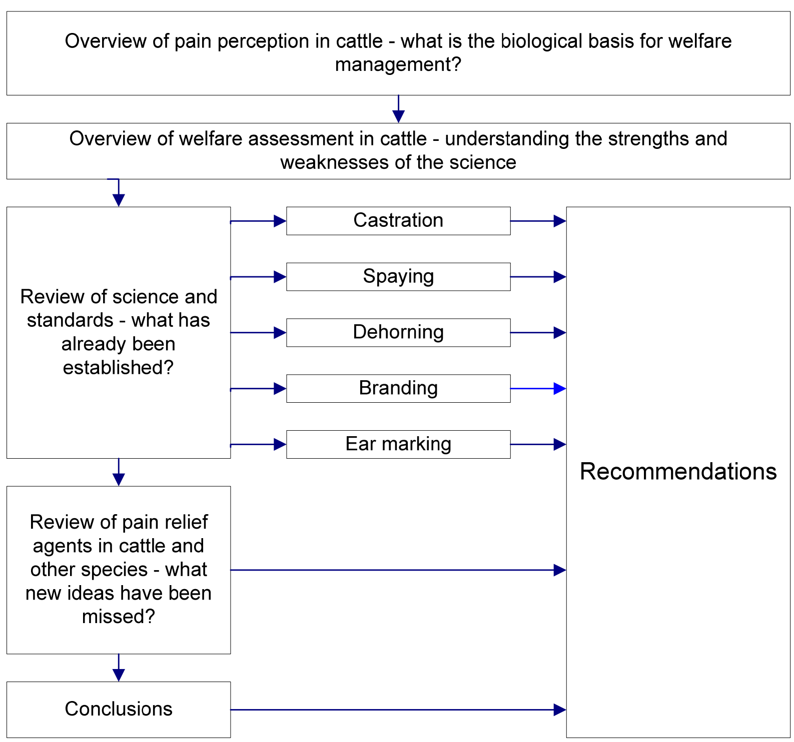
The review of the scientific literature identified some tested and suggested regimes for the control of pain arising from the procedures of interest to this review.

To build upon this information and to broaden the base of ideas for pain management, interviews were conducted with veterinary and medical pain specialists (listed in Appendix 9.1). These interviews allowed the identification of possible pharmacological and non-pharmacological approaches to the procedures of interest, particularly spaying, based upon similarities to situations in other species. Based upon these discussions, a focused review of the human and veterinary medical literature was undertaken.

This phase of the project included a study of the system of access to analgesic agents for deer velveting in Australia and New Zealand. Several people were consulted (see Appendix 9.1), relevant information documented and the relevance of the system to procedures in cattle critically analysed.

3.5 Preparation of the report

This report was prepared according to the following logic:



4 Results and discussion

4.1 Pain perception in cattle

The neurophysiology and neuropharmacology of nociception (perception of a painful stimulus) in farm and companion animals has been described (Anderson & Muir 2005, Viňuela-Fernandez 2007). In overview:

- Noxious mechanical (e.g. pressure), chemical (e.g. prostaglandins released in response to inflammation) or thermal (heat/cold) stimuli are received at receptors on the end of nerves known as C- and Aδ-fibres;

- The stimulus is transduced into an electrical signal, which is transmitted along the nerves to the superficial layers of the spinal cord;

- The electrical signal is modified in the spinal cord by nerves that either increase (facilitate) or decrease (inhibit) the signal; and

- The signal is projected to the brain, where there is perception of the stimulus, creating a subjective experience for the animal and initiating a possible series of physiological responses such as increased heart rate or temperature (Anderson & Muir 2005).

An important question is whether the perception of pain changes during the life of the young animal and whether, therefore, there should be a preferred age range for undertaking painful procedures. New Zealand's National Animal Welfare Advisory Committee (2005b) considers the issue of age in a thorough background paper to its *Animal Welfare (Painful Husbandry Procedures) Code 2005* (NAWAC 2005a). Commenting on all species generally, it notes that:

> While it is generally believed that painful husbandry procedures are best performed on young animals, the rationale for this is not entirely clear. It could be due to:
>
> - A belief that younger animals do not experience pain the same as do older animals, possibly because the expression of pain may differ with age;
> - Some evidence that healing is slightly quicker in younger animals;
> - The greater ease with which younger animals can be physically handled and manipulated compared with older animals;
> - Their smaller size may mean less sensitive tissue is interfered with and consequently pain is less, healing faster and infections rarer;
> - Less specialised anatomical developments (e.g. sinuses invading horns); and/or
> - The possibility of fewer post-operative complications (e.g. phantom-limb pains are less prevalent in children when the amputation is undertaken at a young age) (p. 14).

There is some evidence that pain responses increase with age. For example, Ting et al (2005) showed increasing changes in cortisol and other measures between groups of calves aged 1.5, 2.5, 3.5 and 5.5 months castrated with a Burdizzo (see Section 4.4). The question, though, is whether there are critical points in the development of the growing bovine after (or before) which pain perception becomes markedly more acute – for example, because of the maturing of a synaptic pathway. If such points existed, there might be an argument for requiring painful procedures to be performed within a certain age range.

There are suggestions from the literature that ‘tipping points’ in pain perception may exist, but if so, they are poorly characterised. NAWAC (2005b) notes that ‘While newborns experience pain from a very early age, changes in the degree of pain perception with age are poorly understood’ (p. 14). Studies of pain response and age involving piglets, calves and lambs are cited.

Of particular interest is the citation in the NAWAC report (2005b) of studies for the New Zealand Ministry of Agriculture and Forestry examining electroencephalographic (EEG) responses of lambs to castration (see Section 4.2.1). These studies apparently show that the noxious stimuli of castration rise from birth for about 7-10 days before decreasing over the next 2 weeks. In related work, Johnson et al (2005a) found differences in the EEG response to rubber ring castration between lambs aged 2 weeks or 4 weeks. The younger lambs showed a greater response to the visceral (testicular) components of the procedure while the older lambs responded more strongly to the somatic (scrotal) components. The differences may have been due to the magnitude of the noxious stimulus – for example, variation in the size and type of tissue – or they may have been due to differences in the processing of the pain signals by the nervous system. This latter explanation could involve age-related development.

Even the most premature neonate has the neural pathways described above for nociception and responds to potentially tissue-damaging stimuli. Significant functional and structural changes occur during the first months of life as the expression of a number of molecules and channels involved in nociception are developmentally regulated. There are changes in the distribution and density of many important receptors and the levels and effects of several neurotransmitters alter significantly during the postnatal period. However, these changes do not necessarily lead to increased nociception, and in fact the reverse may be true.

Although C-fibre polymodal nociceptors are mature in their pattern of firing at birth and are capable of being activated in the periphery by exogenous stimuli, their central synaptic connections in the dorsal horn of the spinal cord are initially immature. However, ‘wind-up’ (increased sensitisation to pain) can be produced by relatively low intensity A-fibre (rather than C-fibre) stimulation, as Aβ fibres initially extend up into laminae I and II (layers of the spinal cord) and only withdraw once C-fibres have matured. This overlap is likely to contribute to the larger receptive fields of dorsal horn neurones observed in early development. The N-methyl-D-aspartate (NMDA) receptor, which is important for central sensitisation, is present in a higher concentration and more generalised distribution in the dorsal horn early in development, and activation results in a greater influx of calcium ions. In addition, descending inhibitory pathways, diffuse noxious inhibitory controls and local interneuronal inhibitory mechanisms in the dorsal horn which reduce the pain sensation are not fully mature in early development. Therefore, rather than neonates being less sensitive to painful stimuli as was once thought, the relative excess of excitatory mechanisms and delayed maturation of inhibitory mechanisms produce more generalised and exaggerated reflex responses to lower intensity stimuli during early development (Fitzgerald & Howard 2002).

Pain and injury experienced early in life may lead to long-term chronic consequences for an animal’s (or human’s) perception of pain, manifested as hyperalgesia (increased response to a stimulus that is normally painful) and/or allodynia (pain caused by a stimulus that is normally non-painful). Significant reorganisation of synaptic connections occurs in the postnatal period. Activity within sensory pathways is required for normal development, but abnormal or excessive activity related to pain and injury during the neonatal period may alter normal development and produce persistent changes (Fitzgerald & Walker 2003). In laboratory studies, the degree of long-term change varies with the type and severity of injury. Neonatal full-thickness skin wounds produce prolonged increases in sensitivity in the absence of any visible persistent peripheral injury. The anatomical distribution of peripheral nerve terminals in the spinal cord can be permanently altered by nerve injury or chronic inflammation induced during the first postnatal week in rat pups. Although less severe inflammation does not produce long-term structural effects, an acute reversible change is seen in neonates but not in adult animals subjected to a similar stimulus, thus emphasising the plasticity of the nervous system early in development (Walker et al 2003).

These findings are of considerable importance as pain and injury in neonates may have effects on nociceptive processing that differ in mechanism and duration from that experienced by older children and adults. Clinical studies also suggest that early pain related to surgery and clinical procedures in premature and term neonates may have long-term effects upon pain-related behaviour and the perception of pain (Grunau 2000). Importantly, analgesia at the time of the initial painful stimulus may modulate long-term effects. Male neonates circumcised without analgesia show an increased behavioural pain response to immunisation several months later, but this is reduced if local anaesthetic is used prior to surgery (Taddio et al 1997). Infants who had undergone surgery in the neonatal period with perioperative morphine did not show any increase in later response to immunisation when compared with infants without significant previous pain experience (Peters et al 2003).

In summary, there is no evidence from neurophysiological or related studies to suggest that there exists a critical age or developmental threshold beyond which cattle experience ‘unacceptable’ pain in response to a given stimulus. In fact, there is evidence from other species that painful procedures have a qualitatively different and possibly greater impact on very young animals (days to a few weeks old) than those that are slightly older. Exposure of very young animals to noxious procedures may also create long-term pain hypersensitivity problems.

In practice, the optimum age to carry out a painful procedure is likely to have both minimum (days) and maximum (weeks/months) boundaries but such boundaries are not well characterised.

4.2 Measures used to assess welfare

The subject of pain assessment in cattle has been reviewed by Stafford & Mellor (2006) and will not be discussed at great length here, except to provide background to the discussion below under each of the procedures.

A range of physiological, behavioural and production parameters are used to assess the degree to which animals suffer pain or stress in response to a given intervention. The most informative studies are those that combine as many of these indicators as possible to provide a rich picture of the animal’s experience. It must be noted that humans, as observers, can only judge the objective evidence about the degree of distress experienced by an animal; it is impossible for the human to understand the subjective content of an animal’s noxious experience (Mellor & Stafford 1999).

4.2.1 Physiological parameters

There are two broad stress response systems in the mammalian body: the ‘fight or flight’ sympathetic adrenomedullary system, and the hypothalamic-pituitary-adrenocortical (HPA) system. The first of these acts very quickly to release the catecholamines adrenaline and noradrenaline which in turn affect heart rate, blood pressure, alertness and other body functions. The HPA system is responsible for changes of longer duration that include the suppression of inflammation (Guyton 1986). The use of measured changes in the HPA system as a tool to assess animal welfare has recently been reviewed (Mormède et al 2007).

By far the most common and well-established physiological indicator of stress measured in the studies described here is the change in plasma cortisol profile (occasionally salivary cortisol in earlier studies). Cortisol is one indicator of activity in the HPA system. About 90% of plasma cortisol in plasma is bound to corticosteroid binding globulin (CBG) and albumin, the remaining 'free' or 'unbound' 10% being the biologically active fraction (Mormède et al 2007). McCosker et al (2007) note that bound or total cortisol is more often used as an indicator of acute distress while unbound cortisol is used to demonstrate chronic effects. Mormède et al (2007), however, state that 'whether free cortisol is a better functional measure of HPA axis activity than total cortisol is debatable' and do not distinguish between these acute and chronic applications. Most studies appear to report total cortisol but methods vary, and this must be considered when comparing the results from different studies.

Measurements of cortisol must be interpreted with caution because they vary considerably according to ultradian, diurnal, and seasonal rhythms as well as genetic, physiological, nutritional and environmental factors (Mormède et al 2007). Cortisol also rises in response to handling, so meaningful observations require prior habituation of animals to handling, or correction of observed effects by data from handled but untreated controls. Cortisol measurements are considered to be most informative when repeated samples are taken to provide a concentration-time profile reflecting the full response to a particular stimulus. This response is often complex, so a variety of descriptors is used to describe the profile, including peak cortisol response, time to return to baseline levels, and the integrated response or 'area under the curve' of cortisol concentration vs time (Stafford & Mellor 2006).

Bretschneider (2005), in a meta-analysis of the literature on castration of cattle, concluded that the first post-treatment cortisol measurement should be made as early as possible. Greater differences between the maximum cortisol concentration of castrated and control calves (or between pre-operative and post-operative states) were found when the first measurement was made at 0-12 minutes than in subsequent periods. Thus, the time of first measurement affects the interpretation of the response.

Some cortisol studies include a group treated with adrenocorticotrophic hormone (ACTH) (e.g. Sutherland et al 2002a). ACTH is the hormone released by the pituitary gland to stimulate the release of cortisol and other glucocorticoids from the adrenal gland. The purpose of ACTH administration in such studies is to measure the maximum response to cortisol and therefore quantify the stress 'ceiling'. Sometimes, endogenous ACTH (i.e. that released by the body itself) is measured. Beta-endorphins have been used to assess pain in sheep (Shutt et al 1988) but no records were found of their use in cattle.

Occasionally, adrenaline and noradrenaline are measured to obtain a sense of the 'fight or flight' response (e.g. Mellor et al 2002). These indicators have most value in the first few minutes of a response. Heart rate has been monitored for extended periods (e.g. Grøndahl-Nielsen et al 1999).

Other parameters studied include changes in the concentrations of the plasma proteins fibrinogen, haptoglobin and α_1-acid glycoprotein. These are called 'acute-phase' proteins because of their early role in response to inflammatory processes. Packed cell volume (reflecting the concentration of red blood cells in whole blood), total white blood cell counts and ratios of various white blood cell types are also used to investigate the body's response to inflammation (e.g. Ting et al 2003b).

Other immune responses have also been used. Interferon-γ is a protein released early in the immune response of animals. Some researchers have sensitised cattle to a particular antigen (a substance that stimulates the immune response) prior to a trial, then collected blood during the trial and assessed the interferon-γ release in that blood in response to that antigen (e.g. Earley & Crowe 2002). However, the usefulness of induced interferon-γ release in indicating pain has been questioned (Stafford & Mellor 2006).

Recent studies suggest that electroencephalograms (EEGs) may have a role in some welfare studies (e.g. Gibson et al 2007). The EEG provides a representation of the electrical activity of the cerebral cortex (Johnson et al 2005a), and a strong correlation has been demonstrated between EEG patterns and reported perception of pain in humans (Chen et al 1989). Reports on the use of EEGs in animal welfare seem only to have been published by the Animal Welfare Science Centre (Melbourne) and Massey University (New Zealand).

4.2.2 Behaviours

Changes in behavioural patterns are perhaps the most intuitively recognisable indicators of pain, and indeed they are well accepted scientifically. Many of the studies described in this review report on observed behaviours in a qualitative sense or, in the more sophisticated studies, using numerical scoring scales with testing for statistically significant differences between treatments.

As with other indicators of pain, behaviours must be interpreted carefully. They may reflect irritation, dysfunction or convalescence rather than pain (Stafford & Mellor 2006). Dinniss et al (1999) list four axioms that may be used to determine whether a particular behaviour is useful indicator of pain in lambs:

1. It may identify pain if it is seen during and after a tissue-damaging injury but not in non-damaged animals;
2. It may identify nociception and, by inference, pain if it is seen during and after a tissue-damaging injury but not when local anaesthesia is used;
3. It may identify pain if it is seen after a tissue-damaging injury but not when effective analgesics are provided; and
4. It may be injury-specific.

Examples of behaviours examined in cattle include foot stamping and kicking, licking, standing up and lying down (restlessness), and abnormal postures in the castration study of Thüer et al (2007a); tail wagging, head moving, tripping, rearing, and unprompted backwards locomotion in the disbudding study of Graf & Senn (1999); and ruminating, head shaking, ear flicking, tail flicking, head down, lying, walking, leg to face scratching, head rubbing, neck extending, riding and vocalising due to amputation dehorning (Sylvester et al 2004). Like any welfare measure, behaviours should be considered in conjunction with physiological and other indicators.

4.2.3 Productivity

Productivity measures such as food intake and average daily weight gains are often reported. Stafford & Mellor (2006), however, suggest that productivity may be too blunt an instrument to measure pain unless there is chronic stress involved. In the case of castration, the decrease in testosterone secretion will also confound the effect of the procedure itself (Knight et al 1999). The most useful studies of weight changes use long-term analgesia in one treatment group to remove the effect of the pain (Stafford & Mellor 2006).

4.3 Animal welfare legislation and standards

A description of the legal basis of cattle welfare protection in selected countries is recorded here so that the reader may make sense of the various national provisions described below. Policies and standards of various animal welfare interest groups that were identified during the course of the review are also described.

4.3.1 Australia

A review of the Australian system of model codes of practice for animal welfare protection is provided by Geoff Neumann & Associates (2005) and will not be repeated here, except to summarise those aspects relevant to cattle welfare and specifically to the husbandry procedures reviewed in this report. In summary, each of the States and Territories has an Act entitled ‘Animal Welfare’ or ‘Prevention of Cruelty to Animals’ or similar, with corresponding Regulations. Statutes concerning veterinary practice also have applicable sections, as do those regarding stock identification in the case of branding and ear marking. The government department responsible for legislation covering the welfare of livestock varies between States and Territories – for example, the Department of Primary Industries in NSW, the Department of Local Government and Regional Development in WA.

The *Model code of practice for the welfare of animals – cattle* (second edition) was published by the Primary Industries Standing Committee in 2004 (PISC 2004). PISC is a permanent committee supporting the Primary Industries Ministerial Council (PIMC), which comprises the Commonwealth and State / Territory government ministers responsible for agriculture, forestry, fisheries and related portfolios (PISC 2004). The *Model code of practice for the welfare of animals – the sheep* (second edition) was published by PISC in 2006, following an update that principally involved the addition of a third appendix detailing the conduct of mulesing (PISC 2006).

Also considered here are the *National guidelines for beef cattle feedlots in Australia* (PISC 2002) and the *Model code of practice for the welfare of animals – feral livestock animals – destruction or capture, handling and marketing* (SCAAHC 1995).

The legal force of the Codes varies between States and Territories, as described in Table 1.

Table 1 Status of the Model Codes of Practice for the Welfare of Animals in Australian jurisdictions

State/Territory	Status of Model Codes of Practice
Queensland	• The Department of Primary Industries and Fisheries is the responsible department. • The Model Codes are 'adopted codes' under the *Animal Care and Protection Act 2001*. They assist the user to meet the legal Duty of Care obligation to cattle or sheep in his or her charge. 'Adopted codes are referred to by animal welfare inspectors in assessing whether people are meeting their duty of care obligations under the ACPA and when inspectors are issuing people with animal welfare directions to improve the welfare of their animals. Because adopted codes are not compulsory, non-compliance with an adopted code **is not** automatically an offence under the ACPA. However non-compliance is admissible in evidence (for both the prosecution and the defence) in a court proceeding for an offence, such as breach of Duty of Care'[3].
New South Wales	• The Department of Primary Industries is the responsible department. • 'In NSW, (certain) Codes are adopted by reference into the General Regulation under the *Prevention of Cruelty to Animals Act 1979.* It is not an offence if animals are not kept precisely as specified in the Codes but referencing them makes them admissible in proceedings for a related offence in the Act or Regulations. Even if a code is not referenced into the Regulation, it is still regarded as the minimum standard by which livestock should be kept'[4]. The Model Codes for cattle and sheep have been directly adopted.
Australian Capital Territory	• The Department of Territory and Municipal Services is the responsible department. • An ACT Code of Practice is adapted from the Model Codes for both sheep and cattle (but for the procedures under review in both sheep and cattle, the wording is identical). Neither ACT code is dated. • 'A Code of Practice sets the minimum standard acceptable for dealing with, or interacting with, an animal. A person can not be prosecuted under an omission from the standards contained within a Code of Practice. However an action taken that is required under a gazetted Code of Practice is a defence against a prosecution under the (*Animal Welfare*) Act (1992)'[5]. • Section 19(2)(b)(i) of the *Animal Welfare Act 1992* permits 'a medical or surgical procedure (to be) carried out in accordance with accepted animal husbandry practice in relation to…farming and grazing activities' unless otherwise prescribed by the *Animal Welfare Regulation 2001*, which is effectively achieved by the Code.

[3] http://www2.dpi.qld.gov.au/animalwelfare/15493.html#adopt, accessed 10 December 2007.
[4] http://www.dpi.nsw.gov.au/agriculture/livestock/animal-welfare/general/guidelines/national, accessed 10 December 2007.
[5] http://www.tams.act.gov.au/live/pets/animalwelfare/animalwelfare-governmentresponsibilities, accessed 10 December 2007.

State/Territory	Status of Model Codes of Practice
Victoria	• The Department of Primary Industries is the responsible department[6]. • The *Code of accepted farming practice for the welfare of cattle (Victoria)* (2001) and the *Code of accepted farming practice for the welfare of sheep (Victoria) (revision number 2)* (2007) replace the Model Codes. There are some differences in wording, as detailed under each procedure below. • Compliance with the Victorian Code is a defence to a prosecution under Section 6(1)(b) of the *Prevention of Cruelty to Animals Act 1986*.
Tasmania	• The Department of Primary Industries and Water is the responsible department[7]. • *Animal welfare standard – Tasmania no 2 cattle* (1994) and *Animal welfare standard – Tasmania no 1 sheep* (1994) are based upon the Model Code. There are some differences in wording, as detailed under each procedure below. • The Cattle Standard states: 'Under the *Animal Welfare Act*, Animal Welfare Standards are to include standards: (a) to be followed in the care and management of animals; and (b) for the education and guidance of persons involved in the care and management of animals. Animal Welfare Standards are intended to help people involved in the care and management of animals adopt high standards of husbandry. In addition, Animal Welfare Standards may be used by the Courts as a yardstick to assess husbandry and management practices in cruelty cases which come before them. Although failure to comply with an Animal Welfare Standard is not an offence *per se* under the (*Animal Welfare*) Act (1993), demonstrated failure to comply would increase the likelihood of a successful prosecution for animal cruelty'. • The precise legal status of the Standards is ambiguous, and the Act has been under review (Department of Primary Industries and Water & Animal Welfare Advisory Committee 2006).
South Australia	• The Department for Environment and Heritage is the responsible department. • 'In South Australia, Model Codes of Practice are regulated, making compliance with their requirements mandatory. Such compliance also provides a defence to a charge of ill-treatment. South Australia is the only Australian jurisdiction which gives the Model Codes the force of law'[8]. • Part 3 and Schedule 2 of the *Prevention of Cruelty to Animals Regulations 2000* requires compliance with the Codes of Practice.

[6] http://www.dpi.vic.gov.au/DPI/nrenfa.nsf/LinkView/E1AF1D71AF607629CA256D780013EFCE51F52E6260BC77B8CA2572B10008EED4, accessed 10 December 2007.
[7] http://www.dpiw.tas.gov.au/inter.nsf/WebPages/EGIL-535VVF?open#Tasmania'sAnimalWelf, accessed 10 December 2007.
[8] http://www.environment.sa.gov.au/animalwelfare/codes.html, accessed 10 December 2007.

State/Territory	Status of Model Codes of Practice
Western Australia	• The Department of Local Government and Regional Development is the responsible department, but the Department of Agriculture and Food WA have an inspection role[9]. • The Model Code (Cattle) is provided on the department's web site. For sheep, a document called *Code of practice for sheep in Western Australia* (March 2003) is described as being based on the Model Code (Sheep) and adapted for use in WA. (The WA version of the Code does not include the mulesing appendix of the second edition of the Model Code.) The Model and WA Codes have very similar provisions in relation to the procedures under review here. • 'The codes of practice outline the minimum welfare requirements for the care and management of animals. The Courts may use the Codes as a yardstick to assess husbandry and management practices in cases of alleged cruelty. In the *Animal Welfare Act 2002* these codes are included as a defence. That is, if a defendant can prove they were compliant with the relevant code then this would be a defence against a charge of cruelty under the act'[10]. • Note that a separate document entitled *Department of Agriculture Western Australia's model code of practice for the welfare of cattle in the rangelands of Western Australia* was also obtained. It forms part of two Department of Planning and Infrastructure documents entitled *The grazing of cattle in the northern (southern) pastoral areas of Western Australia: best management practice – July 2005*. This 'Code' has no legal status (M. Paton pers. comm.)
Northern Territory	• The Department of Local Government Housing and Sport is the responsible department[11]. • Compliance with an adopted code (in the case of cattle, the Model Code) is a defence to a prosecution for an offence under the *Animal Welfare Act 2000*. No code for sheep appears on the department web site.

4.3.2 New Zealand

The principal legislative instrument for the protection for animal welfare in New Zealand is the *Animal Welfare Act 1999*. The Act provides for the development of codes of animal welfare, which are designed to promote appropriate behaviour, establish minimum standards and promote best practice for people owning or looking after animals. Each code provides both minimum standards, which are legally binding, and recommended best practices, which are not. The failure to meet a minimum standard can support a prosecution under the *Animal Welfare Act 1999*. Conversely, evidence of meeting or exceeding minimum standards can be used as a defence against prosecution[12].

There is no specific code for cattle, but a code entitled *Animal welfare (painful husbandry procedures) code of welfare 2005* (NAWAC 2005a) is relevant to the current study. A report accompanying the Code, explaining the National Animal Welfare Advisory Committee's reasons for its recommendations and the nature of any significant differences of opinion among submissions to the Code's review or within the Committee itself, is made publicly available (NAWAC 2005b).

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9 http://www.dlgrd.wa.gov.au/Legislation/AnimalWelfare/Default.asp, accessed 10 December 2007.
10 http://www.agric.wa.gov.au/content/pw/ah/animalwelfare_index.htm, accessed 10 December 2007.
11 http://www.animalwelfare.nt.gov.au/, accessed 10 May 2008.
12 http://www.biosecurity.govt.nz/animal-welfare/, accessed 10 December 2007.

The Code addresses castration, horn removal, branding, and ear tagging and marking of cattle and sheep. There are two components to the Code: '(1) general principles and minimising pain and distress, which apply to any painful husbandry procedure, and (2) recommendations and standards relating to specific painful husbandry procedures, namely castration, tail docking, and disbudding and dehorning' (NAWAC 2005b, p. 4). The Report suggests that specific recommendations for other procedures may be developed for future editions of the Code.

The Code does address spaying, which is referred to only in the background section of the Report, where it is noted that:

> The draft Code only refers to castration of male animals. Spaying (removal of the ovaries) of female cattle, sheep, goats or pigs is rarely undertaken for husbandry reasons in New Zealand. Furthermore, it is considered a significant surgical procedure to be performed by a veterinarian or under veterinary supervision (p. 5).

The New Zealand approach to its Painful Procedures Code is recommended as a pointer to future Australian developments in this area. The Code Report presents a discussion of the ethical considerations behind the Code as well as a very thorough review of the relevant science, so that the provisions of the Code are transparent and justified. The setting out of minimum standards and recommended best practice in the Code itself is useful, although it might be expected that such a distinction would become questionable in the longer term, as the expectation develops that best practice should be the universal benchmark.

4.3.3 Canada

Wepruk (2004) provides an overview of animal welfare law in Canada. In Canada, as in Australia, animal health and welfare is primarily a provincial responsibility. Each province, with the exception of Quebec, North West Territories and Nunavut, has dedicated animal protection legislation. In addition, federal acts cover the humane transportation of animals and handling and slaughter of food animals, and the federal Criminal Code prohibits wilful neglect of, or causing pain or injury to, animals.

National Recommended Codes of Practice for the Care and Handling of Farm Animals were developed by producer organisations under the auspices of the Canadian Agri-Food Research Council. The Codes are now the responsibility of the National Farm Animal Care Council (NFACC). NFACC has a broad membership that includes farming bodies, downstream sectors such as food retailers, governments, the veterinary profession and humane organisations[13].

The Code for Beef Cattle was published in 1991 (Agriculture Canada 1991) and the Code for Sheep in 1995 (Canadian Agri-Food Research Council 1995). Neither appears to have been updated since that time. The introduction to Beef Code notes that it 'strives to promote the highest standards of animal husbandry and handling' but also that it intends 'to achieve a workable balance between the best interests of the animals and the producers' (p. 7). The Codes are voluntary and all provincial and federal acts must always take precedence (Agriculture Canada 1991). The Codes do not appear to have any formal status in legislation.

[13] http://www.inspection.gc.ca/english/anima/heasan/transport/infrastructuree.shtml, accessed 5 December 2007.

For the purposes of this review, the Codes are used as the yardsticks of Canadian standards for cattle and sheep welfare. An inspection of several provincial acts and regulations (e.g. Alberta and British Columbia) indicates that these instruments are very general in nature and say nothing about the specific practices with which this review is concerned.

4.3.4 United States

It is very difficult to identify a single set of standards for cattle welfare in the United States (or even a 'typical' set of standards). There is no federal law to regulate the care and welfare of food animals until the period preceding and during slaughter, protection of welfare on-farm instead being the domain of animal anti-cruelty statutes of each of the 50 states (Tomaselli 2003). In contrast to Australia or Canada, the US does not appear to have attempted to develop a set of nationally-agreed standards for farm animal welfare in the form of codes of practice or similar instruments.

Tomaselli (2003) and Turk (2007), of the Animal Legal and Historical Center, provide perspectives on comparative animal cruelty laws and cattle laws specifically in the United States (albeit from a somewhat 'animal rights' perspective). Tomaselli (2003) notes that thirty of the states' anti-cruelty statutes exempt all or some customary farm practices from regulation and that twenty-five of these states exempt all such practices. Turk (2007) argues that 'in general, formalized laws do not exist for cattle outside of slaughter and transportation' and that the industry sets its own standards. He quotes Maryland's relevant statute as typical, in that it precludes 'customary and normal veterinary and agricultural husbandry practices including dehorning, castration, tail docking and limit feeding' from statutes dealing with crimes against animals.

A voluntary industry code entitled *The cattle industry's guidelines for care and handling of beef cattle* has been published by the National Cattlemen's Beef Association (NCBA undated). The *Guidelines* contain recommendations on many aspects of cattle welfare including the procedures of interest to this review.

Another useful guide to cattle welfare standards in the US is the cattle welfare module of the New York State Cattle Health Assurance Program. The program is sponsored by the New York State Department of Agriculture and Markets. The welfare module includes guidelines for castration, dehorning, teat removal and tail docking (NYSCHAP 2007)

4.3.5 European Union

The parent legislation to farm animal welfare directives in the European Union is the *European convention for the protection of animals kept for farming purposes* (1976) (Tomaselli 2003). *European Council Directive 98/58/EC on the protection of animals kept for farming purposes* (1998) is based on the Convention. The Directive is general in nature, seeking to enshrine the 'five freedoms':

1. Freedom from hunger and thirst;
2. Freedom from discomfort;
3. Freedom from pain, injury and disease;
4. Freedom to express normal behaviour; and
5. Freedom from fear and distress.

Of relevance to this review is paragraph 19 of the Annex to the Directive, headed 'Mutilations', which states that:

> Pending the adoption of specific provisions concerning mutilations in accordance with the procedure laid down in Article 5, and without prejudice to Directive 91/630/EEC, relevant national provisions shall apply in accordance with the general rule of the Treaty.

No Directive was found addressing mutilations. However, there is a series of *Recommendations adopted by the Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes* (the Committee is referred to as the T-AP), including a *Recommendation concerning cattle*, adopted in 1988 and a *Recommendation concerning sheep*, adopted in 1992. This T-AP cattle recommendation forbids 'procedures resulting in the loss of a significant amount of tissue, or the modification of bone structure of cattle' with the exception of listed procedures carried out as specified. Details are provided below under individual procedures.

The precise status of the T-AP Recommendations in EU law is not clear to the authors. Its provisions appear to be consistent with domestic legislation examined for this review, but there are inconsistencies – for example, that any castration *should* involve the use of anaesthetic, without an age limit specified. The United Kingdom allows castration by rubber rings until the age of 7 days or by any other procedure until 2 months of age without anaesthetic so it would appear not to conform to the T-AP Recommendations.

Specific rules regarding husbandry practices have also been set down for calf rearing (Directive 91/629/EEC plus amendments). These concern the housing of calves, including dimensions and construction of pens, ventilation, and availability of feed and water.

The European Commission's web site notes that EC legislation establishes minimum standards for farm animal welfare. Member states 'may adopt more stringent rules provided they are compatible with the provisions of the Treaty' (EC 2008).

Two further reports from the European Union are of interest. *The welfare of cattle kept for beef production* (adopted 25 April 2001) presents an opinion of the European Commission's Scientific Committee on Animal Health and Animal Welfare (SCAHAW)[14]. A section entitled 'Mutilations' reviews the welfare impacts of castration, spaying, tail docking, and dehorning and disbudding, and branding. The document reviews the scientific literature and makes specific recommendations regarding each practice (for example, that hot branding should not be used). The formal status of these recommendations is not clear but they do not appear to have been adopted into an EC directive.

No similar documents to those described above were found for sheep. The EC's emphasis seems to be on calves, hens and pigs.

The other report is the *Communication from the commission to the Council and the European Parliament on animal welfare legislation on farmed animals in third countries and the implications for the EU* (EC 2002). The study reported in the Communication was undertaken because of the

[14] The responsibilities of this Committee have since been transferred to the Scientific Panel on Animal Health and Welfare of the European Food Safety Authority, whose Opinions can be found at http://www.efsa.europa.eu/EFSA/ScientificPanels/efsa_locale-1178620753812_AHAW.htm.

recognition that the EC's more stringent animal welfare standards are impacting upon the competitiveness of its agricultural producers which could in turn undermine the standards. It concludes that competitive distortions can be addressed by a combination of:

- Normal market mechanisms providing a premium for higher standards;
- Dialogue with trade partners on how to 'afford greater recognition of animal welfare in a constructive and non-trade distorting manner';
- Bilateral efforts with individual trading partners to promote animal welfare standards;
- Voluntary and mandatory labelling regimes to inform consumers; and
- 'New mechanisms' to allow welfare (and other priorities such as environmental protection) to be reflected in prices paid to producers.

Whilst it is not of direct relevance to this review (it concerns mainly the pig and poultry industries), the Communication is noted as a useful reference in understanding the EU's perspectives on animal welfare and trade. It is clear that the most stringent standards in animal welfare will come from the EU rather than North America. As Tomaselli (2003) observes, this is because of a fundamental divergence of views of animals as either property – as in the US – or as 'sentient beings…endowed with a moral status', as in several EU countries. The latter perspective has led to the EU banning what are common husbandry practices in the US such as sow stalls and battery cages.

4.3.6 United Kingdom

The major pieces of legislation in England are the *Animal Welfare Act 2006* and the subordinate *Welfare of Farmed Animals (England) Regulations 2007*. Also relevant is the *Mutilations (Permitted Procedures) (England) Regulations 2007*. The Act is a UK instrument and Scotland, Wales and Northern Ireland have similar subordinate legislation to the England Regulations.

The Mutilations Regulations defines those procedures that are exceptions to the prohibition on mutilations laid down in the Act. The procedures include castration, dehorning and disbudding, freeze branding, and ear clipping, ear notching and ear tagging of cattle. Schedule 4 of the Mutilations Regulations specifies certain aspects of the procedures (for example, the requirement for anaesthetic during dehorning).

In addition to secondary legislation such as the Mutilations Regulations, the Act also allows for Codes of Recommendations for the welfare of animals to be produced. Two such codes cover cattle and sheep (DEFRA 2003a,b). It and other Codes were produced under the previous *Agriculture (Miscellaneous Provisions) Act 1968* but continue to apply. The Codes do not establish statutory requirements but may be used to 'back up legislative requirements'; failure to comply may be used to as evidence of breaching the Act, in the same way that Codes are used in most States and Territories of Australia. It is a legal requirement that livestock farmers and employers 'ensure that all those attending to their livestock are familiar with, and have access to, the relevant codes'[15].

The provisions of the Code and of the new Mutilations Regulations, in respect to the procedures considered in this review, are the same with one variation (noted below under dehorning).

In addition to the Department for Environment Food and Rural Affairs (DEFRA), which administers the legislation, an important source of information from the UK is the Farm Animal Welfare Council

[15] http://www.defra.gov.uk/animalh/welfare/farmed/on-farm.htm#we, accessed 15 May 2008.

(FAWC). The FAWC is an independent body established by the UK Government to advise on any legislative or other measures that may be necessary to protect the welfare of farm animals from farm to place of slaughter. It publishes opinions on its web site, including a report on dairy cattle (FAWC 1997) and on castration and tail docking in sheep (FAWC 2008).

Recommendations from this report have been noted below under the respective procedures.

4.3.7 Switzerland

There are unofficial translations of the Swiss *Federal Act on Animal Protection 1978* and the *Animal Protection Ordinance 2001* (apparently equivalent to Regulations) available from the Swiss Government web site.

Section 5, Article 11 of the Act stipulates that any ‘operations calculated to cause pain’ (‘calculated to cause’ suggests malicious intent, which is probably not the connotation intended) may only be carried out by a veterinary surgeon, under general or local anaesthesia. The Swiss Federal Council can specify exceptions to this rule, and such exceptions are listed Article 65 of the Ordinance.

The exceptions do not include any of the procedures under review here, with the apparent exception of ear tagging (‘marking of animals, with the exception of tattooing of dog and cats’). While castration of pigs is listed as an exception, castration of calves and lambs was removed from the list in the 2001 amendment to the Ordinance (Falk 2004). Calves and lambs must therefore be castrated by a veterinary surgeon using anaesthesia at any age. This has prompted research on pain-free castration techniques as well as calls for ruminant castration to be delegated to producers for economic reasons (Falk 2004).

It should be noted for the record that Switzerland is not part of the European Union. Swiss provisions are included in the EU section because of very close cultural similarities.

4.3.8 Other countries

Despite best efforts, it was not possible to identify specific cattle welfare standards from any eastern European or South American countries.

The *Animal Protection Act* of Poland states that ‘operations causing pain shall be performed under general or local anaesthesia, except these operations which, according to the principles of the veterinary art, are carried out without anaesthesia’. Details of which operations would fall into this category could not be found.

Brazil’s *Environmental Crimes Law 1999* carries a provision prohibiting the abuse, mistreatment, injury or mutilation of wild, domestic or domesticated animals, native or exotic. A bill was proposed in 2002 or 2003 to provide a clearer definition of cruelty (Clayton 2003). It is not known to the authors whether this bill has been passed. There do not appear to be any more specific provisions than these in respect to cattle husbandry practices.

4.3.9 Animal welfare interest groups and certifying agencies

A number of animal welfare interest groups publish standards or policies for welfare for cattle and other species. This review examined the following:

- RSPCA (Australia): *Policies & position papers. Part B. Farm animals*, 2006 edition (RSPCA (Australia) 2006).

- RSPCA (UK): *RSPCA Welfare standards for beef cattle*, November 2007 and *RSPCA Welfare standards for sheep*, June 2006 set out the criteria required for certification under the RSPCA's 'Freedom Food' scheme. The 'freedom' refers to the five freedoms as defined by the UK's Farm Animal Welfare Council (FAWC). The introduction to each document states that its standards are developed from legislation, government codes, scientific research, veterinary advice, recommendations of the FAWC and practical farming experience (RSPCA (UK) 2006, 2007).

- Humane Society International: *'Humane Choice' Standards – cattle* and *'Humane Choice' Standards – sheep* are published by the HSI Australian office. They describe the standards required for certification under the Humane Choice food labelling program developed by HSI in association with the National Association for Sustainable Agriculture, Australia (NASAA) (HSI (Australia) 2006a,b).

- Animal Welfare Institute: *Animal welfare approved standards for beef cattle and calves* (Animal Welfare Institute 2006) and *Animal welfare approved standards for sheep* (Animal Welfare Institute undated). The Institute, based in Washington DC, describes itself as a 'non-profit charitable organization founded in 1951 to reduce the sum total of pain and fear inflicted on animals by humans'. Its 'Animal Welfare Approved' label is a new labelling program with an emphasis on family farms.

- Federation of Animal Science Societies (FASS) (US): Chapter 5: Guidelines for beef cattle husbandry and Chapter 9: Guidelines for sheep and goat husbandry, from the first revised edition (January 1999) of the *Guide for the care and use of agricultural animals in agricultural research and teaching* (FASS 1999).

- Temple Grandin: *Outline of cattle welfare critical control points on feedlots, ranches and stocker operations* (Grandin Livestock Handling Systems 2008). No recommendations for sheep husbandry practices were found on the web site. Temple Grandin (PhD) is Professor of Animal Science at Colorado State University and is well known and highly regarded internationally as a designer of animal handling facilities. Grandin played a key role in the development of McDonalds' slaughter QA requirements.

- KRAV: *KRAV Standards 2001* (KRAV 2001). KRAV is the Swedish organic certification agency.

- Australian Veterinary Association: *Policies – Part 5 – Identification of animals*, *Part 8 – Cattle health and welfare* and *Part 10 – Sheep and goat health and welfare* as published on the AVA web site (AVA 2008).

- American Veterinary Medical Association: *Policy statements*, as published on the AVMA web site (AVMA 2008). The AVMA does not appear to have any specific policies on sheep except for tail docking.

- Canadian Veterinary Medical Association: *Position statements on animal welfare issues – castration, tail docking, dehorning of farm animals*, as published on the CVMA web site (CVMA 2006).

4.4 Castration

4.4.1 Description of methods and uptake

Stafford & Mellor (2005a) distinguish three categories of castration: physical, chemical and hormonal. The most common are the physical methods which can be further divided into bloodless and surgical (or open) methods.

4.4.1.1 'Bloodless' methods

The bloodless group of methods includes latex or rubber rings or bands and the Burdizzo instrument. All of the bloodless methods work by disrupting the blood supply through the scrotal neck, causing ischaemic necrosis of the scrotum and testes (in the case of rings and bands) or just the testes (Burdizzo).

Rubber or latex rings are of fixed size. They are stretched open using a spreading instrument, placed over the scrotal neck, and released to provide tight constriction of the enclosed tissues. 'Banding' works in a similar fashion to rings but using latex tubing whose length is adjusted and fixed using metal clips to provide the appropriate tension. Banding devices referred to in the literature include the EZE® Bloodless Castrator[16], of which there are several models including one which uses continuous tubing, another using adjustable loops of latex. Another common product is the Callicrate Smartbander®[17], which uses loops of solid latex.

While rubber rings are suitable only for younger calves (due to the size constraint of the rubber ring), banding can be used on much larger bulls because a ratchet system is used to tighten the band and a metal crimp to secure it. The EZE® T-1 device is advertised as suitable for animals from 350lbs (160kg) to 1000lbs (450kg) plus, while the Callicrate Smartbander® is advertised as usable on bulls up to 3000lbs (1350kg). There does not appear to be any welfare research to support these claims of size suitability (Section 4.4.2).

Castration by rings or bands causes the entire scrotum and its contents to undergo avascular necrosis (i.e., tissue death due to complete occlusion of blood supply). Chase et al (1995) found that scrota of banded bulls aged 21 months had all dropped off by 5 weeks; the same process for the younger bulls (8-14 months) of Knight et al (2000) took 4-9 weeks.

The Burdizzo is a clamping device. The operator crushes the spermatic cords at two levels, 1cm apart, by applying the Burdizzo for 5-10 seconds each time. The lower crush is applied after the

[16] Wadsworth Manufacturing, Dublin, Minnesota, http://cattlebanders.com
[17] No-Bull Enterprises, St Francis, Kansas, www.nobull.net

upper one (Kent et al 1996). This is done on both sides for a total of four crushes. It is important that the crushes are offset to leave a width of undamaged skin in the midline so that there is continued blood circulation to the scrotum. After 4-6 weeks there is atrophy of the testes to leave a fibrous knob of tissue of similar diameter to the spermatic cord (Weaver et al 2005).

The use of the Burdizzo was associated with a much greater failure rate of castration than rings, bands or surgery in the survey of UK farmers by Kent et al (1996). This is not surprising, given that it is not possible to be certain that a Burdizzo operation has worked in the same way as surgical testis removal or even the placement of a rubber ring. There are requirements for the maintenance and use of the device that, if not followed, will decrease the chances of success (Kent et al 1996).

A combination of rubber ring and Burdizzo techniques has also been evaluated in calves in one study (Molony et al 1995). The ring / Burdizzo approach was included in the trial because it appeared to be less painful than other methods compared for lambs (Kent et al 1995). Whilst the combination appeared to offer some reduction in acute pain from rubber rings alone, the benefit was less than that observed in lambs, and further development was not considered warranted given the chronic effects of rings observed (Molony et al 1995).

It should be noted that the names given to the various bloodless methods in the literature are sometimes confusing, and care needs to be taken to understand precisely what method is being discussed. For example, 'the bloodless castrator' has been used to describe the Burdizzo (e.g. Clarke-Lewis 1977) or the latex banding device (e.g. Denooy 1992). The term 'elastrator' appears in North American literature describing a device to apply a variable length of latex tubing to a consistent tension (i.e. banding), whereas in Australia it usually means a rubber ring or the device to apply it, which is also the meaning applied by Fenton et al (1958). Stafford & Mellor (2005), in their review of the welfare impacts of castration, refer to ZoBell et al (1993b) using rubber rings when in fact the study involved latex banding.

For purposes of consistency and to minimise confusion, the terms 'rings', 'bands' and 'Burdizzo' are used in this review even where an alternative term is used in a particular paper.

4.4.1.2 Surgical methods

With surgical methods the testes are completely removed following incision of the scrotum and scrotal sacs. Weaver et al (2005) describe four methods of surgical castration that differ in the way they deal with spermatic cord, which carries the blood vessels and therefore the risk of haemorrhage:

- Traction on the cord, in which the testicle is simply pulled until the cord breaks. This is the least preferred method and only suitable on calves up to 2 months of age;

- Torsion and traction, in which the testicle is pulled and twisted at the same time. This method is suitable up to 6 months;

- Crushing using an emasculator[18], suitable for calves and small bulls and preferred to the two options above; and

- Crushing plus ligation (tying-off), where the risk of haemorrhage is high.

Another common method is to scrape the spermatic cord with a scalpel blade until it breaks (for example, Fell et al 1986).

4.4.1.3 Chemical methods

Chemical castration involves the injection of a necrosing agent into the testes. It appears that at least one product is or has been available in Australia: Chem-Cast®, containing 88% lactic (or α-hydroxypropionic) acid (Fordyce et al 1989, Coventry et al 1989, Cohen et al 1990). No information could be found on the current availability of this or any other chemical castration product.

4.4.1.4 Hormonal methods

'Immunocastration' refers to the active or passive immunisation of male animals against gonadotrophin-releasing hormone (GnRH), resulting in suppression of luteinising hormone and follicle stimulating hormone secretion and reduced plasma testosterone, atrophy of the testes and arrested spermatogenesis (Jago et al 1996, 1997).

A commercial immunocastration product (Vaxstrate®[19]) was commercially available for cattle in Australia between the late 1980s and 1996. It was withdrawn from the market due to poor sales, reflecting problems with injection site reactions, the two-dose regime, and individual variation in efficacy and duration of action (Meeusen et al 2007, S. Page pers. comm.). Pfizer Inc. is preparing to launch a commercial anti-GnRH product for cattle in New Zealand and Australia under the brand 'Bopriva'. The draft label for Bopriva® in New Zealand carries a claim for the reduction of 'sexual and aggressive male behaviours' over 12 weeks (S. Rushworth pers. comm.). The product will not be a substitute for permanent castration of all animals.

Other anti-GnRH products have been developed for different indications in other species (e.g. control of boar taint). Various reviews on the development of vaccines against reproductive hormones have been published (Cooper & Larsen 2006, Hardy & Braid 2007, Kutzler & Wood 2006, Meeusen et al 2007, Naz et al 2005, Purswell & Kolster 2006).

MLA is currently funding a project to examine the potential of a single dose treatment for the permanent castration of sheep and cattle. This work is in the very early stages so even if the product is successful its commercial delivery would take between 5-10 years.

4.4.1.5 Adoption of different methods

The only data on beef cattle castration practices come from a survey by ABARE on behalf of MLA for the 2005/06 year (D. Marotti pers. comm.). The survey shows 'scalpel' to be the most common procedure used in southern Australia (43.5%), followed by 'rubber ring' (23.7%) and Burdizzo

[18] An emasculator is an instrument that simultaneously cuts the spermatic cord and crushes the portion of the cord proximal to the cut, to minimise haemorrhage.
[19] Websters Animal Health, NSW

(9.3%), with ‘other’ making up 23.5% of the responses. Calves were castrated at an average age of 2.5 months. The scalpel was even more dominant in northern Australian beef systems (64.3% compared with 9.6% for rings, 6.2% for Burdizzo and 20.0% ‘other’). Average age at castration for northern Australia was 5.1 months.

In New Zealand, rubber rings were the preferred option by a considerable margin in the 1997/98 season, being used on 85% of farms responding to the survey of Stafford et al (2000a). Calves castrated by ring averaged 2.2 months of age at the time of castration, while those castrated surgically averaged 4.3 months. Surgery was used on 18% of farms and the Burdizzo on only 1%. Sixty percent of farmers reported that castration was carried out before 12 weeks.

From a postal survey of castration methods used by cattle farmers in the UK, Kent et al (1996) found that 43% used the Burdizzo, 39% surgery, and 32% rubber rings (some farms used more than one method). Calves were castrated at a range of ages from 1 week to over 6 months, with 62% reporting that castration was carried out before 12 weeks. This was a surprising finding, as calves over 12 weeks may only be castrated by a veterinarian, and only 21% of respondents indicated that a veterinarian did the castrations on their calves.

The USDA survey of feedlot practices for the year 1998/99 showed that 65.3% of operations (i.e. enterprises) used bands to castrate, while 48.4% used surgery and 1.5% other methods (USDA 2000). From a similar survey of the grazing beef industry, 55.4% of operations ‘used a blade’, 37.8% used a ‘rubber band’ prior to 3 months of age, 5.6% used a Burdizzo or similar, and 1.1% used ‘rubber tubing e.g. EZE castrator at more than 3 months’. Larger herds used a blade much more commonly than other methods (USDA 1998).

Nielsen & Thamsborg (2000) found that the Burdizzo was used on 59% and surgical castration on 37% of organic steer production farms in Denmark. The use of rubber bands is forbidden in Denmark.

4.4.2 Welfare and productivity impacts

Personal views: Castration has been the subject of debate in veterinary circles for some years, and it is interesting to read some very personal views emerging from the literature. Clarke-Lewis (1977) wrote to the Veterinary Record condemning the ‘bloodless castrator’ (Burdizzo) as ‘on a par with a gin trap as an extremely cruel instrument which, like it, should be outlawed’. Cox (1977) writes in general support of surgical castration over the Burdizzo, while Hinton (1977) relates a series of letters in support of the Burdizzo from 1929.

A more recent exchange of correspondence in the Canadian Veterinary Journal also argues the merits of ‘bloodless castration’ – in this case, the latex banding device EZE® Bloodless Castrator (Denooy 1992, Longair 1992a,b, Stookey 1992). Stookey argues that there is insufficient evidence to support the Canadian Veterinary Medical Association’s opposition to elastrators generically, while Longair defends that position. There is agreement among the correspondents that the more important issue is whether castration of mature bulls is of itself acceptable practice.

In the same journal, the ethicist Bernard Rollin (1993) criticises the use of rubber rings and bands as ‘probably the most painful’ of all methods and likens them to a rubber band around the finger of a person. He also questions the belief that castration would be less painful in younger animals. More broadly, he challenges the need for castration in the first place, observing that castration followed by hormone implants is like removing the testicles then placing them back in the ears.

Weaver et al (2005), in one of the definitive food animal surgery texts, note that the 'need for castration has been increasingly questioned on scientific, economic and humanitarian grounds' (p. 191). The authors go on to state categorically that rubber rings 'should not be used' (p. 192) and to describe the restrictions on their use in countries such as Switzerland.

Scientific literature: There is a large body of more objective literature on the welfare impacts of castration on cattle and this literature has been reviewed by several authors (AVMA 2006b, Bretschneider 2005, NAWAC 2005b, SCAHAW 2001, Stafford & Mellor 2005a). Of these, the paper by Stafford & Mellor (2005a) is the most comprehensive. The only major articles to have appeared since that review are those of Pang et al (2006), the most recent of a series from Ireland, and a report from work in Switzerland by Thüer et al (2007a). The study of Thüer et al (2007a) was introduced and placed in context by Kevin Stafford in a guest editorial entitled *Alleviating the pain caused by the castration of cattle* in the Veterinary Journal (Stafford 2007).

The review of Bretschneider (2005) effectively provides a meta-analysis of peak plasma cortisol levels and weight loss associated with castration, in calves of different ages, as reported in 19 references.

A summary of the primary research papers describing the effects of castration on cattle is provided in Appendix 1.1. The list includes published short communications or letters in reputable journals that express opinions or describe events of relevance. Two research groups stand out in the literature, especially over the last 15 years. The New Zealand AgResearch group including Fisher and Knight has published extensively, as has a group from the Grange Research Centre and Dublin's University College, Ireland, including Crowe, Earley, Fisher, Pang and Ting.

4.4.2.1 Complications of the procedure

Each of the methods of castration has potential complications with adverse animal welfare impacts.

Bloodless methods such as rubber rings and bands carry the highest risk of tetanus. Sepsis can also occur and incorrect placement may result in cryptorchidism (retained testes) (Weaver et al 2005). Inflammation and sepsis of the scrotal skin around rubber rings has been described by Molony et al (1995) and Thüer et al (2007). A high incidence of necrotic lesions proximal to the band has also been observed in 14-month old bulls with Callicrate® bands applied. These lesions did not resolve until the bands fell off up to 9 weeks after application (Knight et al 2000). MLA's *Guide to best practice husbandry in beef cattle* notes that banding is a 'complicated and difficult procedure' (p. 19) and that, unless the appropriate tension is achieved, there can be very marked and painful swelling of the scrotum with possible fatal consequences (Newman 2007).

Weaver et al (2005) list as (infrequent) complications of the Burdizzo:

- Crushing of the penis, causing urethral blockage and rupture, because the implement is applied too high;
- Bruising and/or oedema of tissues due to slackness of jaws;
- Necrosis of the scrotal skin and possible infection because the clamp lines are contiguous across the scrotal neck; and

- Failure of castration on one or both sides.

Fenton et al (1958) state that ‘crushing of the cord inevitably produces tissue reaction and oedema which are responsible for more pain during the 2 weeks immediately following castration than is seen in the calf castrated by incision’. Clarke-Lewis (1977) refers to the Burdizzo causing the scrotum ‘to swell up like a small football’ and to incidences of its failure to completely sever the cord.

Complications of surgical castration include infection, severe swelling due to infection, oedema, and/or poor drainage (which can extend into the prepuce) and haemorrhage. Tetanus is a rare complication (Weaver et al 2005).

4.4.2.2 Effects on productivity

There have been many studies of the effect of castration *per se* on weight gains of calves (e.g. Bagley et al 1989, Baker & Gonyou 1986, Carroll et al 1963, Champagne et al 1969). These are studies conducted from a productivity rather than a welfare perspective. In many cases, they have been undertaken to compare the performance of various castration and/or hormonal growth promotant (HGP) regimes in North American finishing systems. In some cases (e.g. Bagley et al 1989) there are comparisons of the effect of age at castration.

An exhaustive review of studies such as these has not been undertaken here (although some papers are referred to in Appendix 9.2), for several reasons. As Stafford & Mellor (2005a, 2006) observe, production parameters are a blunt instrument in measuring pain or stress. Calves are subject to a range of nutritional regimes post-castration and there may be interactions between plane of nutrition or feeding system and degree of pain as factors affecting weight gain. Keane (1999), for example, found that castration reduced the walking and grazing time of cattle, suggesting that weight gain effects on extensively grazed cattle would be greater than in feedlot cattle. Studies involving calves implanted with HGPs and provided feedlot rations may therefore have limited relevance to Australian conditions.

Also, the productivity impacts of castration due to pain or stress are difficult to separate from those caused by the hormonal effects of castration, i.e. the decrease in testosterone secretion (Knight et al 1999). The most useful studies in the context of this review, therefore, are those that compare different methods of castration or those that include a castrated group in which pain is managed (Stafford & Mellor 2005a).

Several studies meet these criteria. Fenton et al (1958) found no difference in the average daily weight gain (ADG) over 5 weeks of 7-week old calves castrated by surgery, rubber rings or Burdizzo, but all groups had significantly lower ADG than controls. Mullen (1964) extended Fenton’s work to older calves (3 or 5 months). These authors found that surgical castration imposed less of a setback than the Burdizzo over 12 weeks and less than that imposed by rubber rings. The latter comparison, however, was confounded by different ages at treatment.

A study in Canada by Cohen et al (1990), comparing non-implanted bulls and steers castrated either surgically or by chemical injection at 7-9 months of age, found a significant reduction in ADG associated with surgical but not chemical castration over the first 27 days post-treatment. Differences between the groups were not significant over the 133-day post-treatment period but still apparent (1.1, 0.9 and 1.2 kg/day for controls, surgical and chemical castration groups respectively).

Studies by ZoBell et al (1993b) in a Canadian feedlot environment, with implanted 8-9 month old crossbred steers, showed greater setback in ADG from surgical than banding castration during the first 28 days, although the difference was significant in only one of two trials. The depression in growth rate was 51-53% for the band group and 68-73% for the surgical group. These differences disappeared by day 56 and day 84 respectively. Intact bulls grew faster than steers throughout the measurement period.

Chase et al (1995) found no significant difference in ADG over 35 days between surgically (with local anaesthetic) or band-castrated Hereford, Brahman and Angus bulls, 21 months old, although there was a tendency to lower ADG in banded animals (0.42 compared with 0.64kg/day, while controls grew at 0.93kg/day). There were breed / treatment interactions but these were reported not to have significantly influenced the average ADG figures. Both castration groups tended to have lower ADG than intact control bulls.

The first study to examine the effect of banding on cattle at pasture following castration was undertaken by Knight et al (2000) (further results from the same trial are published in Fisher et al 2001). Bulls were castrated at either 8-9 months or 14 months of age and their ADG compared with both steers and intact bulls. The study showed slower growth rates in the banded group compared with the surgical castrates over 4-5 weeks resulting in a 6-10kg liveweight difference. This difference had disappeared by day 56 in the older bulls but not the younger bulls.

A notable finding by Knight et al (2000) was the high incidence of necrotic lesions above the bands in the older group from day 7. These did not heal until the bands dropped off over 1-2 months. The authors concluded that bands should only be used in bulls less than 14 months.

Bretschneider's (2005) meta-analysis of the effect of castration on weight gain from the studies of ZoBell et al (1993b), Chase et al (1995) and Knight et al (2000) concludes that there was no significant difference in ADG of cattle castrated by surgery or rings / bands during the first month after castration. Nor was there any breed effect. However, castrated cattle had a significantly lower ADG than uncastrated cattle, depending on age at castration. Calves castrated at or close to birth experienced very small castration-associated reduction in weight gain. This reduction increased with age of castration to about 8 months, where the effect levelled off.

Studies demonstrating the effect of local anaesthesia and/or analgesia on weight gain following castration have been published by Faulkner et al (1992), Fisher et al (1996), Stafford et al (2002b) and Ting et al (2003a,b).

Faulkner et al (1992) provided butorphanol and xylazine intravenously to 6-9 month old bulls prior to surgical castration. The analgesic combination had no effect in alleviating the effect of castration on ADG over 27 days. In the study of Fisher et al (1996), Friesian bull calves aged 5.5 months were castrated by surgery or Burdizzo with or without local anaesthetic. Over 35 days, calves given local anaesthetic prior to surgical castration had significantly higher ADG than those surgically castrated without anaesthetic. However, there was no difference in ADG between those castrated with the Burdizzo with or without local anaesthetic, those castrated surgically after local anaesthetic, and uncastrated controls. Stafford & Mellor (2005a) speculate that this observation might be due to a pain threshold beyond which feeding and therefore weight gain are compromised.

Stafford et al (2002b), in a large study involving 190 Friesian-cross calves 2-4 months of age, examined the effects of local anaesthesia or local anaesthesia plus ketoprofen on calves castrated by rubber ring, Callicrate® band, two surgical methods (traction or emasculator) or Burdizzo. The authors reported no difference between any of the groups in bodyweight between 75 and 92 days after treatment, nor in weight gain. There is some confusion in this paper, however, with the 'Materials and methods' section stating that calves were weighed once only at between 29 and 43 days. No further details, including the actual bodyweights or weight gains, are given.

Similar findings were reported by Earley, Ting and others from Ireland (Earley & Crowe 2002, Pang et al 2006, Ting et al 2003a,b). Ketoprofen made no difference to ADG when 5.5 month-old calves were surgically castrated (Earley & Crowe 2002) nor did it have a consistent effect in various regimes with 11-month old calves (Ting et al 2003a). Local anaesthetic or a xylazine + lignocaine caudal epidural block did not mitigate the reduced ADG of 13-month old calves castrated by Burdizzo compared with controls, although ketoprofen did provide partial restoration of ADG over the 35-day period of the trial (Ting et al 2003b). Similarly, Pang et al (2006) found that carprofen had no effect on ADG of 5.5-month old calves castrated by banding or Burdizzo.

In summary, the effects of different methods of castration on weight gain are not consistent, nor are the ameliorating effects on weight gain of anaesthesia or analgesia.

4.4.2.3 Effects on physiology

Castration causes a peak in plasma cortisol between about 24 and 90 minutes after the procedure, depending on the method used and the age of the animal, with older animals tending to display a later peak. Cortisol concentrations then return to normal over a period of 1-2 hours, although this period has been shown to last up to 6-10 hours in 5.5-month-old bulls castrated by a surgical cut method (Fisher et al 1996). Stafford & Mellor (2005a) provide a summary of the cortisol responses to castration as observed in three key studies (Robertson et al 1994, Fisher et al 1996 and Stafford et al 2002) (Table 2).

Table 2 Peak plasma cortisol concentrations and duration of cortisol response to different methods of castration in calves of various ages (adapted from Stafford & Mellor 2005a)

Age at castration	**6 days[1]**	**21 days[1]**	**42 days[1]**	**2-4 mths[2]**	**5.5 mths[3]**
Peak cortisol (nmol/L) and (time to peak (min))					
Ring	60 (36)	45 (48)	45 (60)	76 (90)	
Band				101 (30-60)	
Burdizzo	80 (24)	50 (24)	60 (24)	64 (30)	87 (30)
Surgical (pull)	105 (24)	65 (24)	110 (24)	68 (30)	
Surgical (cut)					129 (30)
Duration of plasma cortisol over pre-treatment levels (min)					
Ring	132		96	132	180
Band				180	
Burdizzo	60	60	72	90	90
Surgical (pull)	132	84	132	180	
Surgical (cut)					360-600

1 Robertson et al (1994)
2 Stafford et al (2002)
3 Fisher et al (1996)

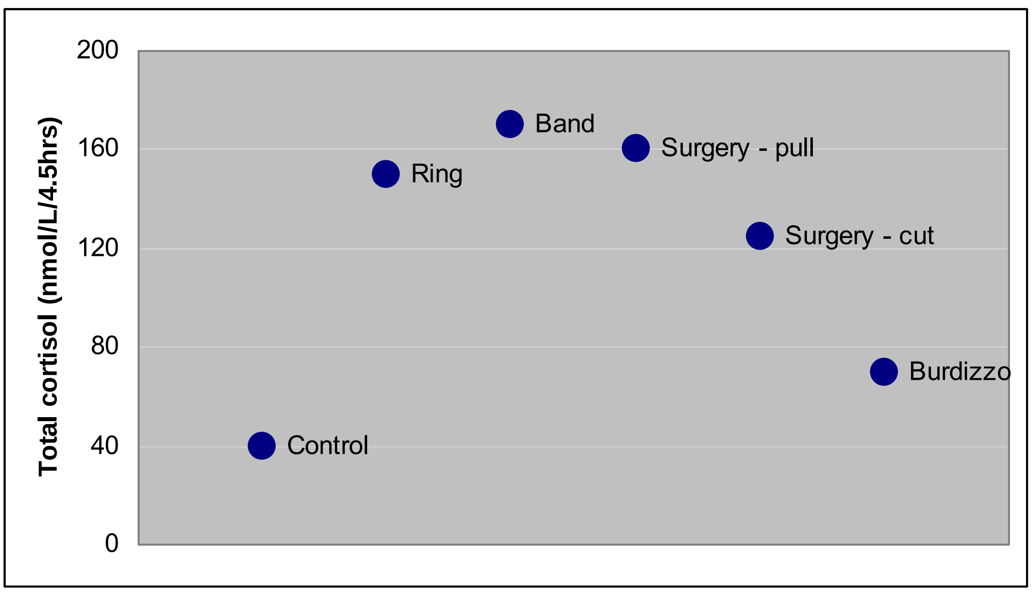
A number of other studies have also reported on the cortisol response to castration at various ages and using various methods. The findings are broadly in line with those shown above.

It is somewhat problematic to comment on age effects from these data because age comparisons must be made across experiments and statistical comparisons are not available. Within castration method, there may be an effect of longer time to peak cortisol with increasing age, especially where rubber rings are used. The duration of plasma cortisol over pre-treatment levels also appears to increase consistently with age across all methods. However, there is no clear inflexion point.

Comparisons between methods can be made more safely. Surgical methods and bands appear to induce the greatest cortisol response as measured by time to peak, height of peak and length of time above baseline levels, at least in older calves. Rubber rings seem to induce a slower onset of peak cortisol than other methods and the height of the peak is lower, at least in younger calves, but the response may persist for a prolonged period. The Burdizzo usually has an intermediate effect.

Figure 2 summarises the results of Stafford et al (2002). In this study there were three control groups: one group handled, bled and manipulated as for castration, a second group as for the first but also receiving local anaesthetic, and a third group receiving local anaesthetic plus ketoprofen. These three groups showed a very similar area under the curve (40 nmol/L/4.5 hrs) for the cortisol response.

Figure 2 Relative total cortisol responses to different methods of castration (data from 2-4 month-old calves in Stafford et al 2002; figure adapted from NAWAC 2005b)



The same broad pattern was observed by Molony et al (1995). Behavioural findings are better presented and explained in this study than those on cortisol, but it appears that rubber rings produced a lower peak cortisol response than Burdizzo, surgical or combined Burdizzo / rubber ring methods in 1-week-old Ayrshire calves. However, the cortisol response to rings lasted longer than that of the Burdizzo, sustained by smaller, later peaks. Findings were similar across 3 age groups in Robertson et al (1994) (Table 2) and in calves aged 21-28 days by Thüer et al (2007a), in whose hands the Burdizzo method caused a much higher cortisol peak than rubber rings but a more rapid return to baseline levels. Mellor et al (1991) were unable to find a cortisol response to rubber rings in hand-reared calves aged 1-7 days.

Fell et al (1986) measured salivary rather than plasma cortisol in hand-reared calves 4-11 weeks old. Calves castrated surgically had higher cortisol responses than those castrated by rubber rings up to 2 hours post-treatment. Levels of both groups had fallen to control levels by 4 hours and remained there at 24 hours and 6 days. In older (2-4 month-old) calves, rubber rings caused a higher peak cortisol than surgical or Burdizzo methods, but a lower and later peak than that from banding. There was wide variation in response to the surgery-cut method, which may be due to individual differences in pain tolerance or anatomy of the spermatic cord (Stafford et al 2002). Pang et al (2006) found that banding induced a later, higher peak and greater area under the curve in hours 0-2 and 0-4 than did the Burdizzo in 5.5-month-old calves. The Burdizzo caused a lower cortisol response than surgery at 6 hours in calves of the same age (5.5mo) in beef breeds in Canada (King et al 1991).

Cortisol responses to castration may be very persistent, suggesting chronic pain, in older animals. Chase et al (1995) found similar cortisol levels in 21-month old surgically or band-castrated steers 2 days after treatment and both were higher than controls. High cortisol at 7 days was reported in 9-month-old calves by Faulkner et al (1992), and Fisher et al (2001) found elevated cortisol at 14 days in 14-month-old surgical and band castrates. In their review, Stafford & Mellor (2005a) note that it is not clear that pain caused the elevated cortisol in these cases because no analgesic-treated group was included.

Surgical castration was compared with chemical castration (using lactic or α-hydroxypropionic acid) by Cohen et al (1990) in 7-9 month-old calves. In this study the cortisol response to surgical castration lasted 6-12 hours, which is similar to the findings of Fisher et al (1996) in calves of similar age. The peak cortisol response was observed much later than that of Fisher et al (1996), at 6 hours, but there were far fewer early data points in the study (0, 3 and 6 hours). Cortisol was significantly lower in chemical castrates at 3 and 6 hours.

Bretschneider (2005), analysing 8 studies (Carragher et al 1997, Chase et al 1995, Cohen et al 1990, Faulkner et al 1992, Fisher et al 1996, 1997b, King et al 1991, and Robertson et al 1994), concluded that age at castration had a significant effect on peak cortisol response. Calves castrated over 6 months of age had a significantly higher peak cortisol than those aged less than 6 months. There was no effect of castration method – surgical vs banding – on ‘stress’ (peak cortisol), causing the author to suggest that banding may be a better option if done properly given the potential complications of surgery. Given the limited value of peak cortisol as a single measure of stress, this would appear to be a recommendation based on thin evidence.

Other physiological parameters have been examined in respect to castration. Increased plasma haptoglobin and/or fibrinogen has been reported by Ting et al (2003b) in response to Burdizzo castration and by Earley & Crowe (2002), Faulkner et al (1992) and Fisher et al (1997b) after surgical castration. The induction of interferon-γ production by lymphocytes in response to antigens (including keyhole limpet haemocyanin and concanavalin A), a measure of an animal’s immunocompetence, has also been investigated (Earley & Crowe 2002, Fisher et al 1997a,b, Pang et al 2006, Ting et al 2003a,b, Ting et al 2005). There were conflicting findings in these studies with some reporting suppression and others finding no effect. As described above, the importance of these findings in assessing the pain response is questionable.

4.4.2.4 Effects on behaviour

Outcomes of behavioural studies tend to mirror those of cortisol studies. Adverse behaviours associated with rubber rings are less immediately obvious but gradually appear and may persist for longer than those due to surgical or Burdizzo castration.

During surgical castration without anaesthetic, 4-11 week-old calves struggled and kicked with their back legs, although there was no vocalising or collapsing. Most calves stood still for 1-2 hours after the procedure and then resumed grazing. The application of rubber rings was accompanied by less severe struggling and stamping. For an hour afterwards some calves made movements to bring the scrotum into contact with the ground, legs or muzzle but thereafter behaved normally (Fell et al 1986).

Burdizzo castration resulted in a higher frequency of standing postures in 13-month-old bulls compared with controls, including a higher frequency of abnormal standing postures such as tail swishing, over a range of time points to 3 hours and then again at 6 hours. Feeding and ruminating were also reduced (Ting et al 2003b). In an experiment of similar design, surgical castration was also associated with higher frequency of standing postures, a reduced frequency of lying postures and reduced rumination compared to controls.

Macaulay et al (1986) found significant treatment effects in the distance moved by 3-week-old calves castrated by surgery, Burdizzo or chemical in open field tests 2 hours and 2 days post-operatively: 13m, 57m, and 59m compared with 91m (controls) at 2 hours, and 26m, 35m, 95m and 125m (controls) at 2 days. This would seem to indicate differences in soreness, but the research is reported only in a brief communication and cannot therefore be scrutinised.

Behaviours indicative of pain were reported by Robertson et al (1994) in 3 age groups over 3 hours. Burdizzo and surgical castration were associated with immediate abnormal standing, which lasted for 24 minutes in younger calves (6 days) and longer in older calves. Six- and 42-day old surgical castrates also showed increased abnormal lying postures with a peak around 120-150 minutes. Rubber ring castrates were slower to show abnormal behaviours but from 12 minutes the time spent in abnormal standing postures increased, peaking at around 30-90 minutes. Abnormal lying mainly occurred between 90 and 180 minutes. The incidences of both abnormal standing and lying postures were higher for rubber ring castrates than all other groups.

Longer term observations by Molony et al (1995) of 1-week-old calves castrated with rubber rings (with or without Burdizzo application) showed increasing interest in the site of castration, and increases in licking, abnormal standing, movements of the tail, alternate lifting of the hind legs and head turning for at least 42 days. Burdizzo-only and surgical castrates showed only occasional licking of the site up to 36 days. However, the ringed calves showed significant inflammation and infection. All calves in the trial were housed and were observed to have sucked each other on the scrota. There is a question, therefore, whether these sequelae would be likely to occur in extensively grazed cattle.

Chronic behavioural effects of ring castration were also observed by Thüer et al (2007a). In this study, there were few signs of pain in 3-4 week-old rubber ring castrates immediately following castration, while a Burdizzo group showed strong signs of pain. However, the rubber ring group showed more total 'active behaviour' (foot stamping and kicking, licking and restlessness, all suggestive of discomfort) during the first 2 hours than any other treatment, and over the following 3 months displayed a significantly greater proportion of abnormal postures than controls. The ringed calves responded to scrotal palpation in a way that suggested pain for 8 weeks, while those castrated by Burdizzo stopped responding in this manner after 2 weeks.

As in the study of Molony et al (1995), the rubber ring castrates of Thüer et al (2007a) showed marked inflammation around the ring. These calves were also housed. Scrota fell off at about 7 weeks, which is longer than the 4-5 weeks reported by Stafford et al (2002), who did not report marked inflammation. The calves of Stafford et al (2002) were older (2-4 months) but were released into small paddocks between handling events.

New Zealand's NAWAC (2005b) report cites some unpublished observations of behaviours associated with banding that warrant mention here. The first is a personal communication from David Mellor referring to the experiment published in Stafford et al (2002), which reports only the cortisol responses to a range of castration methods with or without anaesthesia. The communication notes that the 'behaviour of calves castrated with bands indicated severe pain – they lay on the ground with their hind legs extended, a posture not seen with rubber rings' (p. 32). On the other hand, H. Burrow is cited reporting that indicators of stress were significantly worse in surgically-castrated than banded animals, while Temple Grandin found signs of discomfort in only 6 of 15 banded bulls (although there are few details on this study).

In summary, behavioural studies indicate that castration causes significant discomfort to calves for at least a few days regardless of method. Two studies (Molony et al 1995, Thüer et al 2007a) over longer timeframes provide evidence that calves less than one month old may experience chronic pain for 3 months or more associated with rubber rings. However, these were housed calves that developed inflammatory responses to the rings, so the relevance of these findings to Australian extensive conditions must be questioned. On the other hand, extensively-grazed calves can be exposed to muddy conditions that might predispose to the same problems. More work on the incidence of chronic inflammatory lesions from rubber ringing may be required.

4.4.3 Pain relief

There is now a significant body of research on the alleviation of pain associated with castration. Most of this research has been completed during the last decade, reflecting the growing interest in this area.

Pain relief studies have been described above because they are useful in demonstrating the welfare impact of various castration procedures. This section examines the same studies from the slightly different perspective of pain relief efficacy and practicality.

4.4.3.1 Analgesic protocols

A summary of 32 analgesia protocols investigated for the relief of pain during band, Burdizzo, rubber ring, and surgical castration is presented in Appendix 9.3. The table in Appendix 9.3 assigns a score between 0 and 4 to each protocol according to its efficacy as reflected in cortisol and behavioural indicators, where:

- 0 = No or minor difference compared with castrated control;
- 1 = Significant but short lived effect, < 2h;
- 2 = Significant effect for 2-6h;
- 3 = Significant effect for at least 6h; and
- 4 = Complete or near complete elimination of evidence of pain and distress.

Local anaesthesia: In the study of Stafford et al (2002), local anaesthetic injected into the testes and scrotum of 4-month old calves 15-20 minutes before castration virtually eliminated the cortisol response to (and by inference the pain associated with) rings or bands, when cortisol was measured at 30-minute intervals from 30 minutes prior to treatment. The ring or band would tend to keep the drug in the area and extend its effect. The same regime made little difference to the cortisol responses to surgical or Burdizzo castration, presumably because a large proportion of the pain is being generated where the spermatic cords are being disrupted, proximal to the anaesthetic. However, local anaesthetic did reduce pain-related behaviours while the procedures were being carried out.

Thüer et al (2007a) injected local anaesthetic into the spermatic cords and scrotal neck of 21-28 day-old calves prior to rubber ring or Burdizzo castration. Plasma cortisol and behavioural indicators of pain were reduced substantially but were not eliminated. The authors hypothesised that the short 5-minute period between injection and castration may have contributed to the incomplete suppression of pain. The response of Burdizzo castration was much better than that reported by Stafford et al (2002) and Fisher et al (1996), possibly because the anaesthetic was placed more proximally (i.e. into the spermatic cord) than it had been by the previous groups.

The alpha-2 agonist xylazine has also been evaluated for use as an epidural in castration. Caulkett et al (1993b) reported that xylazine provided effective analgesia when administered by epidural injection, as measured by behavioural reactivity, in about 80% of bulls. The other 20% reacted to traction on the spermatic cords but not to the incision suggesting that visceral analgesia was less complete than somatic (skin) analgesia. Ting et al (2003b) used a combination of xylazine plus lignocaine as a caudal epidural and also achieved effective analgesia for Burdizzo castration, although the suppression of cortisol did not continue beyond one hour. Systemic ketoprofen was more effective in suppressing cortisol in the same study.

Systemic analgesia: Effective analgesia for castration has been achieved with systemic administration of the non-steroidal anti-inflammatory drug ketoprofen (Earley & Crowe 2002, Stafford et al 2002, Ting et al 2003a,b). Stafford et al (2002) showed that ketoprofen, given at 3mg/kg intravenously in combination with local anaesthetic 20 minutes prior to the procedure, virtually eliminated the cortisol responses to all five castration methods examined in 4-month-old calves. The effect of ketoprofen alone was not measured in this study but the authors concluded that for surgical techniques local anaesthetic would still be needed to manage pain in the scrotum.

Earley & Crowe (2002) produced similar results in older (5.5-month old) calves. Ketoprofen (also at 3mg/kg i.v. 20 minutes prior) suppressed the rise in cortisol concentration following surgical castration and reduced the area under the curve to control levels. It also reduced the inflammatory response as measured by haptoglobin and fibrinogen levels. The behaviour of calves during castration was not recorded, so the need for local anaesthetic could not be ruled out on the basis of this study. Further work by the same group showed that ketoprofen was more effective than local anaesthetic or lignocaine epidural in reducing the cortisol response and immune suppression caused by Burdizzo castration, and was more effective than local anaesthetic in reducing pain-related behaviour. The ketoprofen reduced the cortisol area under the curve to control levels and significantly reduced the peak cortisol level (Ting et al 2003b).

Variations on the single-dose ketoprofen regime used by previous authors were tested by Ting et al (2003a), namely a splitting of the dose between -20 and 0 minutes and an additional full dose 24 hours after the split regime. These alternative regimes did not produce a consistent benefit additional to that of the single-dose regime.

Stafford & Mellor (2005a) propose that the studies involving ketoprofen suggest three things: first, that the ketoprofen is acting on sites not affected by the local anaesthetic; second, that the drug exerts a central analgesic effect at the time of the procedure; third, that it may contribute to analgesia by its anti-inflammatory effect post-operatively.

Pang et al (2006) found that carprofen given 20 minutes prior tended to reduce the integrated cortisol area under the curve (0-12 hours) of calves castrated by banding or Burdizzo. It did not reduce the cortisol peak or time to peak as expected, but rather had its effect later: 6-12 hours for the band, day 3 for the Burdizzo. It also moderated the elevation of acute-phase proteins caused by castration. A higher dose or earlier administration was suggested to improve the analgesic effect.

One recent study has examined the value of 50mg/kg oral aspirin (acetylsalicylic acid) or 50mg/kg intravenous sodium salicylate provided immediately prior to castration of 4-6 month-old bulls (Coetzee et al 2007). Plasma salicylate levels of bulls administered oral aspirin did not exceed 10µg/ml at any point and did not reach the limit of quantification (5µg/ml) in 2 of 5 bulls. Not surprisingly, then, oral aspirin had no effect on cortisol response. Sodium salicylate tended to reduce the area under the cortisol curve and the peak level and to delay time to peak compared with castrated controls for the 4 hours before it fell below the limit of quantification. However, the differences were not significant (there were only 5 bulls in each group and considerable variation in individual response).

Sodium salicylate is not registered for use in cattle anywhere in the world (see Section 4.9). Given this fact and its short duration of action there seems little point considering it as a pain relief option.

Intravenous xylazine and butorphanol had no effect on blood cortisol nor haptoglobin, nor on ADG, of surgically castrated bulls 9-11 months old. The drugs were only administered 90 seconds before the procedure (Faulkner et al 1992).

In summary: The evidence from the literature is that local anaesthetic alone, administered into the testicle, provides very good relief from the pain associated with rubber rings or bands. For the Burdizzo and surgical methods, a combination of local anaesthetic and ketoprofen provided intravenously 20 minutes prior to surgery appears to provide very good pain relief. Carprofen may be a substitute for ketoprofen but this has not been definitively established.

4.4.3.2 Cost implications

The provision of pain relief for calves at castration would inevitably increase costs for farmers and this must be considered when evaluating its practicality.

Only one formal study appears to have been published on the potential costs of pain relief for castration of calves. Stafford et al (2005c) examined four scenarios for New Zealand:

1. Status quo – no analgesia – cost per calf $0.28
2. Local anaesthetic – $1.56
3. Systemic analgesic (ketoprofen) plus local anaesthetic – $5.45
4. Castration by a veterinarian, using systemic analgesic plus local anaesthetic – $9.39.

The assumptions used in the analysis look reasonable, although there is no attempt to segment the population of calves being castrated by different methods. The last two scenarios would make little sense in relation to the use of rings in young calves given that local anaesthetic alone provides effective analgesia with this method. There is no allowance for the additional time needed for the agents to take effect, although a sensitivity analysis of castration rate per hour was undertaken (but not reported). A cost for additional labour – perhaps to administer the agents in a parallel procedure – may have been used instead of allowing for additional time. Assumptions about the drug doses are also simplistic and based on one unspecified bodyweight.

The current costs of analgesic drugs for cattle in Australia are shown in Table 33 (Section 4.9). These costs are as supplied to the veterinarian and therefore do not include retail mark-up. Using these figures and allowing a 50% mark-up, the cost of drugs alone for castration is estimated to be:

- For a 100kg animal: $2.75 (local anaesthetic only, using rings) or $6.18 (local plus ketoprofen, for surgical castration or Burdizzo)
- For a 300kg animal: $4.13 or $14.40.

A mark-up of 50% may not be sufficient and certainly would not reflect current pricing by vets. On the other hand, widespread use (for example by lay people under an accreditation scheme) would be expected to drive both wholesale and retail prices down.

Other costs will include consumables (syringes and needles, a minor cost) and additional labour, which might manifest as a slower castration rate or additional labour units/staff and holding facilities, depending on the facilities available. There would also be accreditation costs associated with the use of drugs or veterinary involvement. If more than one procedure was to be carried out at the same time (e.g. disbudding or dehorning) then the NSAID cost would be spread across more than one procedure – although of course it would still be additional to those currently incurred.

4.4.3.3 Key findings from scientific studies

While there are some unresolved questions concerning the welfare impacts of castration of cattle, several messages do emerge from the science:

- Physical castration, by whatever method, causes acute pain in calves. Rubber ring castration may also cause chronic discomfort or pain lasting up to 8 weeks although the evidence for this comes from studies using housed calves where the areas of skin around the rings became inflamed. Two studies have also shown elevated cortisol up to 2 weeks after surgical or band castration. Whether pain was responsible for these findings is not clear.

- The pain associated with castration appears to increase with age at castration, based mainly on cortisol evidence.

- There are variations between studies in their ranking of the relative pain associated with different methods. In general, the Burdizzo seems to cause the least pain as measured by cortisol and behaviour, but several studies and reports from veterinarians express concern about the pain associated with post-Burdizzo swelling that may last for more than 7 days. The Burdizzo is also regarded as a relatively unreliable means of castration. It is difficult to distinguish between rubber rings and surgical methods on total pain response. Surgery appears to be more painful initially, but there is a longer cortisol response to rings and behaviours indicative of pain or irritation may last longer (especially if there is infection). The limited evidence suggests that banding is more painful than either surgical or ring castration and bands can produce chronic wounds.

- Analgesic regimes to reduce the acute pain of all methods of castration have been identified. Ketoprofen plus local anaesthesia appears to almost eliminate the pain associated with surgical and Burdizzo methods in 4-month-old calves. Local anaesthetic alone is effective in reducing the pain of rubber rings or bands. These regimes should be adopted if pain minimisation is the objective.

- Surgical castration using an emasculator, and with pain relief provided by ketoprofen plus local anaesthesia, is probably the most humane method for older calves (over 3 months). This is a fairly arbitrary cut-off age but is around the point at which the skin becomes too thick for rubber rings or the Burdizzo to work efficiently.

- Surgical castration, rubber rings or the Burdizzo are probably equally acceptable in young calves up to 3 months.

- There are relatively few data on high tension latex bands compared with other methods. There is some cortisol and behavioural evidence that they cause a greater degree of pain than other methods and they can cause significant lesions, yet in other studies bands were comparable to or more acceptable than surgical castration from a welfare perspective. Further research into the welfare impacts of bands across a range of ages is warranted if bands have widespread adoption.

Table 3 attempts to rank various combinations of castration method and pain relief options using a 'league table' format similar to that developed by Stafford & Mellor (2005b) for dehorning. It should be noted that this table is approximate only and should not be relied upon for strict scientific accuracy. It is based on a largely qualitative interpretation of the literature by the authors, drawing especially on the review Stafford & Mellor (2005a) and the primary study of Stafford et al (2002). Appendix 9.3 also rates the efficacy of published protocols for pain relief in castration.

Table 3 Ranking of castration methods by animal welfare impact, from most to least severe (following the format of Stafford & Mellor 2005b)

	Procedure
1	High tension band
2	Rubber ring, surgery ('cut' method preferred to 'pull')
3	Prior local anaesthetic + surgery
4	Burdizzo
5	Prior local anaesthetic + Burdizzo
6	Prior NSAID + high tension band
	Prior NSAID + surgery
7	Prior NSAID + local anaesthetic + high tension band
	Prior local anaesthetic + high tension band
	Prior NSAID + Burdizzo
	Prior NSAID + local anaesthetic + rubber ring
	Prior local anaesthetic + rubber ring
	Prior NSAID + local anaesthetic + surgery
	Prior NSAID + local anaesthetic + Burdizzo

4.4.4 Australian and international standards

The following tables summarise the provisions of codes of practice and legislative instruments, in relation to castration of cattle, of the respective jurisdictions in Australia (Table 4) and of selected overseas countries (Table 5), and the policies, positions or standards of selected welfare interest groups and certifying agencies (Table 6). Table 7, Table 8 and Table 9 summarise the corresponding provisions for sheep.

Table 4 Australian codes of practice and legislation applicable to castration of cattle

Jurisdiction	Provisions relevant to castration of cattle
Australia (Model Code for Cattle)	• 5.4.1: Castration without anaesthesia should be confined to calves at first muster and preferably before 6 months of age; only under exceptional circumstances (e.g. range management of older, previously uncastrated bulls) should castration of older bulls be performed, and then preferably by a veterinarian; castration of animals over 6 months is illegal in some jurisdictions. • 5.4.2: Use of rubber rings is only recommended for calves up to 2 weeks of age. • 5.4.3: Castration by Burdizzo should be performed as young as possible.
Australia (Beef Cattle Feedlot Guidelines)	• No reference to castration.
Australia (Model Code for Feral Cattle)	• Captured feral animals should be allowed several weeks to settle into their new environment before management practices such as castration are undertaken.
Queensland	• As for the Model Code. • Section 3(1)(c) of the *Veterinary Surgeons Regulation 2002* specifies that castration of cattle or sheep of less than 6 months is not veterinary science for the purposes of the *Veterinary Surgeons Act 1936*.

Jurisdiction	Provisions relevant to castration of cattle
New South Wales	• As for the Model Code. • Under Section 4(1)(d) of the *Veterinary Practice Regulation 2006*, the castrating of cattle, sheep or goats that are 6 months of age or older is a restricted act of veterinary science for the purposes of the *Veterinary Practice Act 2003*. However, Section 9(2) of the Act permits a person other than a veterinary practitioner to 'do any restricted act of veterinary science if: (a) the person is the owner of the animal, or (b) the person is an employee of the owner of the animal and the act is done incidentally to the primary duties of that employment'. • Section 24(1)(a)(ii) of the *Prevention of Cruelty to Animals Act 1979* permits the castration of an calf under the age of 6 months to be a defence against a charge of cruelty as defined in Section 5, which includes '…where pain is being inflicted upon the animal, to take such reasonable steps as are necessary to alleviate the pain'.
Australian Capital Territory	• 4.4: 'Castration by knife or Burdizzo, without local or general analgesics / anaesthetics should be confined to calves at their first muster and preferably under the age of six months. Only under exceptional circumstances should castration of older bulls be performed, and then preferably by a veterinarian.'
Victoria	• 10.4.1: Castration with Burdizzo should be performed as young as possible. • 10.4.1: Castration with rubber rings should ideally be performed before 6 weeks of age and where 'operations and management make this difficult' not beyond 12 weeks. • 10.4.2: Castration by knife without local or general anaesthetic should be confined to calves under 6-8 months; bulls over this age should receive appropriate anaesthetic; castration of mature bulls should preferably be performed by a veterinarian using anaesthesia.
Tasmania	• 10.4: Castration without local or general anaesthesia should be confined to calves as young as possible but less than 6 months; 'only under exceptional circumstances under range management should castration of older cattle (mickey bulls) be tolerated'; where essential that bulls over 6 months be castrated, local or general analgesics / anaesthesia must be used; rubber rings are not recommended over 3 months of age. • Section 4(d) of the *Veterinary Surgeons Regulations 2004* specifies that castration of cattle that are 6 months of age or less is not a veterinary service for the purposes of the *Veterinary Surgeons Act 1987*.
South Australia	• As for the Model Code. Part 3 and Schedule 2 of the *Prevention of Cruelty to Animals Regulations 2000* requires compliance with the Code of Practice. • Section 4(2)(d) of the *Veterinary Practice Regulations 2005* specifies that castration of cattle that are less than 3 months of age is not a veterinary service for the purposes of the *Veterinary Practice Act 2003*.

Jurisdiction	Provisions relevant to castration of cattle
Western Australia	• As for the Model Code. • The WA Code has identical wording to the Model Code. • In the *Model Code of Practice for Cattle in the Rangelands of WA*, Section 9 is similar to 5.5.2 of the Model Code, but adds 'should be conducted as quickly as possible' and 'preferably a veterinarian'; 'should be done in dry weather' is not included. • Section 26(3)(c) of the *Veterinary Surgeons Act 1960* specifically recognises that 'Nothing in (the Act) applies to or prohibits the performance, whether or not for reward, by a person in a prescribed area of the State and using humane methods, of the operation…of castrating any animal over the age of 12 months'. Section 44 of the *Veterinary Surgeons Regulations 1979* prescribes 'the pastoral region' for the purposes of the Act. Section 26(3)(d) notes that the Act does not preclude a person 'using humane methods, of the operation of…castrating any animal not over the age of 12 months'.
Northern Territory	• As for the Model Code. • Section 6(c) of the *Veterinarians Regulations* specifically excludes 'castrating cattle…that are (i) less than 12 months old; and (ii) kept for human consumption in the course of primary production', as a veterinary service under the meaning of the *Veterinarians Act*.

In summary, there are some significant differences between the various States and Territories in their legislative provisions regarding castration, and there can be confusion between instruments. In NSW, for example, castrating a calf over the age of 6 months is an act of veterinary science. There is a provision in the *Veterinary Practice Act 2003* providing an exemption to this restriction where the operator owns the animal – except that the *Prevention of Cruelty to Animals Act 1979* only provides a defence to cruelty for castration carried out at less than 6 months (A. Paull pers. comm.). So effectively, castration of a calf by a lay person is not permitted over 6 months and the Model Code is not called upon.

The NT permits castration to 12 months of age without a veterinarian while in Queensland, a charge of castrating a calf over the age of 6 months would generally be judged against the Model Code but might also be a breach of the *Veterinary Surgeons Act 1936* (P. Willett pers. comm.). A similar consideration might apply in South Australia where castration of an animal less than 3 months of age is *not* a veterinary service – so castration over that age presumably is.

Other jurisdictions defer to the Model Code or to their own Codes and may or may not specify an upper age limit for castration. Tasmania's Code requires a veterinary surgeon to castrate any calf over 6 months old. Castration is generally preferred under 6 months of age for Victoria and the ACT. Rings should be used before 6 weeks in Victoria but 3 months in Tasmania. These compare with the Model Code recommendation that rings be used within 2 weeks of birth.

Clearly, there is little consistency between jurisdictions in Australia in respect of the legal provisions concerning castration of cattle.

Table 5 Codes of practice and legislation, of selected overseas countries, applicable to castration of cattle

Country	Provisions relevant to castration of cattle

New Zealand	• Minimum standards involve:
	  o Selection and application of method to minimise acute and chronic consequences for the health and welfare of the animal.
	  o Castration without pain relief must be performed as young as possible and not over 6 months old.
	  o Pain relief must be used in animals older than 6 months.
	  o When rubber rings are used, they must be placed above the testes and below the teats and of appropriate tension and size to stop blood flow immediately.
	  o If high tension bands are used, local anaesthetic must be used at any age and the band must be positioned as close to the testes and as far from the abdomen as possible.
	• Best practice involves:
	  o The provision of pain relief at any age.
	  o The obtaining and using of up-to-date expert advice on modifying testicular function so that adverse consequences for the animal are minimised.
	  o Preferential use of conventional rubber rings on young animals over high tension bands at any age.
	  o Ensuring cleanliness of the area, equipment and operator’s hands, and dryness of animals.
	  o Vaccination and other precautions to minimise the risk of clostridial infections.
	• The Code also notes that the preferred method of castration is rubber rings applied when the animal is a few weeks old; these should not be used in larger animals (say >4 months) because the ring cannot effectively stop blood flow, leading to swelling and pain. High tension latex bands cause significant pain in calves 3-4 months old and lesions associated with poor healing may be seen in older cattle. For acute pain control, rubber rings or high tension bands with local anaesthetic, or surgery with local anaesthetic plus analgesia are preferable to rubber rings or surgery without pain relief which are in turn preferable to high tension bands without pain relief.

Canada	• 10.1.4: minor surgical practices must be conducted only by competent personnel using proper equipment and accepted techniques; castration should be performed at an early age, preferably before weaning; all precautions must be taken to avoid unnecessary pain to the animal during surgery and afterwards; when necessary to castrate a mature animal, the operation should be conducted in consultation with a veterinarian.
United States	• NCBA Guidelines note that early castration improves animal performance and reduces health complications and strongly recommends castration before 120 days or 500 pounds liveweight; delayed castration is acceptable where bulls are being considered for breeding or for finishing as intact bulls; tetanus vaccination should be given when bands are used. • The NYSCHAP recommends that closed castration of bulls should be carried out before 2 months of age; castration of older bulls or any open castration procedures should be performed with the use of anaesthetic / analgesic in consultation with a veterinarian; a standard operating procedure must be filed on the farm for any routine or elective surgical procedures.

Country	Provisions relevant to castration of cattle

European Union	• Article 17 of the T-AP Recommendation states that castration is an exception to the forbidding of procedures resulting in the loss of a significant amount of tissue, although it is one of a group of procedures that should be avoided where possible. The article specifically says 'castration of bulls and bull calves, preferably by the surgical removal of the testicles but not by methods which cause unnecessary or prolonged pain or distress'. The Recommendation also notes that 'Procedures in which the animal will or is likely to experience considerable pain shall be carried out under local or general anaesthesia by a veterinary surgeon or any other person qualified under domestic legislation. These procedures…should include castration'.
	• The SCAHAW Opinion recommends that:
	  o '30. As a general rule, mutilations should be avoided and their negative effects minimised as much as possible.
	  o 31. Animals should always be provided with some form of analgesia at the time of surgical mutilations for procedures like docking, dehorning and castration (e.g. local anaesthetic), and for two days or so thereafter (e.g. a non-steroidal anti-inflammatory drug).
	  o 32. If performed, castration should be carried out in animals at as young an age as possible and ideally not in animals aged over six months. Effective techniques to alleviate the pain and distress caused by castration should be used.'
	• In Switzerland, castration of calves or lambs must be carried out by a veterinarian using anaesthesia; similar provisions apparently apply in Denmark (Nielsen & Thamsborg 2001) and Austria (Thüer et al 2007a).

United Kingdom	• The Mutilations Regulations permit castration, subject to the following:
	  o Rubber rings may only be used on animals aged not more than 7 days;
	  o When any other method is used, an anaesthetic must be administered where the animal is aged 2 months or over.
	• FAWC recommendations are as follows:
	  o '370. Calf castration is an undesirable mutilation that should be avoided if at all possible. It should only be carried out to avoid worse welfare problems.
	  o 371. We endorse the existing legislation which states that calves over two months of age must be castrated only by a veterinary surgeon using an anaesthetic.
	  o 372. As soon as a satisfactory and practical way of producing analgesia, or administering an anaesthetic without the necessity of injecting it via a syringe and needle, becomes available it must be adopted for use on calves of any age before castration.
	  o 373. Non-veterinarians should be suitably trained and competent before carrying out castration.'

Internationally, the most onerous legislative provisions on castration are found in Switzerland, where castration of calves or lambs must be carried out by a veterinarian using anaesthesia. According to Nielsen & Thamsborg (2001) and Thüer et al (2007a) similar provisions apply in Denmark and Austria respectively. With these requirements Switzerland and Austria, and possibly other EU countries, are conforming to the recommendations of the EU's SCAHAW (2001) that both peri-operative and post-operative pain of castration be alleviated by anaesthesia and/or analgesia.

The United Kingdom is less restrictive, but it does not allow rubber rings over the age of 7 days and castration by any other method over the age of 2 months requires anaesthetic. In New Zealand, pain relief is required for castration of calves or lambs over 6 months of age, although best practice involves pain relief at any age, suggesting this may be the eventual target of NZ standards.

The loosest standards are apparently found in the US and Canada where cattle may be castrated at any age without real restriction. The Canadian Code prefers but does not require castration at an early age, and only says that a veterinarian 'should' be consulted for castration of mature bulls. The NCBA Guidelines are similar and nominate 4 months as an upper age limit.

Table 6 Policies, positions or standards of selected animal welfare interest groups, in Australia and overseas, applicable to castration of cattle

Organisation	Provisions relevant to castration of cattle
RSPCA (Australia)	• 2.1.5: castration must only be undertaken where a clearly established need – castration opposed where animals turned off prior to sexual maturity. • 2.1.5.1: calves should be castrated less than 4 months old, and as early as possible, using a knife (no anaesthetic necessary, appropriate restraint and adequate post-op drainage required) or rings (only less than 6 weeks, vaccination against tetanus provided, no anaesthetic necessary). • 2.1.5.2: castration of cattle over 4 months is a major surgical procedure; should be performed in suitable place in hygienic conditions; adequate pre-operative preparation, general narcosis and/or general anaesthesia, sedation and/or local anaesthesia, adequate restraint required; triple crush emasculator or other means of haemostasis required, including ligation in older animals; post-op procedures required to minimise untoward sequelae; use of muscle relaxants as only form of restraint and anaesthesia is unacceptable.
RSPCA (UK)	• H 1.21: castration is permitted only by the application of a rubber ring between 24 hours and 7 days of age, or by Burdizzo between 24 hours and 2 months of age; it must not be done on sick animals, and must be done only in a way that minimises suffering, by a veterinarian or trained stock-keeper, using appropriate and well-maintained equipment.
Humane Society International	• 1.6 general principle: surgical treatments only carried out if operator can demonstrate that benefits outweigh consequences and no other acceptable options. • 1.6.2: where shown to be necessary, castration shall be performed in a way that minimises stress and injury to the animal. • 1.6.5: castration must be carried out as soon as possible after birth and no later than 6 months of age; animals over 6 months may only be castrated under scrutiny of a veterinarian and with anaesthetic.
Animal Welfare Institute (US)	• 7(b): some studies suggest surgical castration is less acceptable to welfare than rubber rings; anaesthetic should be used (it is not clear whether this applies specifically to surgery or to all methods); castration should be carried out before 2 months.
Federation of Animal Science Societies (US) Guidelines	• Castration of young bulls is a recommended practice. • It is strongly recommended that calves be castrated as young as possible; stress is lowest when calves are castrated at birth, before 2-3 months of age or before 230kg bodyweight. • Local anaesthetic should be used for surgical or Burdizzo castration of bulls over 230kg; 'bands without special applicators' (rings) should not be used over 1 week of age; banding is acceptable for older animals and local anaesthesia offers no advantage.
Temple Grandin	• Feedlot: no knife castration for sanitary reasons; if castration is required, use banding or if possible obtain calves already castrated. • Ranch: per FASS Guidelines, as early as possible.

Organisation	Provisions relevant to castration of cattle
KRAV (Sweden)	• Castration is permitted if done within the first 8 weeks of life. Calves shall be anaesthetised during castration.
Australian Veterinary Association	• 8.2: castration of calves by knife or Burdizzo without local or general analgesics or anaesthetics should be confined to calves at their first muster and preferably under the age of 6 months; only under exceptional circumstances (e.g. range management of older, previously uncastrated bulls) should castration of older bulls be performed, and then preferably by a veterinarian with suitable anaesthesia; castration with rubber rings is recommended only for calves less than 2 weeks old.
American Veterinary Medical Association	• AVMA supports the use of procedures that reduce or eliminate the pain of castration; castration should be carried out as early as possible; research into improved techniques and alternatives is encouraged.
Canadian Veterinary Medical Association	• The CVMA recommends that when castration (of cattle, swine or sheep) is necessary, it should be carried out within the first week of life. • The policy notes that castration, tail docking and dehorning are routine, and that they should be conducted in a humane fashion, with the onus on the practitioner to determine the most appropriate technique and procedure.

In general, the expectations of animal welfare groups on castration are reasonably benign in comparison with legislated standards, and not very consistent. RSPCA (Australia) places an upper limit of 4 months on castration by laypersons and without pain relief where most Australian jurisdictions set the cut-off at 6 months. RSPCA (UK) and the Animal Welfare Institute in the US appear to be opposed to surgical castration and do not allow it, but otherwise castration is permitted by these groups to 2 months of age (with pain relief in the case of the Animal Welfare Institute) and by others to 6 months. A surprisingly strident standard is that of the Canadian Veterinary Medical Association, which recommends castration within the first week of life.

Table 7 Australian codes of practice and legislation applicable to castration of sheep

Jurisdiction	Provisions relevant to castration of sheep
Australia (Model Code for Sheep)	• 9.4: Castration may be unnecessary if all lambs are to be marketed prior to puberty (3-6 months); where castration is required it should be done as early as management practices allow, preferably before 12 weeks; animals over 6 months require anaesthetic; acceptable methods for castration without anaesthesia are: o Cutting – lamb should be properly restrained and cutting instrument clean and sharp; good post-operative drainage is required. o Rubber rings applied according to the manufacturer's recommendations.
Queensland	• As for the Model Code.
New South Wales	• As for the Model Code.
Australian Capital Territory	• 9.3 duplicates the provisions of the Model Code.
Victoria	• 9.4 duplicates the provisions of the Model Code but without the requirement that castration of animals over 6 months requires anaesthetic.
Tasmania	• 7.4 duplicates the provisions of the Model Code, but importantly it adds that 'emasculators or spermatic cord crushing instruments used according to the manufacturer's recommendations' are acceptable methods, and that vasectomy and induction of cryptorchidism should also be done under anaesthesia over the age of 6 months.
South Australia	• As for the Model Code.

Jurisdiction	Provisions relevant to castration of sheep
Western Australia	• 10.3 duplicates the provisions of the Model Code.
Northern Territory	• As for the Model Code (presumably).

The legislative provisions pertaining to sheep are reasonably consistent across jurisdictions in requiring anaesthetic over the age of 6 months (except Victoria, which does not mandate anaesthetic).

Table 8 Codes of practice and legislation, of selected overseas countries, applicable to castration of sheep

Country	Provisions relevant to castration of sheep
New Zealand	• Minimum standards involve: o Selection and application of method to minimise acute and chronic consequences for the health and welfare of the animal. o Castration without pain relief must be performed as young as possible and not over 6 months old. o Pain relief must be used in animals older than 6 months. o When rubber rings are used, they must be placed above the testes and below the teats and of appropriate tension and size to stop blood flow immediately. o If high tension bands are used, local anaesthetic must be used at any age and the band must be positioned as close to the testes and as far from the abdomen as possible. • Best practice involves: o The provision of pain relief at any age. o The obtaining and using of up-to-date expert advice on modifying testicular function so that adverse consequences for the animal are minimised. o Preferential use of conventional rubber rings on young animals over high tension bands at any age. o Ensuring cleanliness of the area, equipment and operator's hands, and dryness of animals. o Vaccination and other precautions to minimise the risk of clostridial infections. • The Code also notes that the preferred method of castration is rubber ring with local anaesthetic applied when the animal is a few weeks old; surgical castration is not recommended because it causes greater and more prolonged pain and distress and increases the risk of haemorrhage, infection and herniation; for acute pain control, the order of decreasing preference for various methods is rubber ring with local anaesthetic, shortening of the scrotum, rubber ring without pain relief, and surgery without pain relief.
Canada	• 11.2: unnecessary if lambs are to be marketed prior to puberty, usually 3-5 months of age; when castration is to be performed, it should be done as early as practical; rubber rings, rubber rings plus crushing devices or cut and pull should be used after the lamb has had colostrum and before 7 days of age; crushing devices used alone should be done less than 3 months of age; when necessary to castrate an older ram the operation should be done only by a licensed veterinarian using appropriate analgesics and anaesthetics.

Country	Provisions relevant to castration of sheep
European Union	• Article 30 of the T-AP Recommendation has some very confusing provisions regarding castration. Among the exceptions to the forbidding of procedures resulting in the loss of a significant amount of tissue, or which cause a significant amount of pain or distress, is castration by rubber rings, where allowed by national legislation. Another exception is castration by surgical methods or with 'haemostatic tongs', subject to the following: 'Tail-docking and castration, in particular by the use of rubber rings, should be avoided. If these procedures have to be carried out, only surgical methods preceded by anaesthesia or haemostatic tongs should be used'. It is unclear whether rubber rings are acceptable or not. • In Switzerland, castration of calves or lambs must be carried out by a veterinarian using anaesthesia; similar provisions apparently apply in Denmark (Nielsen & Thamsborg 2001) and Austria (Thüer et al 2007a).
United Kingdom	• The Mutilations Regulations permit castration, subject to the following: o Rubber rings may only be used on animals aged not more than 7 days; o When any other method is used, an anaesthetic must be administered where the animal is aged 3 months or over. • Key FAWC recommendations are as follows: o '99. All parties should work towards the ideal situation where all male lambs are either not castrated or, when this is necessary, castrated using pain relief. o 100. When lambs are to be castrated, this decision should be agreed with the farm's veterinary surgeon as part of the farm's health and welfare plan. o 101. When castration is necessary, lambs should be castrated as early as practically possible after a secure maternal bond has been established, but not usually before they are 24 hours old. o 102. Castration of lambs above the age of 3 months should only be undertaken by a veterinary surgeon using pain relief. o 103. Surgical castration should be prohibited except when performed by a veterinary surgeon using pain relief. o 104. Pain relief reduces the impact of castration on welfare and should be used when and wherever possible. Any decisions about pain management and its relief should be made in discussion with a veterinary surgeon. o 105. When practical methods of administering pain relief have been devised and demonstrated under farm conditions, the law concerning castration should be changed to require the use of these. Until then, existing castration methods – with the exception of surgical castration – should continue to be permitted.'

As for cattle, the most onerous international legislative provisions on castration of sheep are found in Switzerland and other EU countries, although the European Commission itself does not appear to have specific requirements for sheep.

The United Kingdom and Canada require castration of rams over the age of 3 months to be carried out by a veterinarian using pain relief. Canada prefers rubber ringing or surgery to be carried out before 7 days, or Burdizzo before 3 months, while the UK prohibits rings after 7 days but allows other methods up to 3 months. Notably, though, the FAWC is calling for surgical castration of lambs to be restricted to veterinarians only.

In New Zealand, pain relief is required for castration of lambs over 6 months of age, although best practice involves pain relief at any age, suggesting this may be the eventual target of NZ standards. New Zealand's NAWAC is also flagging that surgical castration of lambs without pain relief is unacceptable and strongly advocates for the use of rings.

Table 9 Policies, positions or standards of selected animal welfare interest groups, in Australia and overseas, applicable to castration of sheep

Organisation	Provisions relevant to castration of sheep
RSPCA (Australia)	• 2.1.5: castration must only be undertaken where a clearly established need – castration opposed where animals turned off prior to sexual maturity. • 2.1.5.1: lambs should be castrated less than 12 weeks old, and as early as possible, using a knife (no anaesthetic necessary, appropriate restraint and adequate post-op drainage required) or rings (vaccination against tetanus provided, no anaesthetic necessary). • 2.1.5.2: castration of sheep over 12 weeks is a major surgical procedure; should be performed in suitable place in hygienic conditions; adequate pre-operative preparation, general narcosis and/or general anaesthesia, sedation and/or local anaesthesia, adequate restraint required; triple crush emasculator or other means of haemostasis required, including ligation in older animals; post-op procedures required to minimise untoward sequelae; use of muscle relaxants as only form of restraint and anaesthesia is unacceptable.
RSPCA (UK)	• H 2.14: castration must not be carried out if ram lambs are to be slaughtered before sexual maturity or if management allows segregation of sheep; when necessary, it must be carried out by a trained and competent person using a rubber ring between 24 hours and 7 days of age only; in the event of ring failure or 'unintentional omission' of the ring technique an approved bloodless castrator applied by a trained and competent person is permissible between 1 day and 8 weeks.
Humane Society International	• 1.6 general principle: surgical treatments only carried out if operator can demonstrate that benefits outweigh consequences and no other acceptable options. • 1.6.2: where shown to be necessary, castration shall be performed in a way that minimises stress and injury to the animal. • 1.6.4: castration must be carried out as soon as possible after birth and no later than 10 weeks of age; animals over 6 months may only be castrated under scrutiny of a veterinarian and with anaesthetic.
Animal Welfare Institute (US)	• 5.3.1, 5.3.2: if the slaughter age of the ram lamb will arrive before sexual maturity, or if the ram lamb will not be mixing with females after sexual maturity, castration is prohibited. • 5.3.3: the only acceptable method of castration is rings used on lambs less than one week old (any other method must be approved by the Institute officials).
Federation of Animal Science Societies (US) Guidelines	• Castration is used to control time of first mating of females and the annual reproductive cycle, and to reduce aggressive behaviour by males. • Most appropriate technique depends 'partly on prevailing conditions'. • When surgical castration is used it should be done at less than 2 months of age, with anaesthesia and precautions to prevent haemorrhage and infection. • Castration should be done as young as possible, but not in the first 24 hours of life as it may disrupt the maternal bonding process.
Temple Grandin	• No recommendations on castration of sheep were found.
KRAV (Sweden)	• Castration of lambs is not mentioned.

Organisation	Provisions relevant to castration of sheep
Australian Veterinary Association	• 10.2, 10.4: the AVA recommends that castration of adult rams (over 3 months) should be treated as a major surgical procedure, with appropriate pre- and postoperative techniques (analgesia / anaesthesia). • 10.4: the AVA accepts castration of lambs under 3 months of age provided that the operation is conducted by a skilled operator using accepted industry practices.
American Veterinary Medical Association	• The AVMA does not appear to have a specific policy position on sheep castration.
Canadian Veterinary Medical Association	• The CVMA recommends that when castration (of cattle, swine or sheep) is necessary, it should be carried out within the first week of life. • The policy notes that castration, tail docking and dehorning are routine, and that they should be conducted in a humane fashion, with the onus on the practitioner to determine the most appropriate technique and procedure.

Positions of welfare interest groups on castration of sheep are reasonably consistent. Many note the need to consider whether castration is required at all. Most advocate the use of rings before 1 week of age as the preferred method and note the need to avoid ringing in the first 24 hours of life. The Australian organisations (AVA, RSPCA and HSI) allow 10-12 weeks as a cut-off date for non-veterinary castration, while the UK RSPCA allows clamping up to 8 weeks only as a backup. The UK RSPCA reflects the apparently prevailing view in the UK that surgical castration of rams is unacceptable.

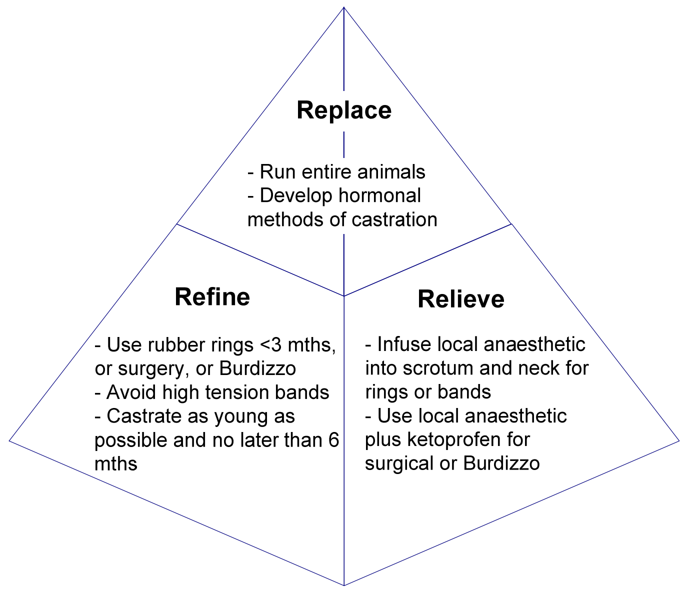
4.4.5 Implications and discussion

A long-term approach to improving the welfare outcome from castration can be considered at two levels. In an ideal world, physical removal or destruction of testes would not be required to achieve the ends currently sought by castration (preventing unwanted pregnancies, safe handling, management and group housing issues). For cattle, two realistic possibilities exist to 'replace' physical castration: development of immunological methods of castration, and developing production systems that allow the running of entire animals. MLA has investments in both areas.

The more pragmatic approach acknowledges the continuation of physical castration but aims to minimise its impact on welfare. This can be split into two parts: use of the least painful procedures, and/or offsetting any pain as far as possible by anaesthesia and/or analgesia.

These ideas are captured in a '3R' model of preferred approaches to castration where the aim is to maximise welfare (Figure 3).

Figure 3 3R model for castration in cattle



The current legislative instruments and codes of practice are concerned primarily with the 'refine' part of the pyramid. The question is whether the new standards will move more towards the area of 'relieve'. Based on the science and international standards as reviewed above, Table 10 lists the major provisions of current codes of practice and legislation and attempts to identify what changes might be expected in the move to scientifically-derived standards.

Table 10 Possible changes to current provisions relating to castration of cattle

Current provisions	Most likely change (pragmatic stance)	Comments
Castration is *preferred* before 6 months without anaesthesia (legislated in some jurisdictions); vet-only after this age.	Mandated 4 or 6-month upper age limit on castration without anaesthesia (except in pastoral regions?).	The science does not indicate a critical age point at which castration without anaesthesia becomes unacceptable, so this will always be an arbitrary choice and best welfare practice would be to use anaesthesia / analgesia at any age. 4-6 months is suggested as the practical compromise that might be reached (4 months is the RSPCA preference, 6 months the current Australian default and NZ choice). However, there may be a push towards eventual mandatory pain relief at any age.
Rubber rings *recommended* before 2 weeks of age.	Mandated upper age limit on use of rubber rings, somewhere between 6 weeks and 3 months.	It is difficult to judge what the upper age limit for rings will be. RSPCA advocates 6 weeks and NZ suggests 4 months, but there is no scientifically-defined limit except that determined by body size and the limits of the ring. For a 9-week calving period (southern beef system) a 10-week upper limit should be practical, otherwise more than one marking event per year may be required.

Current provisions	Most likely change (pragmatic stance)	Comments
Burdizzo *should be* performed as young as possible.	Mandated upper age limit on use of Burdizzo, possibly at 3 months.	The Burdizzo can be associated with painful swelling for at least 7 days after use, and this may be worse in older cattle. There is no clear cut-off point but 3 months is a reasonable guess.
High-tension bands not mentioned.	High-tension bands not permitted except with local anaesthetic.	There is reasonable evidence that high-tension bands cause considerable pain and lesions especially in larger animals, although this is not equivocal. Bands might be disallowed without local anaesthetic pending further and supportive trial work.
Requirements for hygienic practice, adequate restraint not mentioned.	Mandatory requirements for hygienic practice and adequate restraint.	This change would have little practical effect but would be a sensible measure to reinforce the need for best practice in whatever castration method is chosen.

The changes suggested in Table 10 assume a reasonably pragmatic stance by those writing the standards. This has been the approach taken by New Zealand. If best practice welfare outcomes were to be sought, there would be a requirement for pain relief at any age as the science shows that effective pain relief is achievable with existing agents. The 'best welfare practice scenario' would probably take the following form:

- Mandatory use of local anaesthesia with rubber rings, high-tension bands;
- Mandatory use of local anaesthesia plus an NSAID with surgical castration or the Burdizzo;
- Assuming accredited lay operators can be provided with access to drugs for use in castration, an upper age limit of 6 months for lay (non-vet) castration – otherwise castration becomes a vet-only procedure at any age.

The best welfare practice scenario seems highly unlikely given the practical constraints of Australian production systems and the inevitable strong backlash from farmers. However, it is likely to be seen as an ultimate goal, and the industry should be mindful of this in the longer term and gradually develop the capacity to manage it at least cost. For example, if pain relief becomes compulsory, access of lay operators to pain relief drugs would be highly desirable.

There are some gaps in the science that could be addressed. Stafford & Mellor (2005a) note that there has been little work on the chronic pain effects of castration, including rubber ringing, and that little is known about the pain experienced by hand- vs cow-reared calves, and the optimum age for castration in each case. The New Zealand report accompanying the Painful Husbandry Procedures Code (NAWAC 2005b) notes that there are gaps in the literature on the welfare effects of banding and recommends further research. NAWAC's position on bands is an interesting one. Although it acknowledges conflicting evidence about bands, it concludes that they should only be used with local anaesthetic at any age. This is not mandated for any other technique. As much as anything, there appears to be an assumption that the very high pressure generated by the bands (260 vs 100 Newtons of rubber rings) must cause significant pain.

Another area for further research is the role of ketoprofen. While there is a reasonable body of research on the value of ketoprofen to alleviate pain, most of it has been based on treatments given

20 minutes before the procedure. The study of Ting et al (2003a), which included a regime of half doses split between -20 and 0 minutes, is an exception. The split dose regime appeared to be as effective as the single dose at -20 minutes. However, the drug was provided intravenously in both cases as well as in other studies, and this is clearly not a practical route of administration under farming conditions, especially if the industry is to contemplate changes to allow farmer access to such drugs. Neither is it ideal to require dosing 20 minutes prior to undertaking castration and other procedures. There is, therefore, a need for research to better define or validate the flexibility of dosing regimes possible with ketoprofen administered intramuscularly. It is possible to conceive of a modification of existing practices whereby calves are run up a race, injected with ketoprofen or another NSAID intramuscularly, and then castrated, dehorned, earmarked and vaccinated. The analgesic may only have a minute or two to act before the calf at the front of the race is treated but 20 minutes in the last calf.

The industry could also seek to identify other NSAID options (such as carprofen or meloxicam – see Section 4.9.3) for analgesia. Intramuscular meloxicam has been investigated for use after dehorning of dairy calves and preliminary published findings suggest good effect. This might be a lower priority for industry-funded research, however, as ketoprofen is well-researched and relatively inexpensive. If analgesia during castration becomes mandatory at some time in the future, there will be incentives for pharmaceutical companies to invest in research to demonstrate the value of their products.

Ketoprofen does not provide a complete pain relief solution for surgical castration. The development of safe injection methods such as shielded needles would enhance the possibility of access to local anaesthetic (and indeed NSAIDs) by licensed lay people, so that local anaesthesia could be provided to calves without the need for a veterinarian. Local anaesthesia of the scrotum, testes and spermatic cord is not technically difficult in comparison to a cornual nerve block for dehorning (for example). A possible model for use of veterinary drugs by lay people is discussed in Section 4.9.6.

4.4.6 Recommendations

This report recommends that:

- MLA commissions a comprehensive survey of castration, dehorning and branding practices across Australia, so that solid data are available to guide R&D, extension and policy. There is some information on the uptake of different practices but it is limited and this makes it difficult to judge the impact of possible changes in standards.

- MLA commissions a study of the use of ketoprofen under field conditions to manage the pain associated with castration, dehorning, ear marking, branding and other procedures undertaken concurrently. At least two production systems should be included: a southern system involving *Bos taurus* breeds, and a northern system with *Bos indicus* cattle, the ages of which should be determined in consultation with an industry reference group. The study should quantify the costs and benefits of ketoprofen use for each system. It should be conducted in complete confidence and the results retained for future reference.

- MLA commissions a feasibility and cost study for a scheme to license lay people to administer local anaesthesia for castration and dehorning in calves. The study would be preceded by a discussion between MLA and APVMA on the likelihood of success for such a scheme. This study would include the identification of shielded-needle, needleless and possibly other technologies that could be used to deliver local anaesthetic with reasonable operator safety as well as the regulatory changes that would be required to permit the use of local anaesthetics, and also non-steroidal anti-inflammatory drugs, by lay people. As with the recommended ketoprofen study, this study should be conducted in complete confidence and the results retained for future reference.

- If banding is shown to be a widespread practice in Australia, MLA considers research to clarify the welfare implications of this method. New Zealand may already be undertaking or planning such research in which case Australia may be able to benefit from the results. Alternatively, a collaboration on such research with Meat & Wool New Zealand may be appropriate.

4.5 Spaying

4.5.1 Description of methods and uptake

Techniques for spaying or ovariectomising cattle fall into two groups: those performed via incision of the paralumbar flank and those performed via the vagina.

In flank spaying, the standing female is restrained in a crush or, frequently in northern Australia, by the use of electroimmobilisation (McCosker et al 2007). A 15cm incision is made through the skin of the left paralumbar region approximately 5cm behind the last rib. Fibres of the external and internal abdominal oblique muscles are incised and blunt dissected and the fascia and peritoneum incised using scissors (Weaver et al 2005). Webbing (excision of a portion of each oviduct rather than total ovariectomy) is reported by McCosker et al (2007) to be a typical practice in northern Australia.

Vaginal techniques use devices that are inserted into the vagina then pushed through the dorsal vaginal wall into the peritoneal cavity. Passage spaying, once common in northern Australia, involved the use of a mechanical spreader to stretch the vagina and pubic symphysis before insertion of a hand carrying a concealed knife. The knife was used to cut the vaginal wall and permit the entry of an ecraseur or a spay hook to sever the vasculature and ligaments attached to each ovary (T. Jubb pers. comm.). With newer techniques, the intravaginal device is pushed through the vaginal wall and each ovary guided into it using a hand inserted per rectum.

The first vaginal ovariotomy device was that described by Rupp & Kimberling (1982). The Kimberling-Rupp device has one tube within another, each with oval-shaped openings with knife-edged margins. The openings are lined up and the ovary inserted. Turning the inner tube severs the attachments and the ovary is captured within the inner tube (Kimberling & Rupp 1980).

The Willis dropped ovary technique (WDOT) uses a simpler tool with no moving parts. Jubb et al (2003) describe the Australian adaptation of the instrument as ‘a stainless steel rod, about 48 cm long…with a 6-mm diameter shaft; it has a T-bar handle and a flattened spear head with a tear drop-shaped hole and slit cut in it’. The ovary is inserted into the hole and a sharpened section of the slit is used to cut the ovarian attachments. Unlike the K-R device, the ovaries drop into the abdominal cavity. The inability to visually confirm complete ovariectomy after the procedure is regarded as a relative disadvantage to the K-R technique; the lower cost, easier maintenance and easier manipulation are major advantages (Habermehl 1993).

At least one other device, the Meagher Ovary Flute, is now available. No information on this device was found apart from that available on the web site of its developer, a veterinarian from Montana in the US, and that contained within the product patent (Disney 1999). The Meagher Ovary Flute appears to be similar in concept to the K-R device, being a 'tube within a tube' and also removing the ovaries from the body. A superficial review of the patent suggests that the Meagher device does not offer any animal welfare advantages over the Willis instrument.

Flank spaying was the dominant technique in northern Australia for heifers until the introduction of the WDOT in 1996. Uptake of the WDOT has been rapid since that time (Jubb et al 2003). McCosker et al (2007) quote a figure of 25,000 females being spayed annually in northern Australia by experienced operators, of which 20,000 are spayed by the WDOT, most of the remainder being webbed by flank laparotomy. The source of these figures is not provided. T. Jubb (pers. comm.) estimates that experienced operators each spay 20-50,000 animals to a total of possibly one million animals across the rangelands per year, with very few operators now using flank spaying.

According to the ABARE survey of cattle husbandry practices for MLA (D. Marotti pers. comm.), only 10.6% of northern Australian cattle properties spay females that are not required for breeding (19.5% answered 'not applicable'). The Willis technique is used on 52.5% of properties, flank spaying on 28.4% and 'other' on 19.2%. There are interesting differences however between bottom, middle and top thirds of properties (defined by ABARE according to profitability), with WDOT spaying dominating the top and bottom thirds but not appearing in the middle third, for whom flank spaying is the most reported technique. The significance of this finding is not clear. A crush is used for restraint on 61.5% of properties, electroimmobilisation on just 5.5% and 'other' on the remainder. Contractors conduct the spaying for 68.7% of properties, vets for 8.4% and station hands or owners the remaining 22.9%.

The ABARE findings are not entirely consistent with anecdotal reports of common practice (S. Banney pers. comm.), and it is quite possible that respondents would be cautious or misleading in their responses, given the controversial nature of spaying.

Crowe (2006) states that 'widespread ovariectomy is no longer practiced in most beef production units worldwide, except in extensive range management systems'. Ovariectomy is common in South, Middle and North America according to Weaver et al (2005), who report that a veterinarian with a support team can spay 40-60 heifers per hour in restraint chutes. Meyer (2004) describes flank spaying as 'once a common technique…now rarely used in the US' (p. 752-1). In an earlier paper, Garber et al (1990) in the US note that until the advent of vaginal techniques, the cost of spaying was prohibitive. The paper presents a study showing the benefits of concurrent spaying with the WDOT and the use of anabolic implants. Habermehl (1993) from Canada refers to the increasing use of spaying to attract premium prices from feedlot buyers, and cites reports of the use of flank laparotomy ('with varying degrees of pre-surgical anesthesia and presurgical preparation'), the Kimberling-Rupp technique and the WDOT.

SCAHAW (2001) in the EU notes that spaying of female cattle is an 'old technique' that has been used in France and possibly other countries with the main purpose of maintaining a lactation in dairy cattle, or improving growth and carcass traits. The EC report cites studies (in French) suggesting that spaying does not improve productivity and concludes the procedure is 'probably not very frequently done nowadays'.

4.5.2 Welfare and productivity impacts

There is very little information on the welfare impacts of cattle spaying, either by flank or vaginal methods. Indeed a recent article in the Canadian Veterinary Journal was entitled 'Lack of animal welfare assessment regarding trans-vaginal spaying of heifers' (Pinner 2006). In this review, Pinner (2006) argues that post-operative morbidity and mortality due to transvaginal ovariectomy has been the subject of several studies but that assessment of pain in individual animals has received very little attention and limited description. Habermehl (1993), for example, reported a morbidity of 0.5% and mortality of 0.26% in one trial of the WDOT on 384 beef heifers. Mild stiffness and straining was noted in a few animals for 36 hours. Pinner (2006) cites a number of studies, many of them from obscure references, to quote a range of reported mortality rates from 0-4% in healthy non-pregnant heifers.

Jubb et al (2003) note that the WDOT method 'appears not to generate more discomfort than is normally associated with [pregnancy testing and artificial insemination]'. Pinner (2006) cites Shoop et al (1984) who reported that, of 400 heifers spayed by the K-R technique, 17% suffered discomfort for 24 hours after surgery, 7% for 2 days, 3% for 3 days, and none by the fourth day. There was no comment on the degree of discomfort nor indeed how discomfort was assessed.

Spaying has been reported to reduce weight gains. For example, ZoBell et al (1993a) found that the WDOT reduced average daily weight gains of crossbred yearling heifers in a feedlot by 4% from days 0-56, although the loss had been recovered by day 120. Jeffery et al (1997), on the other hand, found no effect of flank spaying on daily weight gains of 6-9 month-old, ½ - ¾ *Bos indicus* crossbred heifers on pasture up to 8 weeks after spaying.

The only formal study of the welfare implications of cattle spaying has been conducted by McCosker et al (2007) for MLA. The evaluation comprised three studies, all conducted in northern Australia using Brahman heifers and cows. In overview, the studies were designed as follows:

Study I was mainly conceived as a pilot for study II. It involved 24, 2-year old heifers treated under experimental conditions. Each animal was assigned to one of four treatment groups: physical restraint only / control (5), ear notch (5), WDOT spay (9), and flank webbing (5). An intensive blood sampling regime was used to measure responses in bound and unbound cortisol, haptoglobin, creatinine phosphokinase, aspartate aminotransferase and non-esterified fatty acids to 96 hours post-op. The general health of the heifers, wound healing in flank-spayed heifers and body weights were also recorded.

Study II involved 100 heifers and 50 cows under commercial conditions and was designed to measure physiological and behavioural responses to spaying. The cattle were each assigned to one of five treatment groups: restraint only / control, artificial insemination (AI, as additional control for the WDOT group), WDOT, electroimmobilisation (as control for the flank spay group) and flank spay. A blood sampling regime based on study I was used to measure responses in the same biochemical parameters. Other assessments were as described for study I, and in addition recordings were made of behaviour in the race, crush, yards and paddocks.

Study IIIa involved 600 heifers under commercial conditions. In IIIa, 200 heifers each were assigned to physical restraint only / control, WDOT and flank spay groups. A number of behaviours were recorded during the 6 hours following the treatment. The health of the cattle was assessed between

36 and 84 hours post-operation and on days 7, 10, 21 and 42. Mortalities were autopsied where possible.

Study IIIb was conducted because there was a higher than expected incidence of mortalities in the WDOT group during study IIIa, and most deaths occurred outside the monitoring period and were not autopsied. Three mobs comprising 574 heifers were spayed using the WDOT and monitored twice daily until day 14. Again, mortalities were autopsied where possible.

Key findings from the studies were that:

- Flank spaying and WDOT spaying caused similar acute (up to 8 hours) responses indicative of pain and stress in cows, but flank spaying also caused a significant chronic stress response, and inflammation and muscle damage were evident for 4 days after flank spaying. The inflammation and muscle damage were worse in heifers than cows;

- The levels of stress and pain due to the WDOT method were comparable to mock artificial insemination (AI) and physical restraint alone in heifers but not in cows, which showed a greater pain / stress response to WDOT than to AI;

- Indicators of pain, inflammation and muscle damage in WDOT-spayed females were not different from unspayed controls at 96 hours, with the exception of haptoglobin in cows, in contrast to flank-spayed females who continued to show elevated levels of bound cortisol, haptoglobin, and the enzymes CPK and AST;

- Electroimmobilisation played a large part in the adverse impacts on flank-spayed animals, especially cows; and

- Mortality rates of 1.5% for the WDOT, 2.5% for flank spaying and 0% for controls were recorded in study IIIa, and a mortality rate of 0.8% for the WDOT in study IIIb. The mortality rates recorded for the WDOT were higher than expected but the number of trial animals was relatively small, and no single cause was identified as the major contributor.

The authors concluded that to improve welfare outcomes while continuing to allow spaying, the procedure should only be done by the WDOT on yearling heifers and that electroimmobilisation should not be used for restraint. Cattle should only be walked a short distance after spaying to a paddock providing good feed and water. The authors also noted the need for more accurate estimates of mortalities from spaying.

The evaluation by McCosker et al (2007) has not been peer reviewed or published but it appears to be rigorous and credible.

4.5.3 Potential for pain mitigation

Surgical techniques of ovariectomy using laparoscopy have been described in the standing bovine (Bleul et al 2005) and equine patient (Alldredge & Hendrickson 2004, Cokelaere et al 2005, Dechant & Hendrickson 2000, Düsterdieck et al 2003, Farstvedt & Hendrickson 2005, Hand et al 2002, Hanson & Galuppo 1999, Lee & Hendrickson 2008, Palmer 1993, Rocken 2000, Rodgerson et al 2001, Van Hoogmoed & Galuppo 2005) as well as ovariectomy in the mare by colpotomy (Colbern &

Reagan 1987, Embertson & Bramlage 1992, Hooper et al 1993). In all cases where procedures were fully documented it was standard practice to inject local anaesthetic (lignocaine, bupivacaine or mepivacaine) into the mesovarium or ovarian pedicle up to 15 minutes prior to transection.

Weaver et al (2005) recommend for ovariectomy of cattle that a swab impregnated with lignocaine be applied to the pedicle for a minute prior to its transection. However, in one study where the ovarian pedicle was irrigated with a local anaesthetic solution, inadequate analgesia was observed (Palmer 1993).

The literature on medical laparoscopic surgery includes many descriptions of intraperitoneal (Alexander 1997, Colbert et al 2000, Ezeh et al 1995, Fiddes et al 1996, Garwood et al 2002, Kelly 1996, Koetsawang et al 1984, Ng & Smith 2002, Paech et al 2008, Spielman et al 1983, Tool et al 1997) and transcervical (Ng et al 2002, Schytte et al 2003, Wrigley et al 2000) administration of local anaesthetics. Effectiveness is greatest when the local anaesthetic is allowed to remain in contact with traumatised tissue. The effectiveness of intraperitoneal lignocaine (ovarian splash block) in reducing anaesthetic requirements for feline ovariectomy has also been demonstrated (Zilberstein et al 2007).

Local anaesthetic could be applied to the ovarian pedicle (by holding a swab against it) during flank spaying as practised in northern Australia and it may even be possible to modify the Willis instrument to allow this to happen prior to the WDOT. However, it would take considerably longer to spay each heifer, especially if a one-minute absorption period was required, and would thus appear to be impractical. One minute may also be insufficient time (Palmer 1993). Another significant constraint that may need to be overcome is ensuring that the ovarian pedicle, which is in a dorsal position in the standing cow, remains in contact with administered local anaesthetic. It is possible that a mucoadhesive or other formulation could be developed to permit the local anaesthetic agent to stick to any in-contact surfaces.

In a review of surgical ovariectomy in the cow, Weaver et al (2005) note that nerves to the ovarian pedicle are not blocked by a paravertebral nerve block, the usual approach to flank anaesthesia in cattle. Epidural anaesthesia has been suggested (and rejected) for spaying by McCosker et al (2007). Caudal (low) epidural anaesthesia is used for intravaginal and intrauterine manipulations and repairs, while cranial (high) epidural blocks are used for flank laparotomy and inguinal surgery. Paralysis of hind limbs is a major risk especially in cranial epidurals (Weaver et al 2005). Because of the risk of paralysis and the skill required, and because the ovarian pedicle is unlikely to be affected, epidural anaesthesia is unlikely to be a realistic option for spaying. Xylazine could be used to provide some degree of analgesia without the risk of paralysis but there would be potential problems of cattle going down. Xylazine is also only available on prescription.

An alternative to ovariectomy is the common practice of webbing (excision of a portion of the oviduct). However the pain caused by webbing in itself, as distinct from the procedure to gain access to the oviduct (e.g. flank laparotomy), has not been examined.

Non-steroidal anti-inflammatory drugs (NSAIDs) provide another option for alleviation of pain associated with spaying. In the literature on equine colpotomy described above, flunixin and/or phenylbutazone were provided in conjunction with the local anaesthesia, either pre- or post-operatively or both. Generally the NSAID was given parenterally prior to surgery with oral medication for up to 4 days after surgery.

McCosker et al (2007) suggest that ketoprofen might reduce the cortisol response from WDOT spaying, citing the work of Stafford & Mellor (2005b) on ketoprofen for dehorning. They estimate the cost of ketoprofen for spaying to be $3-4 per head, assuming a volume price through veterinarians and allowing for the additional labour of injecting prior to spaying. The authors suggest that this additional cost might be recouped by productivity gains. The reasoning behind this conclusion is not provided, however, and would need to be evaluated by field trial, especially given that the study of Stafford & Mellor (2005b) and several others used intravenous ketoprofen administered 20 minutes beforehand. There may be little scope to recoup the cost of the drug given the small productivity impacts reported in studies such as ZoBell et al (1993a).

Neithe & Holmes (2008) estimated that, on 5 northern properties modelled, spaying delivered an average increase in gross margin of between $35 and $306 per cow spayed (on a sixth property, near Alice Springs, there was a loss of -$219). In the context of these gross margins, an injection of ketoprofen would still make spaying a justifiable practice. However the review did indicate that costs need to be considered on a business-by-business basis and as market changes occur so the gross margins may change.

In summary, there may be options for the use of local anaesthesia and/or NSAID analgesia to reduce the welfare impact of spaying in cattle. It is not clear from the study of McCosker et al (2007) whether there is significant pain associated with the transection of the pedicle itself or whether the observed cortisol rise is associated with inflammation (and possibly pain) associated with post-ligation inflammation and wound repair. If the latter, parenteral administration of an NSAID such as ketoprofen is likely to offer a relatively simple means of providing pain relief. One consideration will be the possibility that an NSAID may increase clotting time and therefore increase the risk of intra-abdominal haemorrhage (see Section 4.9 on the pharmacology of NSAIDs). Intramuscular administration of the NSAID at the completion of spaying – thus allowing some clotting prior to the NSAID taking effect – would be one way to reduce this risk, but field trials would be needed to thoroughly investigate the benefit/risk proposition.

If transection of the ovarian pedicle itself is causing significant pain, local anaesthetic options may need to be considered, but these would complicate the procedure considerably.

4.5.4 Australian and international standards

Table 11 summarises the provisions of codes of practice and legislative instruments, in relation to spaying of cattle, of the respective jurisdictions in Australia. Spaying is not undertaken in sheep except as a rare surgical procedure by veterinarians.

Table 11 Australian codes of practice and legislation applicable to spaying of cattle

Jurisdiction	Provisions relevant to spaying of cattle
Australia (Model Code for Cattle)	• 5.5.1: Acknowledgment of benefits in extensive systems; recommendation to separate males and females in 'less extensive' production systems. • 5.5.2: Should be undertaken in dry weather by skilled operator using hygienic materials and technique; adequate restraint is essential; females should be returned to clean surroundings as soon as possible; post-operative inspection is desirable. • 5.5.2: WDOT is preferred method; other methods should be done by veterinarian or trained and competent lay operator using appropriate analgesia. • 5.5.3: Operators should be familiar with responsibilities (including use of analgesics and anaesthetics) under State / Territory legislation.
Australia (Beef Cattle Feedlot Guidelines)	• No reference to spaying.
Australia (Model Code for Feral Cattle)	• No reference to spaying.
Queensland	• As for the Model Code. • Section 3(1)(c) of the *Veterinary Surgeons Regulation 2002* specifies that spaying of cattle using the WDOT is not veterinary science for the purposes of the *Veterinary Surgeons Act 1936*. Flank spaying or passage spaying by hand, by not being included in the list of omissions, is regarded as veterinary science and must be carried out by a veterinarian.
New South Wales	• As for the Model Code. • Under Section 4(1)(d) of the *Veterinary Practice Regulation 2006*, 'the performing of laparoscopic surgery on any animal' is a restricted act of veterinary science for the purposes of the *Veterinary Practice Act 2003.*
Australian Capital Territory	• 4.5: Spaying by vaccination is preferable to surgical; description of benefits of spaying; surgical spaying should be conducted only by a veterinarian. • Section 19(2)(b)(i) of the *Animal Welfare Act 1992* permits 'a medical or surgical procedure (to be) carried out in accordance with accepted animal husbandry practice in relation to…farming and grazing activities' unless otherwise prescribed by the *Animal Welfare Regulation 2001*, which is effectively achieved by the Code.
Victoria	• No reference to spaying. • Section 6(1)(b) of the *Prevention of Cruelty to Animals Act (1986)* allows the Code as a defence against cruelty, but because the Code does not refer to spaying there is no such defence.
Tasmania	• 10.5: 'Costly and unpopular' procedure for which alternative needed but not available; will cause short-term discomfort and stress; general anaesthetic would not be practical but local anaesthesia should be used; adequate restraint essential; females should be returned to clean surroundings as soon as possible. • Requirement for use of local anaesthesia effectively restricts spaying to veterinary surgeons.
South Australia	• As for the Model Code. • Part 3 and Schedule 2 of the *Prevention of Cruelty to Animals Regulations 2000* requires compliance with the Code of Practice.

Jurisdiction	Provisions relevant to spaying of cattle
Western Australia	• As for the Model Code. • The WA Code has identical wording to the Model Code. • In the *Model Code of Practice for Cattle in the Rangelands of WA*, Section 9 is similar to 5.5.2 of the Model Code, but adds 'should be conducted as quickly as possible' and 'preferably a veterinarian'; 'should be done in dry weather' not included. • Section 26(3)(c) of the *Veterinary Surgeons Act 1960* specifically recognises that 'Nothing in (the Act) applies to or prohibits the performance, whether or not for reward, by a person in a prescribed area of the State and using humane methods, of the operation of spaying cattle'. Section 44 of the *Veterinary Surgeons Regulations 1979* prescribes 'the pastoral region' for the purposes of the Act.
Northern Territory	• As for the Model Code. • Section 6(k) of the *Veterinarians Regulations* specifically excludes 'spaying cattle using a technique approved by the Chief Inspector of Stock', subject to written approval from the Chief Inspector, from being a veterinary service under the meaning of the *Veterinarians Act*.

In summary, there are important legislative differences between the States and Territories with respect to spaying, even though the codes of practice are similar. WA and the NT allow flank spaying without anaesthesia in pastoral regions, in both cases by specific exemption of spaying from being an act of veterinary science. The WDOT can be undertaken by non-veterinarians in Qld by specific recognition that it is not a veterinary procedure, while in NSW and SA it can also be used because the Model Code allows it as a defence. The ACT also appears to allow the WDOT although whether it would be regarded as an accepted practice in that region is questionable. In Victoria and Tasmania spaying of cattle by non-veterinarians is effectively not permitted because no such defence is provided in the respective Codes.

A revised position statement on cattle spaying from the National Consultative Committee on Animal Welfare (NCCAW) states, *inter alia*, that:

- The Willis spay technique is a superior technique to surgical spaying;
- The Willis spay technique should be performed by appropriately trained and accredited veterinarians and lay operators, as State and Territory legislation permits; and
- Where spay techniques other than the Willis spay technique are to be used, the NCCAW recommends that they are carried out by a qualified veterinarian or trained person using appropriate analgesia.

The NCCAW position statement also lists a series of best practice recommendations for spaying:

- Animals should not be unnecessarily stressed before, during or after spaying;
- A 12-hour feed curfew assists the operation, but a water curfew is not necessary;
- Concurrent dehorning is not recommended, and animals recently dehorned, carrying heavy tick burdens or weak and emaciated should be allowed to recover before spaying;

- Effective restraint in a crush must be used;
- Spaying must not be done in conditions of extreme heat, cold or rain;
- Hygienic technique must be used;
- Spayed cattle should be allowed to settle onto feed and water in yards for several hours after spaying before returning to paddocks; and
- Until 2 weeks after spaying, cattle should not considered sufficiently recovered for sale or long distance transport.

Table 12 summarises the provisions of codes of practice and legislation of selected overseas countries as they apply to cattle spaying.

Table 13 summarises the policies, positions or standards of selected welfare interest groups and certifying agencies.

Table 12 Codes of practice and legislation, of selected overseas countries, applicable to spaying of cattle

Country	Provisions relevant to spaying of cattle
New Zealand	• There is no reference to spaying in the *Code of Welfare for Painful Husbandry Procedures*. • The Report accompanying the Code notes that spaying is 'rarely undertaken for husbandry reasons in New Zealand. Furthermore, it is considered a significant surgical procedure to be performed by a veterinarian or under veterinary supervision'.
Canada	• Code of Practice 10.1.5: surgical procedures other than castration and dehorning 'must be conducted only by veterinarians or competent, properly trained personnel using surgical techniques and in accordance with the law'. • There is no specific reference to spaying.
United States	• NCBA Guidelines state that a local anaesthetic should be used when heifers are spayed using the flank approach. • The NYSCHAP module does not refer to spaying.
European Union	• Article 17 of the T-AP Recommendation states that spaying is an exception to the forbidding of procedures resulting in the loss of a significant amount of tissue, provided it is permitted under domestic legislation, although it is one of a group of procedures that should be avoided where possible. The Recommendation also notes that 'Procedures in which the animal will or is likely to experience considerable pain shall be carried out under local or general anaesthesia by a veterinary surgeon or any other person qualified under domestic legislation. These procedures…include spaying'. • The SCAHAW Opinion recommends that: o 33: Spaying should not be carried out in females of any age.
United Kingdom	• There is no reference to spaying in the Mutilations Regulations, Code of Recommendations nor in FAWC advice, except in the latter to note that 'mutilations are undesirable in principle and farmers should carefully consider the necessity to perform any mutilations on cattle'.

Table 13 Policies, positions or standards of selected animal welfare interest groups, in Australia and overseas, applicable to spaying of cattle

Organisation	Provisions relevant to spaying of cattle
RSPCA (Australia)	• 2.1.6: 'This procedure should only be performed by a qualified veterinary surgeon using appropriate restraint, anaesthetic and aseptic technique'.
RSPCA (UK)	• H 1.21: the only 'potentially injurious husbandry procedures' permitted (except those done by a veterinarian for therapeutic reasons) are removal of supernumerary teats, disbudding and castration. • Spaying is not specifically mentioned, but Caesarean section 'must not be a routine procedure' (H 1.24.3)
Humane Society International	• 1.6 general principle: surgical treatments only carried out if operator can demonstrate that benefits outweigh consequences and no other acceptable options. • 1.6.1: animal mutilations are not permitted. • Spaying is not specifically mentioned.
Animal Welfare Institute (US)	• 7(e): spaying of heifers is prohibited.
Federation of Animal Science Societies (US) Guidelines	• Spaying is not specifically mentioned.
Temple Grandin	• Anaesthetics are required for flank spaying of heifers; other less invasive methods that do not require flank incision are recommended.
KRAV (Sweden)	• Spaying is not referred to in the Guidelines.
Australian Veterinary Association	• 8.4: AVA supports spaying by the WDOT; does not support flank spaying by non-veterinarians; flank spaying may be carried out by veterinarians with anaesthesia; in States where lay operators are permitted to spay, they should be trained by cattle veterinarians in the WDOT and accredited; animals must always be sufficiently healthy to be spayed.
American Veterinary Medical Association	• 'The AVMA considers flank ovariectomies, if performed without anesthesia, to be inhumane.'
Canadian Veterinary Medical Association	• Spaying is not specifically mentioned in animal welfare position statements.

There is no support for spaying without anaesthesia among the official international standards or animal welfare organisations surveyed here, except for Temple Grandin, although she too advocates less invasive methods. Several organisations oppose the practice, including the AVA and RSPCA in Australia.

4.5.5 Implications and discussion

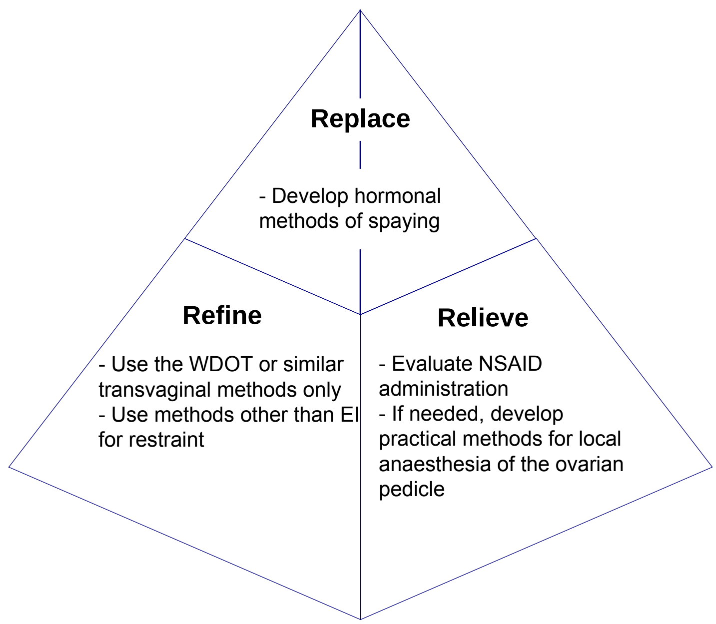
Cattle spaying presents particular problems as a welfare issue for the Australian cattle industry. Spaying clearly has a role in improving welfare on extensive holdings. Yet, common sense and experience and one scientific report indicate that flank spaying without pain relief causes significant pain and distress to cattle. The WDOT seems to have much lower impact on welfare but, on the only evidence available, it too causes acute pain.

Australia is the only country known to rely heavily on spaying for management purposes. On the one hand, this gives cattle spaying a low profile, so that it appears infrequently in the literature of animal rights organisations (see for example the Farm Sanctuary's report *The Welfare of Cattle in*

Beef Production: A Summary of the Scientific Evidence (Farm Sanctuary undated), which does not refer to spaying). On the other hand, spaying tends not to be recognised as a legitimate farming practice in other countries and therefore is not exempted from animal cruelty laws. RSPCA Australia is opposed to any form of spaying by lay persons.

As for castration, spaying can be considered using a 3R model of preferred practice from a welfare perspective (Figure 4).

Figure 4 3R model for spaying in cattle



There are reasonable prospects for the development of hormonal methods to replace spaying (D'Occhio et al 2002), and research in this area should be supported. In case effective hormonal treatments do not materialise, the industry should invest resources in research on ways to manage the pain associated with the WDOT. The simplest solution would be to provide an intramuscular injection of ketoprofen or other NSAID, and this should be the first option evaluated. The provision of local or regional anaesthesia is problematic because of limited access to the ovarian pedicle. However, an innovative approach to instrument design might allow local anaesthesia to be delivered through the Willis or other instruments. Another option to explore is a mucoadhesive formulation of lignocaine that would obviate the need for prolonged contact with a swab or blind injection.

This report has paid little attention to webbing, the practice of removing a portion of the oviduct and leaving the ovary *in situ*. It is not important that the ovary be removed. However, the problem with webbing is that it requires laparotomy (unless a *per vaginum* instrument could be developed), so none of the pain associated with incising the skin, muscle and peritoneum is addressed. Webbing would certainly be an appropriate approach for a veterinarian undertaking flank laparotomy under appropriate local anaesthesia but it is unlikely to be a lay option unless it can be achieved through the vagina.

It would be very surprising if the process of developing national standards did not require flank spaying, whether for ovariectomy or webbing, to be treated as an act of veterinary science and subject to appropriate anaesthesia or analgesia, in all jurisdictions. The NCCAW already takes this position, Queensland has recently changed its laws and it seems impossible to justify the current status of flank spaying given the widespread availability of a better method in the WDOT.

4.5.6 Recommendations

This report recommends that:

- MLA continues to support research into hormonal technologies for suppression of fertility in female cattle.

- MLA commissions research on pain relief options for WDOT spaying. A preliminary study might focus on the welfare benefit of an NSAID such as ketoprofen administered shortly after spaying using the WDOT. If there is evidence that local anaesthesia will be required, surgical instrument engineers might be approached to develop a modification to the Willis instrument that allows the injection or spray of a local anaesthetic into or onto the ovarian pedicle at the time it is transected. A mucoadhesive formulation of lignocaine is another option for consideration.

4.6 Horn removal

4.6.1 Description of methods and uptake

Horns on cattle develop from a group of specialised skin cells over the poll called the corium. Initially the cells form buds that can be freely moved around. At around 2 months of age the corium attaches to the underlying bone and the horns begin to develop. This is highly variable in *Bos indicus* cattle, which may not develop buds until some time later (Prayaga 2005). Over time, the frontal sinus (a cavity of the skull found under the poll) extends into the horn itself, creating a continuous cavity which is exposed if the horns are amputated (La Fontaine 2002, Newman 2007).

'Disbudding' refers to the removal or destruction of the corium at an early stage. Disbudding, done properly, permanently prevents horn re-growth because it removes the germinal cells. An important part of the procedure is to take a ring of skin from around the bud to ensure all horn cells are deactivated (La Fontaine 2002). Disbudding has been achieved by:

- Topical application of a caustic chemical, such as NaOH, KOH, or collodion, usually in the form of a paste or stick (Vickers et al 2005, Weaver et al 2005). Calcium chloride has also been injected under the bud (Koger 1976), as has lactic acid (Wiersma 1985);

- Burning the area with an electrical or gas hot-iron (e.g. Graf & Senn 1999);

- Freezing the buds (Bengtsson et al 1996); or

- Physical excision of the buds using a knife, shears, dehorning scoops and other devices (e.g. Petrie et al 1996).

Dehorning refers to the removal of horns once the bud has attached. A number of devices have been or are used for dehorning (Newman 2007) including:

- Scoop dehorners such as the Barnes-type, in which two handles are pushed apart, causing rounded sharp blades to come together and cut through tissue with a scooping action. Scoop dehorners can cut more deeply than intended and open up the frontal sinus;
- Cup dehorners;
- Guillotine shears, such as the keystone type, in which the handles are pushed together to move a sharp blade through bounded square or rectangle;
- Saws;
- Dehorning knife;
- Embryotomy wire; and
- Tippers.

The wound healing process following dehorning of mature cattle by wire has been described by Kihurani et al (1989). The process took up to 84 days, suggesting the potential for chronic pain effects.

'Tipping' refers to the removal of a short length from the tip of mature horns. It is often used when the horns are growing in towards the face. Larger devices such as guillotine shears can be used. Embryotomy wire and saws are also useful, particularly when it is not possible to place a guillotine or other device over the end of the horn.

Prayaga (2005), aggregating figures from breed societies, estimates that around 52% of cattle in Australia are horned, 47% polled and 1% scurred. The survey of cattle producers for MLA by ABARE found that in southern beef systems, 45.4% of cattle were dehorned, 10.2% were left with horns and 44.4% were polled. Corresponding figures for northern Australia were 65.8%, 2.8% and 31.5% (D. Marotti pers. comm.).

In the US, 27.8% of calves born in 1996 had or were expected to have horns, although 62.1% of operations had one or more 'non-polled' calves born during that year, so it is difficult to compare US and Australian figures (USDA 1997). Sixty-one percent of horned calves were expected to be dehorned before leaving the property. The average age of dehorning was 108 days (3.5 months) in large herds and 176 days (6 months) in smaller herds (USDA 1997).

4.6.2 Local anaesthesia techniques

The procedure for blocking the cornual branch of the zygomaticotemporal division of the maxillary nerve is well established. The site of injection is just below the lateral ridge of the frontal crest about halfway between the lateral canthus (outside corner) of the eye and the lateral base of the horn. Five to 10ml of a local anaesthetic agent such as lignocaine is injected. Three to 5 minutes is needed for analgesia to take effect. Adult cattle may require a further injection under the skin behind the horn base (Weaver et al 2005). The technique requires a reasonable level of skill and even veterinarians check that anaesthesia has been successful before dehorning. However, it could be learned by a lay person without too much difficulty.

There are some differences in the regimes used in various studies. In addition to 5ml at the site described by Weaver et al (2005), Graf & Senn (1999) injected 5ml of lignocaine caudal to (behind) the horn and a further 3ml medial to (inside) it. Doherty et al (2007) also used an augmented blocking regime, injecting 3ml adjacent to the cornual branch of the zygomaticotemporal nerve, 3ml adjacent to the cornual branch of the infratrochlear nerve, and 4ml rostral to (in front of) the horn base, for a total of 10ml in 10-12 week-old calves.

The animal health company Animal Ethics Pty Ltd, in conjunction with Bayer Animal Health and the University of Sydney, has recently announced Australian Research Council (ARC) support for a project to develop its product Tri-Solfen®[20]. Tri-Solfen® is a formulation of local anaesthetic, a vasoconstrictor and a disinfectant that is currently used as a wound dressing following mulesing in sheep. The funding announcement refers to the possible use of Tri-Solfen® as a dehorning wound treatment. No information regarding this application has yet been published. As a post-operative treatment, however, Tri-Solfen® will clearly have no impact on any pain experienced at the time of dehorning – the question is how quickly and to what degree it would ameliorate the post-operative pain.

The effects of local anaesthesia are described below under each of the individual techniques.

4.6.3 Welfare and productivity impacts and pain management

As for castration, there is a large body of literature on the welfare impacts of horn removal (disbudding, dehorning, and tipping) on cattle. Reviews have been published by AVMA (2006a), NAWAC (2005b), SCAHAW (2001), and Stafford & Mellor (2005b). As for castration, a paper by Stafford & Mellor (2005b) appears to be the most comprehensive.

A summary of the primary research papers describing the effects of horn removal on cattle is provided in Appendix 9.4. The table includes published short communications or letters in reputable journals that express opinions or describe events of relevance. A summary of 53 analgesia protocols for dehorning is presented in Appendix 9.5 and a discussion of published reports is set out below under each method.

4.6.3.1 Complications of horn removal

The major complications of dehorning are haemorrhage, infection and flystrike. Bleeding from the site is common and not usually a concern in young calves, but needs to be managed carefully in older calves and adults or it may lead to severe weight loss and death. A rubber tourniquet is sometimes used to minimise bleeding.

Infection is seen mainly in larger animals that have developed a cornual sinus (the extension of the frontal sinus into the horn). Disbudding or early dehorning, avoiding wet or dusty weather, and not feeding recently-dehorned cattle with overhead hay racks all minimise the risk of sinus infection.

[20] http://www.animalethics.net.au/news301107.html, accessed 5 May 2008.

Flies can be avoided by the appropriate timing of disbudding or dehorning and the use of fly repellents where needed (Irwin & Walker 1998, Parsons & Jensen 2004, Weaver et al 2005).

4.6.3.2 Disbudding by cautery

Calves between about 2 and 12 weeks of age, subjected to disbudding by cautery, consistently show a short-lived rise in plasma cortisol (see especially Graf & Senn 1999 and Petrie et al 1996 but also Boandl et al 1989, Doherty et al 2007, Grøndahl-Nielsen et al 1999, Laden et al 1985, Milligan et al 2004, Morisse et al 1995, and Wohlt et al 1994). The peak response is typically at 30 minutes and return to baseline levels by 1.5-2.5 hours, although Morisse et al (1995) reported significantly raised cortisol in cautery-disbudded calves 24 hours after treatment. In probably the most comprehensive study of cortisol responses, Petrie et al (1996) found that the area under the cortisol curve for 6-week-old cauterised Friesian calves was, on average, 45% of that of ACTH-stimulated calves (compared with 23% for handled controls). Taschke & Folsch (1993) also found that salivary cortisol peaked at 30 minutes after cautery disbudding.

Laden et al (1985) found no effects of cautery disbudding on glucose, albumin, haemoglobin or packed cell volume during the hour following the procedure. Similarly, Doherty et al (2007) measured no change in total plasma protein, fibrinogen or α_1-acid glycoprotein (an acute-phase protein), although there was an increase in the neutrophil to lymphocyte ratio and the percentage of circulating neutrophils in the first 12 hours. These changes were seen in calves anaesthetised with 2% lignocaine as well as unanaesthetised calves, but not calves anaesthetised with 5% lignocaine, which broadly corresponded to the respective cortisol and behavioural responses. The authors concluded that the changes in leukocyte populations reflected the glucocorticoid stress response, while the inflammation associated with the dehorning was insufficient to induce a change in the acute-phase proteins.

Negative behaviours associated with cautery disbudding have been described by a number of authors including Doherty et al (2007), Faulkner & Weary (1999), Graf & Senn (1999), Grøndahl-Nielsen et al (1999), Milligan et al (2004), Millman et al (2005), Morisse et al (1995), and Vickers et al (2005). Graf & Senn (1999) observed increased frequencies of tail wagging, head moving, tripping, and rearing during disbudding in unanaesthetised compared with anaesthetised calves. During the first hour post-operation there was a high level of unprompted backwards locomotion. Disbudding produced a high level of head shaking that lasted for 2-4 hours depending on the group, with some individuals showing an extremely high level of this behaviour (200 times per hour in one case). Stafford & Mellor (2005b) cite this finding as possible evidence that pain persists longer than the cortisol peak suggests. Notably too there was a complete avoidance of head pushing for 4 hours in the unanaesthetised but not the anaesthetised group.

The heart rate of disbudded calves was elevated for about 3.5 hours in the study of Grøndahl-Nielsen et al (1999), also suggesting a longer period of distress than that indicated by the cortisol responses.

Morisse et al (1995) reported behaviours indicative of pain, such as restlessness and shaking of the head, within the first 4 hours. After this time all such signs disappeared. There were no significant differences between unanaesthetised, saline, and 2% and 5% lignocaine groups in average daily behaviours over three days in the study of Doherty et al (2007).

The balance of evidence on cautery disbudding seems to argue for an initial hour or so of relatively high distress, possibly followed by low-grade pain persisting for several hours. One paper suggests a pain response lasting 24 hours or even longer but this is not typical of the literature.

Pain management using local anaesthetic

Local anaesthesia appears to have a beneficial effect on the pain response to cautery disbudding, although there are differences in findings between studies. Boandl et al (1989), for example, found similar cortisol responses in calves disbudded with or without local anaesthetic. Handling, injection of anaesthetic and disbudding each imposed stresses. Similarly, Petrie et al (1996) found little effect of local anaesthetic. There was a small rise in plasma cortisol, lower than that of unanaesthetised calves but not significantly so, in blocked calves and a return to baseline levels by 60 minutes. In contrast, there was a marked deferral of the cortisol response to scoop dehorning in the same study, suggesting cautery is a less stressful procedure.

Morisse et al (1995) found that local anaesthesia reduced the intensity of immediate avoidance reactions to disbudding on average, but that it was clearly effective in only 60% of calves. Local anaesthesia had no effect on behaviours during the 4 hours following.

In the study of Doherty et al (2007), 5% lignocaine appears to have virtually eliminated the initial cortisol peak due to disbudding while 2% lignocaine did not. The 5% group had higher cortisol at 4 hours, although the removal of one calf from the analysis neutralised this difference. Behaviours indicative of pain were greatly reduced in the 5% group as were changes in neutrophil populations.

Graf & Senn (1999), using an augmented cornual block, concluded that ‘local anaesthesia eliminated or markedly attenuated all behavioural and endocrine responses’ to disbudding. There was a small rise in cortisol from 2-4 hours, significantly different from controls at 3 and 3.5 hours, suggesting some deferral from the active period of the anaesthetic. However, while area-under-the-curve data are not presented, the integrated cortisol response was clearly much reduced by the provision of local anaesthetic. The same authors reported suppression of ACTH and vasopressin levels in response to local anaesthesia.

Pain management using other agents

A combination of xylazine sedation plus butorphanol, with or without local anaesthetic, prior to disbudding was evaluated by Grøndahl-Nielsen et al (1999) in 4-6 week-old calves. The sedation appeared to have little effect.

Faulkner & Weary (2000) showed that ketoprofen provided orally (in milk) before and twice after disbudding reduced behavioural signs of pain (ear flicking, head shaking and head rubbing) in 1-2 month-old calves. Both groups were sedated with xylazine and given a nerve block. Ketoprofen was also considered to have reduced the short-term pain of cautery disbudding in calves less than 2 weeks old in the study of Milligan et al (2004). In this case ketoprofen (3mg/kg) was administered intramuscularly 10 minutes prior to disbudding, with both control and treatment groups also receiving a cornual nerve block. However, the positive conclusion was based only on the difference between 0- and 3-hour cortisol levels, which was lower in the ketoprofen group – there were no differences in the cortisol levels themselves, nor in feed intake nor a number of behavioural parameters. The evidence from this study for a benefit from ketoprofen is therefore thin at best.

A further study, also from the University of Guelph and published only in a short communication, compared lignocaine alone and ketoprofen alone immediately prior to dehorning (method not specified, but calves were less than one month old). Physiological and behavioural parameters were measured. There were no differences across any of the measures between ketoprofen and control groups, indicating that ketoprofen was not a suitable replacement for local anaesthesia (Millman et al 2005).

The University of Guelph's Applied Animal Behaviour and Welfare group has recently worked on the use of meloxicam for analgesia of dairy calves after disbudding – specifically, an MSc project by Annaliese Heinrich. No journal articles have yet been published but contact was made with the head of the group, Assoc. Prof. Suzanne Millman, who supplied several abstracts from recent and upcoming conference proceedings (Heinrich et al 2007a,b, Heinrich et al 2008).

Heinrich's work measured behavioural and physiological responses to heat cauterisation dehorning with or without a single intramuscular dose of meloxicam (0.5mg/kg) plus a cornual nerve block. Significant improvements were found in all indicators including behaviours for at least 44 hours after treatment (when the experiment concluded). Some differences in pain response were seen as early as 10-15 minutes after dosing. Millman (pers. comm.) is confident that meloxicam is effective in reducing the post-operative pain of dehorning.

Papers from the research, including a description of the pharmacokinetics of meloxicam, are currently being prepared and will be submitted to journals in coming months (Millman pers. comm.)

4.6.3.3 Disbudding by amputation

Two papers have been published on amputation disbudding (i.e. physical removal of the bud): Petrie et al (1996), in 6-8 week-old Friesian calves and Mellor et al (2002) in 10 week-old calves of unspecified breed. Both concern the use of scoop dehorners. No papers were found that examined the use of a disbudding knife. It can be reasonably assumed that the welfare impacts of the two devices would be equivalent given the similar modes of action.

The two papers on amputation disbudding are considered below under amputation dehorning.

4.6.3.4 Disbudding by cryosurgery

Only one paper appears to have been published in English[21] on the welfare implications of disbudding by cryosurgery. Bengtsson et al (1996) disbudded calves 7-29 days old using either liquid nitrogen applied directly or a probe cooled with nitrous oxide. This was a preliminary study involving small numbers of calves and only qualitative observations were made. The authors believed that cryosurgery probably caused less pain than cautery, but on the basis of observed defensive behaviour and vocalisation, both techniques caused some pain. The direct liquid nitrogen may have caused less struggling.

Neither technique reliably provided permanent horn removal and the time taken to perform the procedure (10 minutes) was a major hurdle to its commercial use.

[21] Papers by Baer et al (1990) and Menzel (1990), in German, are cited in the Bengtsson article. There is no indication these papers present substantial welfare findings.

4.6.3.5 Disbudding by caustics

Four-week-old calves disbudded with a KOH caustic stick showed a peak in cortisol over the first hour after treatment, returning to base levels by 4-24 hours. The peak was lower than that of calves receiving ACTH injections (12-18 vs 40ng/ml) but higher than that of 8-week-old calves disbudded by cautery. The caustic group did more lying down / standing up and head shaking, and less self-grooming over 4 hours than the cautery calves, although the statistical significance of these findings is not clear. Overall the findings suggest that the caustic stick is more painful than cautery although the age difference between the groups confounds this conclusion (Morisse et al 1995).

In the same study, local anaesthetic reduced the immediate reactions to caustic paste disbudding. However, these beneficial effects were observed in only 60% of the calves, suggesting that 40% had not been effectively anaesthetised, possibly due to anatomical variations or poor technique. There were no longer-term benefits from anaesthetic. The researchers used 4ml of lignocaine, which is slightly less than the 5ml recommended for calves by Weaver et al (2005).

Vickers et al (2005), on the other hand, concluded that the use of caustic paste after sedation with xylazine induced pain, but less than that from heat cautery after sedation and local anaesthetic, on the basis of certain behaviours. Local anaesthetic did not improve outcomes from the caustic paste plus sedation treatment.

In an abstract-only publication, Stilwell et al (2004) in Portugal reported that local anaesthesia plus intravenous flunixin totally blocked the cortisol response to caustic paste disbudding while local anaesthetic alone did not. A more recent paper by the same group (Stilwell 2008) looked at the value of flunixin alone, reporting the cortisol and behavioural effects of caustic disbudding with or without intravenous flunixin administered 60 minutes or 5 minutes prior to treatment. The calves were 10-40 day-old Holstein-Friesians. Neither regime of flunixin was considered effective at reducing cortisol or behavioural changes due to the disbudding and the authors concluded that both anaesthesia and analgesia are required to control the pain. A limitation of this study was the infrequent blood sampling (at -5 minutes and +1, +3, +6 and +24 hours).

Between the Morisse et al (1995) and Vickers et al (2005) papers there is a gap in the science. There is no clear evidence at this stage which of caustic or cautery disbudding has the best animal welfare credentials. It should be noted that caustic preparations present some practical problems, notably the risk of their running off the poll area and into sensitive parts of the eyes. Calves may also rub the caustic into the udder of the dam. The abstract of Stilwell et al (2004) compares scoop, caustic and cautery methods and concludes that scoop dehorning is significantly more painful than the other methods, even with local anaesthesia, on the basis of cortisol responses. The abstract does not comment on caustic vs cautery methods.

One study provides some evidence that calves disbudded by caustic paste suffer no long-term behavioural problems. Compared with naturally polled animals, 6-9 month-old beef calves which had been disbudded at less than 1 week of age responded similarly to a series of restraint and handling tests (Goonewardene et al 1999).

The only literature describing the subcutaneous injection of lactic acid for disbudding is a letter from a practising veterinarian in Canada noting its apparent efficacy and safety in calves less than 3 weeks old (Wiersma 1985).

4.6.3.6 Amputation dehorning

The bulk of the literature on removal of mature horns, especially that from the mid-1990s, is concerned with the scoop dehorner. This includes a series of papers from the Massey University, New Zealand group of Gibson, McMeekan, Mellor, Petrie, Stafford, Sutherland, Sylvester and others.

Amputation (cutting) methods of dehorning induce a similar plasma cortisol profile to cautery disbudding initially, reaching a peak at around 30 minutes. Rather than returning to baseline levels after 1.5-2.5 hours, however, there is a plateau in the profile that continues until 7-9 hours after the procedure. This very consistent pattern is seen in the studies of Petrie et al (1996) in 6-8 week-old Friesian calves, Mellor et al (2002) in 10-week-old calves, McMeekan et al (1997, 1998a,b), Stafford et al (2003) and Sutherland et al (2002a,b) in 3-4 month-old Friesian calves, and in Sylvester et al (1998a,b) in 5-6 month-old Friesian calves. The data range for cortisol studies is therefore 6 weeks to 6 months.

Cooper et al (1995) found an increase in plasma progesterone between 5 and 60 minutes following amputation dehorning. Mellor et al (2002) showed a peak in noradrenaline concentration at 30 minutes followed by a decline to below pre-treatment values by 60 minutes. Mean concentrations were significantly greater than controls between 10 and 50 minutes. Adrenaline peaked in dehorned groups at 5 minutes and at a higher level than that of non-dehorned controls but after that time all groups were below pre-treatment values except for a spike in the local anaesthetic plus dehorning group at 90 minutes.

Stafford & Mellor (2005), drawing on the findings of McMeekan et al (1998b) and Sutherland et al (2002a) in particular with ketoprofen and ACTH, suggest that the peak phase of the cortisol profile may indicate the direct nociceptor response while the plateau phase reflects inflammation-mediated pain. The entire story has not been resolved, however, and is clearly complex. Local anaesthetic tends to defer the cortisol spike but not to reduce the overall cortisol response. The cortisol triggered by the nociceptors may act to reduce the inflammatory pain. If so, ACTH injected during the period of local anaesthesia to induce a cortisol surge might be expected to reduce the deferred cortisol response. A reduction due to ACTH administration was in fact observed in the study of Sutherland et al (2002a) but it was small. The authors hypothesised that the exogenous ACTH might inhibit endogenous ACTH, further complicating the picture. Clearly, some of the details of the physiological response to dehorning have yet to be clarified.

There were no significant differences between the integrated cortisol responses or mean cortisol levels to deep or shallow scoop dehorning (McMeekan et al 1997). Sylvester et al (1998b) found similar cortisol responses to dehorning by wire, guillotine shears, saw or scoop dehorners. The choice of instrument for dehorning therefore seems to make little difference to the level of pain experienced.

Behavioural studies on amputation dehorning have been reported by Stafford et al (2000b) with 6-week-old calves, McMeekan et al (1999) (3-4 months), and Sylvester et al (2004) (6 months). Again, the reports are consistent, perhaps not surprising given that all studies were carried out by the same research group and all in Friesian calves.

Sylvester et al (2004) recorded ruminating, head shaking, ear flicking, tail flicking, head down, lying, walking, leg to face scratching, head rubbing, neck extending, riding and vocalising. The first four of these were the most significant with rumination tending to appear in inverse relationship to head shaking and ear and tail flicking ('restlessness'). There was a high degree of restlessness for up to 6 hours post-dehorning and almost no rumination during this period. By 6 hours, restlessness returned to normal levels except tail flicking, which continued to between 10 hours and 26 hours. All groups were similar at 26-29 hours.

There is some question over the longevity of pain from dehorning. One study shows a more persistent cortisol response than those observed in the New Zealand studies, although in calves that were both dehorned and castrated, the latter by an unspecified method (Johnston & Buckland 1976). Cortisol was elevated and in fact rising at 24 and 48 hours when the only two measurements were made. It would be unwise to ascribe too much significance to that finding, but unpublished data from Stafford, cited in Stafford & Mellor (2005b), showed that dehorned calves graze and ruminate less in the 24-48 hour period post procedure than they do before dehorning or 48-72 hours afterwards. This may suggest some level of pain that is not sufficient to register in either the cortisol or other behavioural signs.

Effects of dehorning on weight gain have been reported. In Australia, Winks et al (1977) found that mature-age Brahman cross steers dehorned by a guillotine-type device gained 10.2 and 13.6kg less than non-dehorned counterparts over 5 months in two trials. Steers that were tipped gained 8.6kg less than horned cattle in the first trial. There was an inverse relationship between size of hole in the sinus and liveweight gains in the first 24-day period although this disappeared over subsequent periods.

Loxton et al (1982), also in Australia and working with Brahman cross cattle, compared weight gain effects in groups dehorned at various ages: branding (4 months), weaning (7 months), yearlings (19 months), or adults (30 months). Differences in liveweight gain between horned and dehorned cattle were most pronounced in the first 2 weeks and gradually diminished thereafter, and were not significant at 12 months. There were no differences due to age at dehorning. Wounds were reported to heal by 4 weeks in weaning and yearling groups, and at least 6 weeks in adults.

In Canada, Goonewardene & Hand (1991) found negative effects on weight gain due to dehorning in crossbred *Bos taurus* feedlot cattle during winter. The differences were still statistically evident at the end of the trial on day 106. Although small, they amounted to a 5.3kg liveweight difference.

<u>Pain management using local anaesthetic</u>

Petrie et al (1996) reported that local anaesthetic reduced the cortisol response to scoop dehorning in 6-8 week-old Friesian calves. The cortisol showed a small rise then dropped to pre-treatment levels, although it rose again and was generally higher than that of unanaesthetised, disbudded calves from 2.5 to 8.5 hours (although significantly so at only 3.5 hours). Anaesthetic made no difference to the integrated cortisol response over the full 9.5 hour recording period. In effect, the response was simply deferred.

This result seems to have prompted some discussion on whether local anaesthesia is justified before dehorning. In a reply on the matter, Mellor & Stafford (1997) pointed out that the study measured only one aspect of the stress response and that its findings should not be interpreted to mean that local anaesthesia is unwarranted.

This deferral phenomenon was also reported by Mellor et al (2002) using lignocaine and by McMeekan et al (1998a,b) with lignocaine and also bupivacaine. In the latter case, the deferral lasted about 4 hours, corresponding to the long-acting effect of the anaesthetic. Calves provided a second injection of bupivacaine at 4 hours showed an 8-hour deferral effect. A cortisol peak appeared after the 8 hours, but it was not clear whether the total cortisol response was different to other treatment groups because the experiment ended (McMeekan et al 1998a). Sutherland et al (2002a) gave lignocaine 15 minutes prior and bupivacaine 2 hours after scoop dehorning and observed a 5-hour suppression of the cortisol response; again, cortisol rose at the conclusion of the local anaesthetic effect. In each of these studies, the total cortisol response over 24 hours was unchanged by anaesthesia.

Sylvester et al (1998a), however, from the same research group in New Zealand, found a reduction in the overall cortisol response by local anaesthesia in 5-6 month-old Friesian calves. The cortisol area under the curve over 9 hours was significantly lower in the local anaesthetic group compared to unanaesthetised calves. Local anaesthetic plus cautery of the wound produced the lowest cortisol response.

The only study involving catecholamines did not find any significant effect of local anaesthesia on adrenaline or noradrenaline profiles (Mellor et al 2002). The reasons for this lack of effect, especially in noradrenaline, were not clear given that cortisol was suppressed.

Behavioural observations by Sylvester et al (2004) appear to support the cortisol studies. Anaesthetised calves were similar to control calves until 2 hours after dehorning when head shaking and tail and ear flicking increased and rumination decreased. The authors noted that the changes observed after 2 hours ‘were similar in magnitude and possibly in duration to that displayed by the dehorned calves’. They discuss at length whether the anaesthetic has reduced or merely deferred the pain of dehorning, and settle for the former, arguing that the behaviours at the time of dehorning were not factored into the current study and also noting that the sister study on cortisol (Sylvester et al 1998a) had shown an overall decrease in response (Sylvester et al 2004).

On the other hand, the behavioural studies of McMeekan et al (1999) and Stafford et al (2000b) produced equivocal results. In Stafford et al (2000b) anaesthetised calves behaved similarly to their unanaesthetised counterparts during the first 2 hour period. The authors suggested that the methodology may not have been sensitive enough to detect subtle differences.

Most recently, Gibson et al (2007) have assessed the use of electroencephalographic (EEG) responses as indicators of pain, using scoop dehorning as a test case. Six- to 9-month-old calves were maintained under general anaesthesia and either received or did not receive local anaesthesia. Electrocardiographic (ECG) recordings were taken in addition to the EEGs.

There were significant changes in the EEGs of the ‘nil local’ group compared with the group treated with local anaesthetic. Similarly, there was a brief period of slow heart rate immediately after dehorning and possibly the start of a more rapid heart rate from 15 minutes (when the last measurement was made) in the ‘nil local’ group. The authors concluded both that local anaesthesia had attenuated the noxiousness of dehorning and that the EEG had been validated as a tool for assessment of noxious stimuli.

Pain management using other agents or cautery

Ketoprofen, xylazine and cautery have been evaluated for their effects in reducing the pain of amputation dehorning.

Ketoprofen administered intravenously 15-20 minutes prior to dehorning 3-4 month-old calves had little effect on the initial cortisol peak but abolished the plateau, such that mean plasma cortisol concentrations were similar to non-dehorned controls by 2 hours and for at least 9.5 hours (McMeekan et al 1998b). However, ketoprofen appeared to offer only a small reduction in adverse behaviours (McMeekan et al 1999).

In the same studies, a combination of ketoprofen plus a cornual nerve block with lignocaine virtually eliminated both the cortisol peak and plateau to give a greater reduction in cortisol than either local anaesthetic or ketoprofen alone. The combination seemed to reduce pain-associated behaviours for around 4 hours. The reduction was very clear at 2 hours, with treated calves similar to the non-dehorned controls, but became less significant at the 4-hour measurement and beyond (McMeekan et al 1998b, 1999). The ketoprofen plus lignocaine block also virtually abolished the cortisol response to dehorning in 3-month-old calves, except for a small peak at 4 hours, in the study of Stafford et al (2003).

Sutherland et al (2002a) reported similar findings using ketoprofen plus lignocaine plus bupivacaine, although the deferred cortisol response following a longer period of local anaesthesia (5 hours in this case) was not as effectively reduced. Phenylbutazone did not have the same effect as ketoprofen, thought to be because it was less effective in reducing the pain associated with inflammation in the delayed cortisol response. The dose rate of phenylbutazone used may also have been too low.

Xylazine given 20 minutes before dehorning 3-month-old calves significantly reduced the cortisol response for three hours, while xylazine plus lignocaine virtually abolished it over the same period. However, in both groups, cortisol rose again from 3 hours and persisted for about 5 hours. There were no differences in the integrated responses to xylazine, xylazine plus lignocaine or dehorning alone groups. The administration of tolazoline to reverse the xylazine at 5 minutes after dehorning seemed to create an additional cortisol spike for reasons not well understood (Stafford et al 2003).

The value of cautery immediately after scoop dehorning was evaluated by Sylvester et al (1998a) and Sutherland et al (2002b). In the former study, cautery alone provided some reduction in the cortisol response compared with dehorning alone in 5-6 month-old calves, but the integrated response over 9 hours was not significantly different. Local anaesthetic plus cautery led to an integrated cortisol response that was lower than either intervention alone and not significantly different from non-dehorned controls (Sylvester et al 1998a).

Interestingly, cortisol concentration at a single time point 36 hours following treatment was similar to the other dehorned groups and different from controls. The dehorned groups had similar cortisol to pre-treatment levels, suggesting an absence of noxious stimuli, although the control and local anaesthetic-only groups returned cortisol concentrations around half those of pre-treatment. This finding was not explored. Perhaps it reflects reduced handling stress in the control groups who have no memory of a stressful procedure.

Sutherland et al (2002b) reported similar findings in 3-4 month-old calves. Local anaesthetic plus cautery virtually abolished the cortisol response for at last 24 hours when the study concluded.

Cautery may destroy sufficient nociceptors (pain receptors) that, once the effect of local anaesthetic wears off, the pain response does not return. Cautery by itself may however contribute an additional level of stress that offsets its beneficial effects (Stafford & Mellor 2005b).

Pain management using electroimmobilisation

One paper worth noting for completeness is that of Carter et al (1983) from Australia on the effect of electroimmobilisation (EI) on the dehorning of cattle. Jersey heifers aged 18-22 months were dehorned by guillotine device with either no pain management, lignocaine cornual block, or EI. The study was a simple one involving measurements of cortisol only before dehorning and at 15 and 60 minutes after dehorning. There were no significant differences in cortisol between the three dehorned groups compared with controls, nor any difference in haemorrhage. There is no statistical analysis of the results and the authors admit that the study 'could not resolve the question of whether the application of the immobiliser causes pain and whether, when applied, it reduces the pain of a surgical operation', so the paper is of little value to the present discussion.

4.6.3.7 Key findings from scientific studies

In summary:

- Cautery disbudding produces a shorter and smaller stress response than horn or bud amputation and is less noxious. The method of amputation dehorning does not appear to be important to the welfare outcome.

- The relative noxiousness of cautery and caustic disbudding is not clear from the literature. However, there are practical problems with the use of caustic disbudding preparations that make them a less preferred option.

- Amputation dehorning affects liveweight gains in the first few weeks following the procedure. The production penalties have been shown in some cases to persist for several months, while in others, compensatory growth causes differences to disappear quickly.

- The evidence that local anaesthesia prior to cautery disbudding confers a welfare benefit is equivocal but probably real in the opinion of Stafford & Mellor (2005b). Similarly, the benefits of local anaesthesia prior to amputation dehorning are not always clearly demonstrable from either cortisol or behavioural responses, with some studies showing that pain is simply deferred for the duration of the anaesthesia. However, the weight of evidence is slightly in favour of local anaesthesia reducing the pain of amputation dehorning.

- Local anaesthetic prior to, plus cautery of the wound immediately after, amputation dehorning appears to significantly decrease the pain response compared to no treatment or local anaesthetic alone.

- The benefits of ketoprofen for disbudding are not clear, although meloxicam may be useful. Ketoprofen offers significant welfare improvements when used in combination with a local anaesthetic block for amputation dehorning. Effective local anaesthetic blocks for dehorning require some degree of skill. However, the skills could be learned by lay people.

- There is no clear evidence of a benefit from systemic xylazine prior to dehorning.

Stafford & Mellor (2005b) have ranked the various methods of horn removal based on a semi-quantitative weighted index of acute cortisol, behavioural and production effects. The table is adapted and reproduced here (Table 14) because it summarises and synthesises the bulk of the work described above and provides a single reference point on dehorning. The ranking is described as non-linear. For example, procedures ranked 4, 5 and 6 are associated with similarly high cortisol responses but differ in the amount of struggling they cause.

The authors recommend that operators select the lowest-ranked procedure that is practically feasible for their circumstances.

Table 14 Ranking of horn removal methods by animal welfare impact, from most to least severe (adapted from Stafford & Mellor 2005b)

Rank	Procedure
6	Amputation dehorning + wound cautery
5	Amputation dehorning
4	Prior local anaesthetic (cornual nerve) + amputation dehorning
	Prior xylazine + amputation dehorning
3	Prior xylazine + local anaesthetic (cornual nerve) + amputation dehorning
	Caustic disbudding
	Cautery disbudding
2	Prior local anaesthetic (cornual nerve) + caustic disbudding
	Prior local anaesthetic (cornual nerve) + cautery disbudding
	Prior NSAID + amputation dehorning
1	Prior local anaesthetic (cornual nerve) + NSAID + amputation dehorning
	Prior local anaesthetic (cornual nerve) + amputation dehorning + wound cautery
	Prior local anaesthetic (cornual nerve and around base of each bud) + cautery disbudding
	Prior xylazine + local anaesthetic + ketoprofen before and after

4.6.4 Australian and international standards

The following tables summarise the provisions of codes of practice and legislative instruments, in relation to horn removal from cattle, of the respective jurisdictions in Australia (Table 15) and of selected overseas countries (Table 16), and the policies, positions or standards of selected welfare interest groups and certifying agencies (Table 17). Table 18, Table 19 and Table 20 summarise the corresponding provisions for sheep.

Table 15 Australian codes of practice and legislation applicable to horn removal from cattle

Jurisdiction	Provisions relevant to horn removal from cattle
Australia (Model Code for Cattle)	• 5.8.1: All horned cattle should be dehorned as young as possible, preferably prior to weaning, when flies are less of a problem; inspection needed for 10 days after dehorning and infected wounds treated; apply fly repellent if needed. • 5.8.2: Dehorning domestic cattle without analgesia should be done at first muster and preferably less than 6 months of age; older animals may be tipped without anaesthetic; dehorning over 12 months of age is not recommended and illegal in some States / Territories unless done by a veterinarian. • 5.8.3: Recommended methods are scoop dehorners, gouging knife or heat cautery as soon as buds are palpable; method used must remove all horn-growing tissue in one action with minimal damage to adjacent tissue. • 5.8.4: Cattle must not be dehorned with corrosive chemicals. • 5.8.5: Horns growing in towards the face should be trimmed. • 5.8.6: QA programs, feedlots, livestock exporters and markets are moving to favour polled cattle.
Australia (Beef Cattle Feedlot Guidelines)	• 2.8 Dehorning, particularly with mature cattle, is not recommended; tipping (removal of 4-5cm) is acceptable; provision should be made for horned cattle in allowance for feed trough space and transport density.
Australia (Model Code for Feral Cattle)	• Captured feral animals should be allowed several weeks to settle into their new environment before management practices such as dehorning are undertaken; an exception is tipping to reduce injury during transport.
Queensland	• As for the Model Code. • Section 3(1)(b) of the *Veterinary Surgeons Regulation 2002* specifies that dehorning of cattle under 6 months of age is not veterinary science for the purposes of the *Veterinary Surgeons Act 1936*.
New South Wales	• As for the Model Code. • Under Section 4(1)(d) of the *Veterinary Practice Regulation 2006*, 'the dehorning of cattle that are 12 months of age or older is a restricted act of veterinary science for the purposes of the *Veterinary Practice Act 2003'*.
Australian Capital Territory	• 4.8: duplicates the provisions of the Model Code, but adds 'dehorning of adults must be done by a veterinarian using anaesthetic' and 'dehorning by means of chemicals should only be performed by a competent operator and within the first few days after birth'.
Victoria	• 10.6: duplicates the provisions of the Model Code.
Tasmania	• 10.8: Where possible, all horned cattle should be dehorned prior to weaning; all horned cattle should be dehorned as young as possible; dehorning of domesticated cattle without the use of local analgesics should be confined to calves and weaners under 12 months of age, although old animals may be tipped in order to reduce their potential to cause injury; dehorning by means of chemicals is not recommended. • Section 4(g) of the *Veterinary Surgeons Regulations 2004* specifies that dehorning of cattle that are 6 months of age or less is not a veterinary service for the purposes of the *Veterinary Surgeons Act 1987*.
South Australia	• As for the Model Code. • Section 4(2)(c) of the *Veterinary Practice Regulations 2005* specifies that dehorning of cattle that are less than 6 months of age is not a veterinary service for the purposes of the *Veterinary Practice Act 2003*.

Jurisdiction	Provisions relevant to horn removal from cattle
Western Australia	• As for the Model Code. • The WA Code has identical wording to the Model Code. • In the *Model Code of Practice for Cattle in the Rangelands of WA*, Section 11 reproduces section 5.8.1 of the Model Code only. • Section 26(3)(d) of the *Veterinary Surgeons Act 1960* notes that the Act does not preclude a person 'using humane methods, of the operation of…dehorning cattle…not over the age of 12 months'.
Northern Territory	• As for the Model Code. • Section 6(b) of the *Veterinarians Regulations* specifically excludes dehorning of cattle under 12 months of age as a veterinary service under the meaning of the *Veterinarians Act*.

As for castration, the precise legal situation regarding dehorning in Australian jurisdictions is confusing. Dehorning cattle over 12 months of age is illegal in NSW unless carried out by a veterinarian. In Tasmania, SA, WA and NT dehorning is exempted as a veterinary act if cattle are less than 6, 6, 12 and 12 months respectively, but whether dehorning older cattle breaches the respective Acts or would be considered against the Model Code is not entirely clear. The ACT requires that 'adult cattle' (undefined) be dehorned by a veterinarian using anaesthetic.

Table 16 Codes of practice and legislation, of selected overseas countries, applicable to horn removal from cattle

Country	Provisions relevant to horn removal from cattle
New Zealand	• Minimum standards involve: o The management of animals with intact or tipped horns to minimise the risk of injury to other animals. o When disbudding or dehorning, the selection and application of a method to minimise pain and distress and other negative health consequences (e.g. infection) for the animal. o If disbudding with thermal cauterising equipment, use in such as way as to minimise thermal injury to tissues other than horn bud and adjacent skin. o If disbudding with caustic or chemical techniques, use only by skilled personnel and in such a way as to minimise injury to tissues beyond the horn bud and to other animals. o If dehorning without pain relief, as early as possible and no later than 9 months of age, beyond which time pain relief must be used. • Best practice involves: o The provision of pain relief for disbudding or dehorning at any age. o Disbudding in preference to dehorning, at the youngest age compatible with minimising any negative health and welfare consequences. o When dehorning, use of an effective means to prevent excessive blood loss and of a wound dressing or medication; if flies are likely to be a problem, the application of an insecticide. o Regular inspection during the healing period, especially for the first 2 weeks after disbudding and where dehorning has exposed the frontal sinuses of the skull, and treatment of any infected wounds. o Vaccination and other precautions to minimise the risk of clostridial infections. • The Code also notes that caustic chemical disbudding requires careful management to prevent contact of the chemical with other tissues, other animals and humans. The risk is increased by rain and where animals are hungry and suck or rub their dams or herd mates. The use of petroleum jelly around the horn bud can lessen injury to surrounding tissue. Caustic chemical disbudding is best performed when the horn bud is just palpable or just erupting, at around 7-10 days old.
Canada	• 9.1.7: Overly aggressive, horned animals should be segregated or properly dehorned to prevent injury to other animals. • 10.1.4: Minor surgical practices must be conducted only by competent personnel using proper equipment and accepted techniques; dehorning should be performed at an early age, preferably before weaning; all precautions must be taken to avoid unnecessary pain to the animal during surgery and afterwards; when necessary to dehorn a mature animal, the operation should be conducted in consultation with a veterinarian.
United States	• NCBA Guidelines strongly recommend that when horns are present calves be dehorned prior to 120 days of age; tipping of horns can be done with little impact on the well-being of individual animals. • The NYSCHAP recommends that dairy calves should be routinely dehorned before 2 months of age; beef calves should be dehorned as early as possible and no later than weaning; the use of anaesthesia / sedation / analgesia is recommended for all ages; a standard operating procedure must be filed on the farm for any routine or elective surgical procedures.

<table>
<tr><th>Country</th><th>Provisions relevant to horn removal from cattle</th></tr>
<tr><td>European Union</td><td>Article 17 of the T-AP Recommendation forbids ‘procedures resulting in the loss of a significant amount of tissue…and in particular…dehorning by means other than the surgical removal of horns’. Disbudding is permitted, without anaesthetic, if carried out in such a way as to avoid unnecessary or prolonged pain or distress by a skilled operator; under the age of 4 weeks; by chemical cauterisation or by heat cauterisation provided that the instrument used produces sufficient heat for at least 10 seconds. Surgical disbudding and dehorning, and disbudding calves over 4 weeks of age using heat cauterisation, are permitted but must be carried out under local or general anaesthesia by a veterinary surgeon or any other person qualified under domestic legislation.
The SCAHAW Opinion recommends that:
‘30. As a general rule, mutilations should be avoided and their negative effects minimised as much as possible.
31. Animals should always be provided with some form of analgesia at the time of surgical mutilations for procedures like docking, dehorning and castration (e.g. local anaesthetic), and for two days or so thereafter (e.g. a non-steroidal anti-inflammatory drug).
34. As a general rule, dehorning should not be performed. If dehorning has to be carried out, however, systemic analgesia and local anaesthesia should be provided by a veterinary surgeon.
36. Disbudding in young calves is much more acceptable than dehorning from a welfare point of view. The use of caustic substances is not acceptable.’
Anaesthesia or analgesia is compulsory for horn removal at any age in Switzerland, and caustic preparations are not permitted (Weaver et al 2005)</td></tr>
<tr><td>United Kingdom</td><td>The Mutilations Regulations permit dehorning and disbudding, subject to the following:
Disbudding may only be carried out in animals aged not more than 6 months (note that this restriction does not appear in the older Code of Recommendations);
If chemical cauterisation is used, the procedure may only be carried out on an animal aged not more than 7 days;
Any other method of disbudding, or dehorning, requires the use of an anaesthetic.
FAWC recommendations are as follows:
378. Non-veterinarians should be suitably trained and competent before carrying out disbudding.
379/384. If disbudding is deemed necessary, it should be done before 2 months of age, the upper age limit to be determined by bud size; legislation must be reviewed and maximum age for disbudding by non-veterinarians should be stated; the calf must be no more than 2 months old.
380. Chemical cauterisation should not be used due to pain and stress caused.
381. Dehorning must only be done by a veterinarian and only when necessary; it should not be a routine procedure (Veterinary Surgeons Act 1966 should be amended accordingly).
382/383. Pain control methods such as analgesics should be used in addition to local anaesthesia for dehorning; sufficient time should be allowed for local anaesthesia to take effect.
FAWC also notes that:
375. Disbudding with a hot iron is preferable to dehorning.
377. Genetic selection for polledness should be further investigated and implemented.</td></tr>
</table>

As for castration, the countries with the most restrictive legislation are in the EU, including Switzerland and probably others such as Austria, where anaesthesia or analgesia must be used when dehorning cattle or sheep at any age. The UK also applies tight restrictions. Calves are only exempted from anaesthesia / analgesia if they are disbudded with a caustic preparation prior to 7 days of age. Caustics may not be used in calves older than 7 days.

New Zealand does not permit dehorning without pain relief after 9 months of age. The report accompanying the Painful Procedures Code (NAWAC 2005b) acknowledges that 9 months is quite an arbitrary choice; 6 months was the original cut-off, but it was changed to accommodate the extensive beef farming system of the South Island highlands for which anaesthesia over 6 months would have posed significant problems. The report acknowledges that there is little scientific basis on which to discriminate between the two ages.

No mandatory provisions in relation to dehorning were found in the US or Canada but there are surprisingly strong recommendations that calves be dehorned prior to 4 months (NCBA undated) or weaning (NYSCHAP 2007).

The various standards around the world reflect the findings of the science in this area that there is no simple and readily-recognised threshold beyond which dehorning causes unacceptable distress, as acknowledged in New Zealand's NAWAC report. However, it is clearly less painful to remove horns early by disbudding and anaesthesia / analgesia improves outcomes. As with other husbandry procedures, Australia has a relatively lenient position on dehorning and this may be criticised, but welfare outcomes would not differ meaningfully from those of New Zealand or North America.

Table 17 Policies, positions or standards of selected animal welfare interest groups, in Australia and overseas, applicable to horn removal from cattle

Organisation	Provisions relevant to horn removal from cattle
RSPCA (Australia)	• 2.1.2.1a: for calves of less than 6 weeks, acceptable methods are cautery (heat only) or physical removal of the bud using a scraper blade or dehorning shears; no anaesthetic is required; husbandry precautions should be applied to avoid damage of the surrounding tissues, post-operative infection, and myiasis. • 2.1.2.1b: for cattle over 8 weeks, acceptable methods are dehorning shears or embryotomy wire; appropriate restraint, general narcosis and/or local anaesthesia are required, and appropriate pre- and post-operative procedures are required as above.
RSPCA (UK)	• H 1.21: disbudding is permitted only if done during the first 5 weeks of life, or as soon as a prominent bud has formed, using a hot-iron under local anaesthesia; it must not be done on sick animals, and must be done only in a way that minimise suffering, by a veterinarian or trained stock-keeper, using appropriate and well-maintained equipment.
Humane Society International	• 1.6 general principle: surgical treatments only carried out if operator can demonstrate that benefits outweigh consequences and no other acceptable options. • 1.6.4: 'debudding' shall be undertaken shortly after birth if necessary and within the first 3 months of life; cautery paste and scoop methods are unacceptable; dehorning of animal over 3 months must be done under anaesthetic.

Organisation	Provisions relevant to horn removal from cattle
Animal Welfare Institute (US)	• 7(d): disbudding is the preferred approach, and anaesthetic should be used; where dehorning is required, proper anaesthetic must be administered by a veterinarian and analgesics supplied post-op; using naturally 'dispelled' (polled?) breeds avoids the need for disbudding (provisions of this section are under review).
Federation of Animal Science Societies (US) Guidelines	• Polled breeds should be used wherever possible. • Horns should be removed while cattle are young under the supervision of experienced people using proper techniques. • Disbudding can take place at birth or within the first month by methods including hot cauterising irons, chemicals, a sharp knife or commercially-available mechanical devices. • Adults should only be dehorned if they are aggressive; this should be done by a knowledgeable and experienced person using methods to minimise pain and bleeding and prevent infection; anaesthetic should be used in cattle older than one month; cattle should be monitored for haemorrhage and infection post-op. • Tipping of horns can be done with little impact on animal welfare.
Temple Grandin	• Feedlot: no dehorning or cutting of horn tips at the feedlot. • Ranch: horns should be removed before 4 months of age; removal of horns from older cattle requires local anaesthesia.
KRAV (Sweden)	• Dehorning is permitted if done within the first 8 weeks of life.
Australian Veterinary Association	• 8.5: AVA supports dehorning as necessary for herd welfare provided that it is done by competent operators using an appropriate technique, done as early as possible (preferably under 6 months of age), and analgesia is used where appropriate; tipping may be acceptable in some circumstances; AVA opposes the use of topical caustic chemicals for dehorning.
American Veterinary Medical Association	• AVMA supports the use of procedures that reduce or eliminate the pain of dehorning; dehorning should be carried out as early as possible; research into improved techniques and alternatives is encouraged.
Canadian Veterinary Medical Association	• The CVMA recommends that when dehorning (of cattle and goats) is necessary, it should be carried out within the first week of life. • The policy notes that castration, tail docking and dehorning are routine, and that they should be conducted in a humane fashion, with the onus on the practitioner to determine the most appropriate technique and procedure.

Animal welfare groups and certifying agencies tend have more restrictive requirements than legislated standards in relation to dehorning, ranging from the compulsory use of anaesthetic and disbudding only allowable before 5 weeks of age (RSPCA UK), to a requirement for anaesthetic over 3 months but no strict upper age limit (HSI). Caustic pastes are not approved by several groups and HSI finds scoop methods unacceptable. RSPCA Australia expects the use of anaesthesia for dehorning cattle over 8 weeks of age.

Table 18 Australian codes of practice and legislation applicable to horn removal from sheep

Jurisdiction	Provisions relevant to horn removal from sheep
Australia (Model Code for Sheep)	• 8.6: The horns of rams, stags and some wethers may need to be cut back to avoid injury from an ingrowing horn, injury to other sheep and to allow free movement through handling races. The amount of horn removed should be limited to avoid damage to soft horn tissue and associated bleeding.
Queensland	• As for the Model Code.

Jurisdiction	Provisions relevant to horn removal from sheep
New South Wales	• As for the Model Code.
Australian Capital Territory	• 8.6 duplicates the provisions of the Model Code.
Victoria	• 8.6 duplicates the provisions of the Model Code and adds that complete permanent dehorning should only be undertaken under general anaesthesia.
Tasmania	• 6.8 duplicates the provisions of the Model Code.
South Australia	• As for the Model Code.
Western Australia	• 9.6 duplicates the provisions of the Model Code.
Northern Territory	• As for the Model Code (presumably).

Table 19 Codes of practice and legislation, of selected overseas countries, applicable to horn removal from sheep

Country	Provisions relevant to horn removal from sheep
New Zealand	• Minimum standards involve: o The management of animals with intact or tipped horns to minimise the risk of injury to other animals. o When disbudding or dehorning, the selection and application of a method to minimise pain and distress and other negative health consequences (e.g. infection) for the animal. o If disbudding with thermal cauterising equipment, use in such as way as to minimise thermal injury to tissues other than horn bud and adjacent skin. o If disbudding with caustic or chemical techniques, use only by skilled personnel and in such a way as to minimise injury to tissues beyond the horn bud and to other animals. o If dehorning without pain relief, as early as possible and no later than 9 months of age, beyond which time pain relief must be used. • Best practice involves: o The provision of pain relief for disbudding or dehorning at any age. o Disbudding in preference to dehorning, at the youngest age compatible with minimising any negative health and welfare consequences. o When dehorning, use of an effective means to prevent excessive blood loss and of a wound dressing or medication; if flies are likely to be a problem, the application of an insecticide. o Regular inspection during the healing period, especially for the first 2 weeks after disbudding and where dehorning has exposed the frontal sinuses of the skull, and treatment of any infected wounds. o Vaccination and other precautions to minimise the risk of clostridial infections. • The Code also notes that caustic chemical disbudding requires careful management to prevent contact of the chemical with other tissues, other animals and humans. The risk is increased by rain and where animals are hungry and suck or rub their dams or herd mates. The use of petroleum jelly around the horn bud can lessen injury to surrounding tissue. Caustic chemical disbudding is best performed when the horn bud is just palpable or just erupting, at around 7-10 days old.
Canada	• 11.4: horns may need to be trimmed; the amount of horn removed should be kept to a minimum. • 11.5: if it is necessary on young animals, dehorning should be carried out using acceptable methods; dehorning a mature animal should be done by a veterinarian.

Country	Provisions relevant to horn removal from sheep
European Union	• Article 30 of the T-AP Recommendation forbids procedures that result in the loss of a significant amount of tissue or which cause a significant amount of pain or distress, in particular disbudding of the horns, among other procedures. However, dehorning is noted as an exception provided it is carried out by a veterinarian using an anaesthetic.
United Kingdom	• The Mutilations Regulations permit dehorning and disbudding of sheep, as well as the removal of the insensitive tip of the horn. However, an anaesthetic must be administered for dehorning and this apparently refers to disbudding as well, because the Code states that disbudding and dehorning may only be carried out by a veterinarian.

Table 20 Policies, positions or standards of selected animal welfare interest groups, in Australia and overseas, applicable to horn removal from sheep

Organisation	Provisions relevant to horn removal from sheep
RSPCA (Australia)	• 2.1.2.2a: for lambs of less than 12 weeks, acceptable methods are cautery (heat only) or physical removal of the bud using a scraper blade or dehorning shears; no anaesthetic is required; husbandry precautions should be applied to avoid damage of the surrounding tissues, post-operative infection, and myiasis. • 2.1.2.2b: for sheep over 8 weeks, acceptable methods are dehorning shears, embryotomy wire or hacksaw; appropriate restraint; general narcosis, sedation and/or local anaesthesia are required if all or a substantial part of the horn are to be removed, with appropriate pre- and post-operative procedures; if only tipping or trimming, no analgesia is required.
RSPCA (UK)	• Dehorning or disbudding sheep is not mentioned.
Humane Society International	• Dehorning or disbudding sheep is not mentioned.
Animal Welfare Institute (US)	• 5.4.2: dehorning is prohibited; horns may be tipped as long as living tissue inside the horn is not cut.
Federation of Animal Science Societies (US) Guidelines	• Dehorning or disbudding sheep is not mentioned.
Temple Grandin	• No recommendations on dehorning or disbudding of sheep were found.
KRAV (Sweden)	• Dehorning or disbudding sheep is not mentioned.
Australian Veterinary Association	• The AVA does not appear have a specific policy position on sheep dehorning.
American Veterinary Medical Association	• The AVMA does not appear to have a specific policy position on sheep dehorning.
Canadian Veterinary Medical Association	• The CVMA does not appear to have a specific policy position on sheep dehorning.

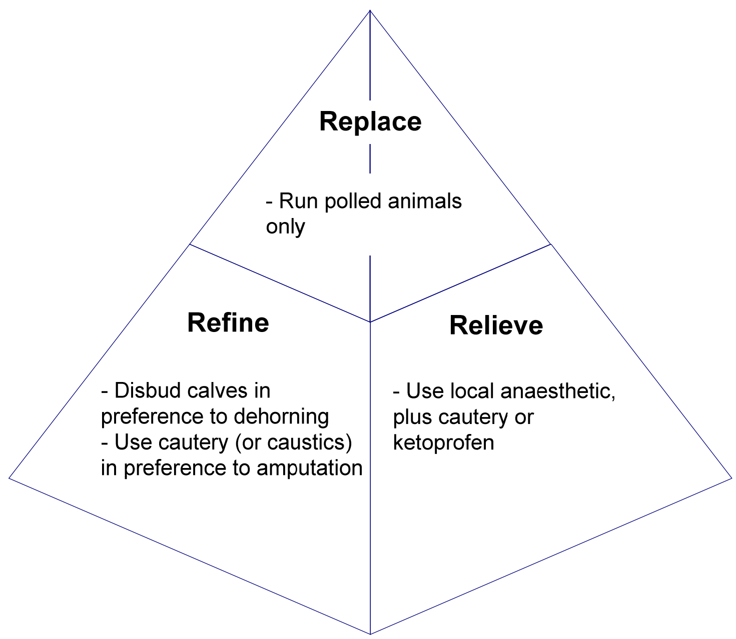
Dehorning of sheep attracts relatively regulatory or welfare attention compared with cattle dehorning or other sheep husbandry procedures such as castration. There is strong consistency across Australia jurisdictions on sheep dehorning, although Victoria specifies that complete permanent dehorning should be carried out under general anaesthetic. The overseas countries looked at allow tipping but not dehorning or disbudding without anaesthesia.

Only the RSPCA in Australia and the Animal Welfare Institute in the US have a position on sheep dehorning of the welfare organisations examined. RSPCA generally lines up with accepted practice while the Animal Welfare Institute only allows tipping of horns.

4.6.5 Implications and discussion

As for castration, the issue of animal welfare and dehorning can be considered strategically using a 3R model (Figure 5).

Figure 5 3R model for horn removal from cattle



The best welfare outcome is clearly obtained by breeding polled rather than horned cattle. Professor Joseph Stookey at the University of Saskatchewan in Canada has been a particular advocate of this approach. In June 2000 Canada's Expert Committee on Farm Animal Welfare and Behaviour made a recommendation that the use of polled sires be promoted within the Canadian beef industry. The background to the recommendation reviews the welfare impacts of dehorning, the genetics of polledness and the comparative performance of horned and polled cattle, and concludes that there are no productivity disadvantages in moving to polled genetics. A trend to using polled beef bulls in North America may already be underway (Stookey c2000).

Several studies show advantages or no disadvantages in using polled rather than horned bulls (for example Frisch et al 1980 in Australia, and Goonewardene et al 1999, Stookey & Goonewardene 1995 from Canada). Phillips (2005) in the Northern Territory notes that there is increasing pressure from exporters and feedlots for producers to supply cattle without horns and outlines options for breeding polled cattle for pastoral conditions.

MLA has already undertaken a major review of the genetic options to replace dehorning in beef cattle (Prayaga 2005, published in Prayaga 2007). Notwithstanding the inevitable sensitivities of certain cattle breed societies, the breeding of polled cattle should be strongly encouraged by MLA and the industry. MLA is also funding work (a literature review and survey of cattle vets) looking at any possible connection between the polled gene and bull sexual deformities.

At the pragmatic level, there are steps that can be taken at the 'refine, relieve' level of the 3R model to reduce the welfare impact of dehorning. The 'league table' of Stafford & Mellor (2005b) (Table 14) provides a clear ranking of preferred approaches to horn removal. Clearly, disbudding by cautery or caustic is preferable to amputation dehorning / disbudding (although amputation following administration of an NSAID would be of similar acceptability).

Table 21 suggests what changes in respect to horn removal may arise when animal welfare standards for cattle are introduced. It shows that, unless a 'welfare best practice' stance is adopted, there are unlikely to be significant changes except to mandate an upper age limit.

Table 21 Possible changes to current provisions relating to horn removal from cattle

Current provisions	Most likely change (pragmatic stance)	Comments
Dehorning *should be* done before 6 months; over 12 months is *not recommended* unless done by a vet.	Mandated 6, 9, or 12-month upper age limit on dehorning without anaesthesia (or 6 months with exemption for pastoral regions?).	The science indicates that disbudding by cautery (and possibly caustics) is considerably less stressful than amputation dehorning. However, the standards are unlikely to allow only disbudding by cautery or horn removal by a veterinarian given the huge practical problems that would impose (although this may be the long-term push). The age cut-off then becomes quite arbitrary.
Recommended methods are scoop dehorners, gouging knife or heat cautery as soon as buds are palpable.	No change.	Disbudding by cautery is preferred, but if removal of mature horn is to be allowed (see above) then amputation methods must be permitted. The new standards may express a preference for disbudding.
Cattle *must not be* dehorned with corrosive chemicals.	No change.	The science actually suggests that caustics are preferable to amputation methods, but there may be Australian experiences that change this perception. It is unlikely the standard would be changed especially given RSPCA's opposition to caustics.

The science of the welfare impacts of dehorning is quite comprehensive and there are no obvious gaps in the literature. Much of the work has been done on dairy breeds, but it is unlikely that additional work on beef genotypes would significantly improve understanding of the welfare impacts of horn removal in cattle.

As for castration, the New Zealand Painful Husbandry Procedures Code provides a good model for Australia's development of new standards. If this is the case, there may be increased emphasis on the use of cautery disbudding instead of the other physical methods. Otherwise there may not be significant changes to the current Code unless it is determined that a 12-month cut-off for dehorning without anaesthetic is unacceptable.

4.6.6 Recommendations

This report recommends that:

- As above, MLA commissions a comprehensive survey of castration, dehorning and branding practices across Australia, so that solid data are available to guide R&D, extension and policy. There is some information on the uptake of different practices but it is limited and this makes it difficult to judge the impact of possible changes in standards.

- MLA uses the findings from AHW.094 to promote the uptake of polled breeds of cattle. It is recognised, however, that there are negative perceptions about polled cattle in some parts of industry and that these may need to be addressed first.

- As above, MLA commissions a study of the use of ketoprofen under field conditions to manage the pain associated with castration, dehorning, ear marking, branding and other procedures undertaken concurrently. At least two production systems should be included: a southern system involving *Bos taurus* breeds, and a northern system with *Bos indicus* cattle, the ages of which should be determined in consultation with an industry reference group. The study should quantify the costs and benefits of ketoprofen use for each system. It should be conducted in complete confidence and the results retained for future reference.

- As above, MLA commissions a feasibility and cost study for a scheme to license lay people to administer local anaesthesia for castration and dehorning in calves. This study would include the identification of shielded-needle, needleless and possibly other technologies that could be used to deliver local anaesthetic with reasonable operator safety as well as the regulatory changes that would be required to permit the use of local anaesthetics, and also non-steroidal anti-inflammatory drugs, by lay people. As with the recommended ketoprofen study, this study should be conducted in complete confidence and the results retained for future reference.

The first of these recommendations arises because there is limited information available on dehorning and other practices adopted by Australian cattle producers. The second is a strategy recognising that running polled cattle is the best long-term solution to the welfare impacts of dehorning. The third and fourth recommendations are defensive strategies to provide options to producers should some form of pain relief become mandatory.

There are no recommendations for further basic research, because this does not appear to be warranted.

4.7 Branding

4.7.1 Description of methods and uptake

Branding is a process by which identifying marks are created on an animal by the destruction of hair follicles and alteration of hair regrowth (Newman 2007). There are two primary approaches: fire or hot-iron branding and freeze branding. Hot-iron branding has been used for thousands of years, while freeze branding was introduced in 1966 as a (supposedly) painless alternative to the heat method (Lay et al 1992b).

Heat branding irons are made from iron, steel, stainless steel or a rust-resistant copper alloy. The iron is heated using electricity or a gas- or wood-heated furnace until it is blue-hot before being pressed against the hide for 2-3 seconds. State regulations specify which areas of the body may be used for branding (Brown undated , O’Sullivan 2007).

Freeze branding irons are made from heavy gauge brass or copper. Liquid nitrogen or dry ice plus methylated spirits is used to super-cool the iron which is applied for 30-60 seconds depending on the coolant and the size and colour of the animal (Newman 2007, O'Sullivan 2007).

The animal should be restrained in a calf cradle or crush for branding. The brand site must be clipped prior to freeze branding. Branding is preferably carried out at 2-6 months of age (Newman 2007).

Other methods of branding may also be in use. An information sheet from the Kansas Animal Health Department, for example, refers to 'acid brands' (KAHD undated). No scientific literature could be found on acid branding. Less aversive methods have also been investigated, including depigmenting compounds (e.g. Schwartzkopf et al 1994). No realistic alternatives to heat or freeze branding – apart from substitutes such as electronic identification methods – appear to be in development. Electronic methods do not allow visual recognition from a distance and if they are placed in the ear they are not permanent.

Branding is compulsory in Queensland and the Northern Territory (see Table 22). The hot-iron method is invariably used in northern Australia because of the practical problems associated with freeze branding, including difficulties of accessing or maintaining a supply of coolant in remote areas and the length of time required by this method (Petherick 2005).

In the US, 51% of operations used a method of herd identification, and of the population of cows in herds using herd identification, 54.5% were in herds using hot-iron branding and 1.7% freeze branding. Herd identification is more common in the western states (98.7% of operations), where grazing is extensive and herds commingle, and 96.9% of beef cows in the west were held by operations using hot-iron branding (USDA 1997).

A survey of four abattoirs in Canada found brands on 37% of cattle. Six percent of cattle had multiple brands (Van Donkersgoed et al 1997).

4.7.2 Welfare and productivity impacts

The welfare implications of branding have been examined primarily by two groups: Lay and others in Texas, US, who published a series of three papers in 1992; and Schwartzkopf-Genswein, Watts, Stookey and others in Saskatchewan, Canada, with a series of five papers in 1997/98. No other references of relevance to this review were found.

In the first of the Texan studies (Lay et al 1992b), mixed-sex crossbred calves (Simmental / Hereford / Brahman) 8-9 months old were hot-iron branded, freeze branded, or sham branded with a room temperature brander. Blood samples were taken and heart rate measured at intervals from 5 minutes before to 20 minutes after the procedures (which is a short timeframe for a welfare study). Vocalisations by the calves during treatment were recorded and later analysed. Skin temperature at the brand and other sites was measured daily for 5 days. The blood samples were analysed for cortisol and the catecholamines adrenaline and noradrenaline.

The authors observed that the hot-iron group had a strong immediate avoidance response while the freeze-brand group did not respond for about 8 seconds. The only significant measured difference between groups in the study was an elevation in adrenaline in the hot-iron group 0.5 minutes post-branding. Heart rate tended to be higher in both of the branded groups at 0.5 min (p=0.098 and 0.16). There were no differences in cortisol or noradrenaline, and only three calves vocalised. The authors hypothesised that restraint and handling in themselves may have raised cortisol, catecholamines and heart rate to high levels and therefore masked any treatment effects.

The second study in this series (Lay et al 1992c) used a very similar methodology to the first but with Angus calves of similar age. The escape-avoidance reaction was also measured objectively by videotaping the calves and quantifying movement against marked lines on a vertical axis on the squeeze chute.

In this study, hot-iron branding was associated with a substantially and significantly greater escape-avoidance reaction. Half of the calves in each branding group vocalised. Cortisol levels increased in all three groups during treatment but there were no significant differences between sham and hot-iron groups. Cortisol levels were higher in the freeze-branded group than the other two groups at 15 and 20 minutes, while adrenaline levels were again higher in the hot-iron group at 0.5 min. The hot-iron group had the highest heart rates during and for 0.5 min after branding.

The authors concluded that the hot-iron branding caused a greater pain sensation but that, on the basis of the cortisol results, the freeze-branded calves may have experienced more prolonged pain. The increase in vocalisation compared with the first study may have been due to the fact that calves were not isolated during treatment in the later work.

The third of the Texan studies (Lay et al 1992a) virtually repeated the protocol of the first two but with mature lactating dairy cows (Holsteins and Jerseys). The stated aim of the study was to eliminate the effects of restraint and handling that were thought to have been observed in Lay et al (1992c) and Lay et al (1992b). The cows were treated in isolation in a set of stocks. Behavioural reactions including kicking were recorded.

Hot-iron cows reacted more strongly than freeze-brand cows. There were no vocalisations (as for the first study, treatment was carried out in isolation). The heart rate of both groups increased during branding but that of the freeze-band group remained elevated throughout the 25-minute monitoring period, while that of the hot-iron group returned to baseline levels at 5.5 minutes. Cortisol was increased in both groups but was significantly higher in the hot-iron than the freeze-branded group at 10.5, 15.5 and 25.5 minutes when the study ended. The rise in adrenaline at 0.5 minutes in the hot-iron group of previous studies was not seen.

In Canada (Schwartzkopf-Genswein et al 1997d), a much larger trial looked more closely at the effects of branding as indicated by behavioural changes. The subjects were 320kg Charolais-cross steers. The cattle were restrained in a headgate and squeeze chute equipped with sensors to measure the forces exerted as the cattle moved in response to the branding. Behaviours including tail flicking, kicking, falling down and vocalising were recorded, as was the handling ease of each animal at day zero and every second day for 10 days after treatment, based on a 1-6 point scoring system.

Hot-iron branded cattle had a higher frequency of all behaviours than freeze-branded cattle despite the procedure taking half as long. The freeze-brand group did more tail-flicking than the sham group and were intermediate in the exertion force and duration measurements from the headgate and squeeze chute. There was no difference in subsequent handling ease between the groups. Overall, hot-iron branding was considered to cause greater discomfort at the time of application but that freeze branding also produced signs of discomfort.

The behavioural and exertion force findings were repeated in a smaller trial (Schwartzkopf-Genswein et al 1998), in which these measures were compared with image analysis for detecting treatment differences. Image analysis was shown to be a superior method.

A further study by Schwartzkopf-Genswein et al (1997c) on yearling heifers of mixed beef breeds examined the cortisol responses to branding and also the phenomenon of stress-induced analgesia (SIA), in which pain sensitivity is reduced following a psychological or environmental stressor. The latter was measured by the time taken to respond to a laser applied to the back of the leg. The study showed no differences in SIA between the sham, hot-iron and freeze-brand groups, nor in sensitivity to touch at the brand site. Cortisol levels were elevated in both branding groups for 40 minutes after treatment but were higher in hot-iron animals over that period. There were no significant differences between the treatments from 40 minutes to 180 minutes when the trial stopped, although there was a trend for freeze-brand cortisol to rise from 120 to 180 minutes while hot-iron cortisol fell.

The longer-term impacts of branding were the subject of two trials by Schwartzkopf-Genswein et al (1997b). Three hundred and 248 Charolais-cross steers respectively, averaging 303 and 335kg, were hot-iron or freeze branded or held in a headgate for an equivalent period. Rectal temperature, antibiotic treatment rates and weight gain were monitored over 10 days and again at 28 days in trial 1. Handling ease was also measured in trial 2. Antibiotic treatment rates did not differ between groups in either trial, nor were there any differences in average daily weight gain. The only significant difference in handling ease was at day 6 when freeze-brand steers required more pressure. This may have been due to lingering tenderness at the site. Interestingly, though, the same research group also demonstrated by infrared thermography that inflammation at brand sites was prolonged in hot-iron brands compared with those of freeze-brands. Although both methods cause inflammation, the findings suggested that hot-iron branding causes more intense and prolonged pain (Schwartzkopf-Genswein et al 1997a).

Finally, a paper by Watts & Stookey (1999) of the same Canadian group reports on the usefulness of vocalisation as a welfare indicator during stressful procedures. Only hot-iron branding was used. The branded group differed significantly from a restraint-only group in a number of characteristics of the audiospectrogram. It was concluded that vocalising offers a sensitive, non-invasive means of assessing acute distress.

Two other papers are of minor interest. Yeruham et al (1996) and O'Toole & Fox (2003) reported chronic hyperplastic and neoplastic lesions on hot-iron and freeze brand sites in cattle. These appear to be rare complications of branding.

In summary, the science on branding is quite restricted. However, it does point to significant pain associated with branding lasting for at least 20-40 minutes. Hot-iron branding appears to be more aversive than freeze branding, at least over this time period, but freeze branding also appears to cause pain and may have delayed effects – which may not be shown due to the limited timeframes used in the studies.

4.7.3 Australian and international standards

The following tables summarise the provisions of codes of practice and legislative instruments, in relation to branding of cattle, of the respective jurisdictions in Australia (Table 22) and of selected overseas countries (
Table 23), and the policies, positions or standards of selected welfare interest groups and certifying agencies (Table 24).

Branding is not used on sheep, except for some hot branding of horns on Merinos (see Table 28).

Table 22 Australian codes of practice and legislation applicable to branding of cattle

Jurisdiction	Provisions relevant to branding of cattle
Australia (Model Code for Cattle)	• 5.7.1: ear-tagging, ear-marking, ear-notching, ear-tattooing, udder-tattooing, udder implanting, freeze-branding, photography and radio frequency identification devices (RFID – e.g. microchips) are the preferred methods of identifying cattle from a welfare viewpoint. In some situations, however, fire branding may be the only practical method of permanently identifying cattle. As States / Territories may have differing regulatory requirements for cattle identification, these should be checked. Cheek (face) branding is illegal in some States. • 5.7.2: cattle must not be branded with corrosive chemicals.
Australia (Beef Cattle Feedlot Guidelines)	• No reference to branding.
Australia (Model Code for Feral Cattle)	• No reference to branding.
Queensland	• As for the Model Code. • The *Brands Act 1915* requires all cattle of 100kg or more to be branded before being sold (earmarking is not sufficient); brands must be registered.
New South Wales	• As for the Model Code. • Under the *Rural Lands protection Act 1998*, branding is not compulsory but a brand must be registered.
Australian Capital Territory	• 5.7.1: ear-tagging, ear-marking, tattooing, implanting, freeze-branding, electronic characterisation and photography are the preferred methods of identifying cattle, from a welfare viewpoint; 5.7.2: Cattle must not be branded with corrosive chemicals. Section 19(2)(b)(i) of the *Animal Welfare Act 1992* permits ‘a medical or surgical procedure (to be) carried out in accordance with accepted animal husbandry practice in relation to…farming and grazing activities’ unless otherwise prescribed by the *Animal Welfare Regulation 2001*, which is effectively achieved by the Code. • Under the *Stock Act 2005,* branding is not compulsory but a brand must be registered.

Jurisdiction	Provisions relevant to branding of cattle
Victoria	• No reference to branding, but 10.1.2 states that 'Procedures and practices that cause pain should not be carried out if painless and practical methods of husbandry can be adopted to achieve the same result'. • Section 6(1)(b) of the *Prevention of Cruelty to Animals Act (1986)* allows the Code as a defence against cruelty, but because the Code does not refer to branding there is no such defence. • There is no formal system of brand recognition; the National Livestock Identification Scheme is mandatory.
Tasmania	• 10.7: similar wording to the Model Code. • The *Animal (Brands and Movement) Act 1984* requires all cattle to be branded or marked with a registered earmark before the age of 6 months.
South Australia	• As for the Model Code; Part 3 and Schedule 2 of the *Prevention of Cruelty to Animals Regulations 2000* requires compliance with the Code of Practice. • The *Brands Act 1933* allows but does not require branding but a cattle owner must register a brand before use.
Western Australia	• As for the Model Code. • The WA Code has identical wording to the Model Code. • In the *Model Code of Practice for Cattle in the Rangelands of WA*, Section 10 states that 'Ear-tagging, ear-marking, ear-notching, ear-tattooing, freeze-branding, and electronic characterisation are the preferred methods of identifying cattle, from a welfare viewpoint. In rangeland situations, however, earmarking and/or fire branding remains the only practical method of permanently identifying cattle. Branding with corrosive chemicals is unacceptable'. • The *Stock (Identification and Movement) Act 1970* requires all cattle owners to register a brand and to brand or earmark cattle before 6 months of age or before removal from the property, if the property is in the South West Land Division, or before 18 months / removal from the property in the pastoral areas.
Northern Territory	• As for the Model Code. • Section 6(g) of the *Veterinarians Regulations* specifically excludes 'branding or marking animals' as a veterinary service under the meaning of the *Veterinarians Act.* • The *Brands Act* makes it compulsory for cattle 8 months and over to be branded before they are sold or moved off a property.

Table 23 Codes of practice and legislation, of selected overseas countries, applicable to branding of cattle

Country	Provisions relevant to branding of cattle
New Zealand	• The Code does not contain specific minimum standards or best practice guidelines for branding. There are minimum standards relating to general principles of painful procedure management: o The painful husbandry procedure must be justifiable – i.e. there are no other practical, economically viable, effective, less noxious alternatives available; and the procedure results in an overall enhancement of the animal's welfare, or facilitates advantageous farm management systems, or results in an enhanced animal product, or reduces the safety risk to humans. o The procedure must not be carried out on animals less than 12 hours old. o If the procedure is not carried out, any consequential risks to animal health and welfare must be managed.

Country	Provisions relevant to branding of cattle
Canada	• The Code states: o 11.1.3: Under some circumstances, hot iron or freeze branding is necessary. It is acknowledged that branding is a brief, painful experience. When branding is required, it should be done quickly, expertly, with the proper equipment, and in accordance with accepted standards. Brands should be an appropriate size to achieve clear identification and cause the least possible pain to the animals. o 11.1.4: Cattle should not be rebranded; Government and industry are encouraged to eliminate regulations requiring rebranding.
United States	• NCBA Guidelines note that permanent identification can be an important management tool; when cattle are housed or pastured where they can be readily checked, systems such as ear tags are strongly encouraged; hot or freeze branding is necessary under many management conditions (e.g. communal grazing in remote locations), and required by law in some states; branding should be done quickly expertly and with the right equipment; feeder cattle should not be re-branded when entering a feedlot unless legally required; brands should be big enough; jaw brands should not be used. • The NYSCHAP module does not refer to branding, although it does state that a standard operating procedure must be filed on the farm for any routine or elective surgical procedures; branding may require an SOP.
European Union	• Article 18 of the T-AP Recommendation states that 'the marking of cattle for identification should be done with care by competent operators so as to avoid unnecessary pain or distress to the animals at the time of marking or subsequently. In particular toxic materials should be prohibited and caustic paste or hot irons shall only be used when absolutely permanent identification for special purposes (for example disease control) cannot be achieved by other methods'. • The SCAHAW Opinion recommends that: o '38. Hot branding should not be used.'
United Kingdom	• The Mutilations Regulations permit freeze branding of cattle but do not specify how it is to be carried out. • Branding is not mentioned in the Code of Recommendations nor does it appear to be included in FAWC advice.

Table 24 Policies, positions or standards of selected animal welfare interest groups, in Australia and overseas, applicable to branding of cattle

Organisation	Provisions relevant to branding of cattle
RSPCA (Australia)	• Policies – B Farm Animals, 1.3: 'RSPCA Australia supports the marking of animals for identification. The preferred method is by microchip or other electronic methods which cause minimal pain or suffering. Tattooing, branding or tagging must be done humanely. Where branding is necessary, freeze branding should be used. The RSPCA believes that hot iron (fire) branding and ear mutilation are unacceptable means of identification'.
RSPCA (UK)	• H 5.2: the marking of cattle must be done with care by trained, competent operators; acceptable methods of permanent on-farm marking include ear tagging as approved by DEFRA, tattooing, and freeze-branding (in a manner which avoids unnecessary pain).
Humane Society International	• 1.7.2: hot and freeze branding are not permitted unless required by a statutory authority.
Animal Welfare Institute (US)	• 7(c): hot branding is prohibited; eartagging is permitted (other methods of identification are under review).

Organisation	Provisions relevant to branding of cattle
Federation of Animal Science Societies (US) Guidelines	• Branding is one of the procedures listed which may be carried out by properly trained, non-professional personnel.
Temple Grandin	• Feedlot: no branding at the feedlot unless required by law. • Ranch: branding should be avoided unless required by law; no face branding.
KRAV (Sweden)	• Branding is not referred to in the Guidelines.
Australian Veterinary Association	• 5.4: AVA supports ear tags and rumen implants as the most humane method of accurately identifying cattle; where branding is necessary, the AVA recommends freeze branding in preference to hot-iron branding.
American Veterinary Medical Association	• Branding is not specifically mentioned in animal welfare position statements.
Canadian Veterinary Medical Association	• Branding is not specifically mentioned in animal welfare position statements.

4.7.4 Implications and discussion

The science on the welfare impacts of branding is not nearly as comprehensive as that of castration or dehorning. Nevertheless, it does indicate that there is significant pain associated with branding that lasts for at least 20-40 minutes. Hot-iron branding appears to be more aversive than freeze branding, at least over this time period, but freeze branding also appears to cause pain and may have delayed effects.

There is significant opposition to branding (especially by hot-iron) internationally and from animal welfare groups, with only North American countries and Australia accepting branding on the grounds of practicality. Clearly, there are good reasons for branding cattle in remote areas, although these do not include animal welfare benefits in the same sense that spaying or dehorning can claim to have a positive net welfare impact. The argument for branding is therefore one of management efficiency in the face of environmental constraints, which may be more difficult for the industry to sustain in the long term.

It is difficult to see where more welfare-friendly practices may come from. The evidence suggests that, even if it were practical, there would be marginal if any benefit to animal welfare in switching from hot-iron to freeze branding, especially given that a large part of the stress response to branding seems to arise from the restraint of the animal. An analgesic agent may ameliorate the pain of branding, and ketoprofen would be a good starting point, not necessarily for its pharmacological actions, but because of its proven effect for castration and dehorning and therefore the possibility that it might eventually find wide use in the field.

Smaller brands would help to improve welfare outcomes, as well as causing less hide damage, and there may be potential to substitute NLIS identification devices for branding, but these are of no use for visual identification at any distance from the animal and assume changes to legislation (Petherick 2005). Additionally the NLIS is not a permanent form of identification like a brand and to some extent an ear-mark. Automatic drafting systems might eventually reduce the need for visual identification but not proof of legal ownership of cattle.

4.7.5 Recommendations

This report recommends that:

- As above, MLA commissions a survey of castration, dehorning and branding practices across Australia, so that solid data are available to guide R&D, extension and policy. There is some information on the uptake of different practices but it is limited and this makes it difficult to judge the impact of possible changes in standards. Branding presents the lowest priority of these three practices, however.

- As above, MLA commissions a study of the use of ketoprofen under field conditions to manage the pain associated with castration, dehorning, ear marking, branding and other procedures undertaken concurrently. At least two production systems should be included: a southern system involving *Bos taurus* breeds, and a northern system with *Bos indicus* cattle, the ages of which should be determined in consultation with an industry reference group. The study should quantify the costs and benefits of ketoprofen use for each system. It should be conducted in complete confidence and the results retained for future reference.

- MLA maintains a watching brief on the development and uptake of newer identification management systems with a view to identifying opportunities for branding to be dispensed with as a management tool. Alternatively, MLA could take a proactive stance on R&D to develop new identification systems, although branding is a lower welfare priority than other procedures.

The latter recommendation is a longer-term strategy, because it will involve changes to the legislation of several States and Territories. However, the replacement of branding by a non-stressful procedure should be the long-term goal of the industry. This is not an easy area of research. In its attempts to replace methods for mulesing and crutching of Merinos, Australian Wool Innovation has recognised the difficulty of killing hair follicles without undesirable systemic effects. Permanent depilation is also an unrealised goal of the human cosmetic industry despite vast investments.

Alternative identification systems might derive from paradigms other than hair or follicle alteration – for example, the adhesion of distinguishing marks to the hide. A ‘skunkworks’ of experts would be a good starting point for a program of R&D.

4.8 Ear marking and ear notching

4.8.1 Description of methods and uptake

Ear marking or ear notching involves the removal of an area of skin using special pliers. The area removed may be from the edge of the ear or may be fully contained within it. Ear tags for identification or insecticidal reasons may also be placed in one or both ears, necessitating the punching of a pin through the ear to hold the tag.

It is compulsory in Queensland, NSW, WA, SA, and NT to identify cattle treated with hormonal growth promotants by placing a triangular punch mark in the ear. Spayed cattle must also be identified by a circular earmark in Queensland, WA and NT. A registered earmark may be used as a brand in Queensland or WA and in addition to a brand in NT (Newman 2007).

In the US, 51% of operations in 1997 used a method of herd identification, and of the population of cows in herds using herd identification, 19.7% were in herds using ear notching, 6.4% tattooing, and 32.5% ear tagging (USDA 1997).

4.8.2 Welfare and productivity impacts

Only one published article was found on the welfare impacts of ear notching (Friend et al 1994). Two-month old Holstein calves had a V-shaped notch 6mm wide x 14mm deep cut from the dorsal edge of their left ears. The authors reported a ‘mild startle response’ followed by a resumption of normal behaviour. Average heart rate was not affected in comparison with calves sucking a rubber nipple (although the data are somewhat difficult to interpret).

Commenting on practices in northern Australia, Petherick (2005) makes the comment that ‘ear notching and punching undoubtedly causes some pain to the animals and our own studies revealed that ear-notch wounds could take many weeks to heal’.

The unpublished study of McCosker et al (2007) on spaying provides a limited assessment of the welfare impacts of ear notching as one of the control groups in the first trial of the study were ear-notched. There were no differences in any of the blood biochemical parameters (bound or unbound cortisol, haptoglobin, NEFA, CPK, AST) between controls and ear-notched heifers over the 96 hours following the procedure. There was, however, a significant 10kg liveweight difference between notched and control calves at the 42-day mark, with the notched animals very similar to the spayed heifers. The reason for this finding is not explored by the authors.

There have been several publications from the UK concerning the welfare implications of ear tags in cattle (Johnston & Edwards 1996, Wardrope 1995) and sheep (Edwards & Johnston 1999, Hosie 1995). Johnston & Edwards (1996) compared the damage to ears caused by metal and polyurethane tags by a controlled study of calves and inspection of cattle at slaughter. They found that metal loop tags were associated with more damage to the ear, especially in the young calves, where nearly 10% had moderately severe changes including haemorrhage, necrosis, enlargement of the hole and sepsis. However, there was no statistical analysis of the findings.

Problems with metal loop tags are also described in case reports of Hosie (1995) in sheep and Wardrope (1995) in cattle, in both of which a high incidence of suppurating lesions was associated with metal loop tags.

The study of Edwards & Johnston (1999) on sheep included more tag types than the earlier cattle study (as well as statistical analysis). Metal loop tags again gave poor results but so too did rigid plastic loop tags, while Allflex® flexible plastic tags with male and female parts were the least damaging. The authors concluded that shape of tag may have more influence on adverse sequelae than the material, and that loop tags are more sensitive to correct placement than other styles.

Poorly-placed ear tags have been reported as the cause of an outbreak of tetanus in lambs (Aslani et al 1998).

4.8.3 Australian and international standards

The following tables summarise the provisions of codes of practice and legislative instruments, in relation to ear marking and ear notching of cattle, of the respective jurisdictions in Australia (Table 25) and of selected overseas countries (
Table 26), and the policies, positions or standards of selected welfare interest groups and certifying agencies (Table 27). Table 28, Table 29 and Table 30 summarise the corresponding provisions for sheep in Australia. An extensive review of the legislative requirements for identification of sheep was not undertaken given the current implementation of the National Livestock Identification Scheme (NLIS) which will presumably change any such provisions (for example, the requirement in Tasmania for all sheep except certain stud animals to carry a registered earmark).

Table 25 Australian codes of practice and legislation applicable to ear marking and ear notching of cattle

Jurisdiction	Provisions relevant to ear marking and ear notching of cattle
Australia (Model Code for Cattle)	• 5.7.1: ear-tagging, ear-marking, ear-notching, ear-tattooing, udder-tattooing, udder implanting, freeze-branding, photography and radio frequency identification devices (RFID – e.g. microchips) are the preferred methods of identifying cattle from a welfare viewpoint…States / Territories may have differing regulatory requirements for cattle identification, these should be checked.
Australia (Beef Cattle Feedlot Guidelines)	• No reference to ear marking or ear notching.
Australia (Model Code for Feral Cattle)	• No reference to ear marking or ear notching.
Queensland	• As for the Model Code.
New South Wales	• As for the Model Code.
Australian Capital Territory	• 5.7.1 has the same provisions as the Model Code in respect of ear tagging, ear marking, and tattooing.
Victoria	• No reference to ear marking, ear notching or ear tagging.
Tasmania	• 10.7: has the same provisions as the Model Code in respect of ear tagging, ear marking, and tattooing.
South Australia	• As for the Model Code.
Western Australia	• As for the Model Code. • In the *Model Code of Practice for Cattle in the Rangelands of WA*, Section 10 has the same provisions as the Model Code in respect of ear tagging, ear marking, and tattooing and adds that in rangeland situations earmarking and/or fire branding remains the only practical method of permanently identifying cattle.
Northern Territory	• As for the Model Code.

Table 26 Codes of practice and legislation, of selected overseas countries, applicable to ear marking and ear notching of cattle

Country	Provisions relevant to ear marking and ear notching of cattle
New Zealand	• The Code does not contain specific minimum standards or best practice guidelines for ear marking or ear notching. There are minimum standards relating to general principles of painful procedure management: o The painful husbandry procedure must be justifiable – i.e. there are no other practical, economically viable, effective, less noxious alternatives available; and the procedure results in an overall enhancement of the animal's welfare, or facilitates advantageous farm management systems, or results in an enhanced animal product, or reduces the safety risk to humans. o The procedure must not be carried out on animals less than 12 hours old. • If the procedure is not carried out, any consequential risks to animal health and welfare must be managed.
Canada	• 11.1.5: wattling[22], ear splitting and other unnecessary surgical alterations of cattle for identification or cosmetic purposes are strongly discouraged.
United States	• NCBA Guidelines state that ear notching may be used to identify cattle; wattling, ear splitting and other surgical alterations for identification are strongly discouraged. • The NYSCHAP module does not refer to ear marking or ear notching, although it does state that a standard operating procedure must be filed on the farm for any routine or elective surgical procedures, which would presumably include these procedures.
European Union	• Article 17 of the T-AP Recommendation states that notching or punching of animals' ears if required or allowed by domestic legislation is an exception to the forbidding of procedures resulting in the loss of a significant amount of tissue. The procedure is permitted, without anaesthetic, if carried out in such a way as to avoid unnecessary or prolonged pain or distress by a skilled operator. • The SCAHAW Opinion does not specifically address ear marking or ear notching, but it recommends that: o '30. As a general rule, mutilations should be avoided and their negative effects minimised as much as possible. o 31. Animals should always be provided with some form of analgesia at the time of surgical mutilations for procedures like docking, dehorning and castration (e.g. local anaesthetic), and for two days or so thereafter (e.g. a non-steroidal anti-inflammatory drug). • In Switzerland the marking of animals is exempt under article 65 of the Ordinance from the requirement for anaesthetic.

[22] Wattle – 'a flap of skin that hangs from the neck, jaw, shoulder, or brisket of a cow or steer, used by buckaroos to identify the ownership of animals at a distance. Produced when calves are branded by cutting away a short length of hide' – from http://memory.loc.gov/ammem/ncrhtml/crgloss.html, accessed 7 January 2008.

Country	Provisions relevant to ear marking and ear notching of cattle
United Kingdom	• The Mutilations Regulations permit ear clipping, notching and tagging of cattle but do not specify how these procedures are to be carried out. • The Code notes the need for: o 18. A properly trained and accredited operator for fitting ear tags; careful choice of the best type of tag; following the manufacturer's instructions and using the correct applicator; hygienic conditions. o 19. Proper restraint of the animal; avoiding the main blood vessels and ridges of cartilage; tag properly closed to minimise snagging; a suitable gap under the tag and at the edge of the ear to allow growth; fly precautions where needed. • FAWC recommendations for ear tagging are as follows: o 390. An ear tag should be lightweight and of a design that is easily applied and causes minimal damage to the ear. o 391. Site of application is crucial and operators should be trained and competent. o 392. The use of micro-chips should be pursued, although visual identification will still be needed. o 393. Fly control measures should be taken after tag application and calves checked frequently. o 394. Research should be undertaken into tag design for maximum retention and least likely to cause damage by tearing, as well as other more welfare-friendly methods of marking. • FAWC also notes that: o 389. Recent work indicates that metal tags cause more damage than plastic ones and the manner in which they are applied is more crucial.

Table 27 Policies, positions or standards of selected animal welfare interest groups, in Australia and overseas, applicable to ear marking and ear notching of cattle

Organisation	Provisions relevant to ear marking and ear notching of cattle
RSPCA (Australia)	• Policies – B Farm Animals, 1.3: 'RSPCA Australia supports the marking of animals for identification…the RSPCA believes that hot iron (fire) branding and ear mutilation are unacceptable means of identification'.
RSPCA (UK)	• H 5.2: the marking of cattle must be done with care by trained, competent operators; acceptable methods of permanent on-farm marking include ear tagging as approved by DEFRA, tattooing, and freeze-branding (in a manner which avoids unnecessary pain).
Humane Society International	• 1.6.2: where shown to be necessary, earmarking shall be performed in a way that minimises stress and injury to the animal. • 1.7.1: tags or markers shall be affixed to any animals requiring individual identification. • 1.7.2: approved identification includes (*inter alia*) earmarking, tattooing, National Livestock Identification Scheme, and ear tags.
Animal Welfare Institute (US)	• 7(f): earmarking by cutting the ears or cutting of dewlaps is prohibited.
Federation of Animal Science Societies (US) Guidelines	• Ear tagging is one of the procedures listed which may be carried out by properly trained, non-professional personnel. • Ear notching is not specifically mentioned.
Temple Grandin	• Cutting the animal's ear or dewlap for identification purposes is not permitted; small notches made with a punch are permitted.
KRAV (Sweden)	• Ear marking and ear notching are not referred to in the Guidelines.

Organisation	Provisions relevant to ear marking and ear notching of cattle
Australian Veterinary Association	• 5.4: AVA supports ear tags and rumen implants as the most humane method of accurately identifying cattle.
American Veterinary Medical Association	• Ear marking and ear notching are not specifically mentioned in animal welfare position statements.
Canadian Veterinary Medical Association	• Ear marking and ear notching are not specifically mentioned in animal welfare position statements.

Table 28 Australian codes of practice and legislation applicable to ear marking and ear notching of sheep

Jurisdiction	Provisions relevant to ear marking and ear notching of sheep
Australia (Model Code for Sheep)	• 9.6: when it is necessary to mark sheep for permanent identification, the ear may be tattooed, tagged, notched or hole-punched; electronic methods may also be acceptable; horns may be hot branded provided care is taken not to burn sensitive tissues or predispose to infection. • 9.2: ear marking instruments should be sharp, with the cutting edges undamaged, and careful technique should be used to prevent tearing of the ear.
Queensland	• As for the Model Code.
New South Wales	• As for the Model Code.
Australian Capital Territory	• 9.5 duplicates the provisions of the Model Code.
Victoria	• 10.5 duplicates the provisions of the Model Code.
Tasmania	• 7.2 and 7.6 have similar wording to the Model Code, but add that it is a legal requirement to earmark all sheep (except certain stud sheep) with a registered earmark before they reach 6 months of age (this may have been changed with the move to NLIS).
South Australia	• As for the Model Code.
Western Australia	• 10.5 duplicates the provisions of the Model Code.
Northern Territory	• As for the Model Code (presumably).

Table 29 Codes of practice and legislation, of selected overseas countries, applicable to ear marking and ear notching of sheep

Country	Provisions relevant to ear marking and ear notching of sheep
New Zealand	• The Code does not contain specific minimum standards or best practice guidelines for ear marking or ear notching. There are minimum standards relating to general principles of painful procedure management: o The painful husbandry procedure must be justifiable – i.e. there are no other practical, economically viable, effective, less noxious alternatives available; and the procedure results in an overall enhancement of the animal's welfare, or facilitates advantageous farm management systems, or results in an enhanced animal product, or reduces the safety risk to humans. o The procedure must not be carried out on animals less than 12 hours old. • If the procedure is not carried out, any consequential risks to animal health and welfare must be managed.
Canada	• 10.2: to mark sheep for permanent identification, the ear may be tagged, tattooed, notched, punched, or an electronic implant may be inserted; should be carried out by a competent operator using well-maintained instruments and good hygiene; ear tags should be of a suitable size; excessive use of tags (more than 2 per ear) should be avoided; when re-tagging, holes should be re-used.

Country	Provisions relevant to ear marking and ear notching of sheep
European Union	• Article 30 of the T-AP Recommendation states that ear marking by tagging or tattooing, identification by implantation of an electronic device or horn branding are exceptions to the forbidding of procedures resulting in the loss of a significant amount of tissue. However, they must be carried out subject to conditions which appear to specify that: 'procedures in which the animal will, or can reasonably be expected to, experience pain may only be carried out with the use of an anaesthetic and shall be carried out only by a veterinarian or other person qualified in accordance with national legislation'. The notching and punching of ears is permitted without further conditions where allowed under national legislation. • In Switzerland the marking of animals is exempt under article 65 of the Ordinance from the requirement for anaesthetic.
United Kingdom	• The Mutilations Regulations permit ear clipping, notching and tagging of sheep but do not specify how these procedures are to be carried out. • The Code notes the need for tagging, tattooing, notching or punching to be done by a skilled stockman using properly maintained instruments; use of tags suitable for sheep; care to avoid flystrike; horn branding is to be preferred if available.

Table 30 Policies, positions or standards of selected animal welfare interest groups, in Australia and overseas, applicable to ear marking and ear notching of sheep

Organisation	Provisions relevant to ear marking and ear notching of sheep
RSPCA (Australia)	• Policies – B Farm Animals, 1.3: 'RSPCA Australia supports the marking of animals for identification…the RSPCA believes that hot iron (fire) branding and ear mutilation are unacceptable means of identification'.
RSPCA (UK)	• M4.1: sheep must be marked for identification purposes as required by legislation. • M 4.2: all identification procedures must only be undertaken by trained, competent operators using appropriate, well-maintained equipment and in a way that minimises risks to welfare.
Humane Society International	• 1.6.2: where shown to be necessary, earmarking shall be performed in a way that minimises stress and injury to the animal. • 1.7.2: approved identification includes (*inter alia*) earmarking, tattooing and ear tags.
Animal Welfare Institute (US)	• 5.5: acceptable forms of identification include tattooing and ear tagging. • 5.5.2: if permanent marking is required by legislation, then a two-piece, self-piercing ear tag may be applied to one or both ears.
Federation of Animal Science Societies (US) Guidelines	• Ear-notching, ear-tattooing, ear-tagging may be performed on sheep at any age.
Temple Grandin	• No recommendations on ear marking or tagging of sheep were found.
KRAV (Sweden)	• There is no reference in the Guidelines to ear marking, notching or tagging.
Australian Veterinary Association	• The AVA does not appear to have a specific policy position on ear marking, notching or tagging of sheep.
American Veterinary Medical Association	• The AVMA does not appear to have a specific policy position on ear marking, notching or tagging of sheep.
Canadian Veterinary Medical Association	• The CVMA does not appear to have a specific policy position on ear marking, notching or tagging of sheep.

There is little that is remarkable in the international provisions and standards on ear tagging and related procedures for either cattle or sheep. Of all the positions examined, only RSPCA (Australia) specifically condemns 'ear mutilation' for stock identification although others such as the RSPCA (UK) omit notching as an acceptable means of identification. The EU legislation is ambiguous and appears to require anaesthetic for tagging or tattooing but not notching or punching, but this seems to be a very unusual position. Most of the statements stress the need for skilled operators, suitable equipment and sound procedures.

4.8.4 Implications and discussion

There is very little information on the welfare impacts of ear marking or ear notching on cattle. These procedures generally attract little regulation, partly because they are a minor insult in comparison with branding and also castration, dehorning and spaying. Ear marking and notching are also very simple to do. Except for attending to the size of the cut and the cleanliness and sharpness of the pliers, there is little that can be done to vary the welfare outcome.

Ear marking and notching would appear to be low priorities among other animal welfare issues. On the other hand, it is worth noting the opposition of the Australian RSPCA to 'ear mutilation' and also the weight loss observed by McCosker et al (2007). Further clarification of the effects of ear marks on productivity and welfare might be justified, as well as a review of the need for spay or HGP marks given the opportunities presented by NLIS. It is noted, however, that NLIS ear tags can be lost or removed and this may present food safety and ownership assurance problems.

4.8.5 Recommendations

This report recommends that:

- MLA considers conducting research to quantify the welfare impacts of ear tagging and notching given the dearth of information currently available. This is a relatively low priority, however, as ear tagging and notching are second-order welfare issues compared with castration, spaying and dehorning.

- As above, MLA commissions a study of the use of ketoprofen under field conditions to manage the pain associated with castration, dehorning, ear marking, branding and other procedures undertaken concurrently. At least two production systems should be included: a southern system involving *Bos taurus* breeds, and a northern system with *Bos indicus* cattle, the ages of which should be determined in consultation with an industry reference group. The study should quantify the costs and benefits of ketoprofen use for each system. It should be conducted in complete confidence and the results retained for future reference.

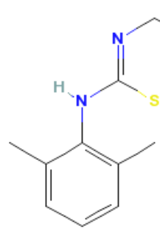
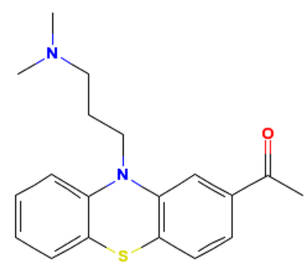
- MLA reviews the potential of NLIS to take over the role of identifying HGP-treated and spayed animals and thereby obviate the need for ear notches in these circumstances. This is a lower priority given the relative unimportance of ear notching as a welfare issue.

4.9 Agents for pain control

The use of veterinary medicines for sedation, restraint or analgesia in cattle is currently the domain of the veterinary practitioner as all approved agents are prescription animal remedies. Registered products for sedation or analgesia of cattle are listed Appendix 9.6 and include acepromazine and xylazine as sedative and restraining agents, two local anaesthetics (lignocaine and prilocaine), four non-steroidal anti-inflammatory agents (ketoprofen, meloxicam, flunixin and tolfenamic acid) and one opioid (pethidine). In addition to these products that have appropriate approved indications, three other agents may find a role in the future as a component of analgesic protocols for cattle. These agents include dexamethasone (a steroidal anti-inflammatory agent), ketamine (a controlled substance) and magnesium (available over-the-counter), each of which have been found to be beneficial as analgesic adjuvants in experimental studies and clinical studies in humans.

4.9.1 Agents for sedation and restraint

Agents used to provide sedation or restraint of cattle have historically included chloral hydrate (with or without magnesium sulphate), which is administered either orally or by slow intravenous (i.v.) injection; pentobarbital, which is given i.v.; and more recently acepromazine (oral or parenteral) and xylazine (parenteral), both of which are approved for use in cattle in Australia.

	
Xylazine IUPAC: N-(2,6-dimethylphenyl)-5,6-dihydro-4H-1,3-thiazin-2-amine **Molecular Weight:** 220.33384 g/mol **Molecular Formula:** $C_{12}H_{16}N_2S$ **XLogP:** 2.8	**Acepromazine** IUPAC: 1-[10-(3-dimethylaminopropyl) phenothiazin-2-yl] ethanone **Molecular Weight:** 326.45578 g/mol **Molecular Formula:** $C_{19}H_{22}N_2OS$ **XLogP:** 4.1

Acepromazine: A phenothiazine derivative that acts via blockade of central dopamine receptors to induce sedation by reducing brain stem activity and connections with the cerebral cortex. Motor functions are generally unaffected and arousal is readily accomplished. However, arterial blood pressure is decreased as is cardiac output and heart rate. Intramuscular (i.m.) doses of 0.03-0.10 mg/kg result in mild sedation in cattle but may be ineffective in unmanageable and hyperexcited animals.

Xylazine: An agonist at the G-protein coupled 7TM (seven transmembrane) α_2-adrenoceptors that are widely distributed in the cardiovascular, respiratory, renal, endocrine, gastrointestinal, haematological and central and peripheral nervous systems. There are at least four subtypes of α_2-adrenoceptors. Xylazine appears to be non-selective, although sedative and analgesic actions are likely to be mediated by the α_{2A} subtype (MacMillan et al 1998, Maze & Fujinga 2000). Pharmacologically xylazine is classified as a sedative, analgesic and skeletal muscle relaxant. Actions on α_2-adrenoceptors present in the central nervous system and spinal cord lead to antinociceptive activity though analgesia is generally not present except in deeply sedated animals

(Clarke and Hall 1969, Lin & Riddell 2003, Mbiuki 1981). The actions of xylazine in cattle can be reversed by α_2-adrenoceptor antagonists such as yohimbine (approved for use in cattle) (Guard & Schwark 1984, Van Metre 1992), atipamezole (Arnemo & Søli 1993; Lee et al 2003b; Thompson et al 1991), tolazoline (Powell et al 1998, Roming 1984, Skarda et al 1990, Thompson et al 1991, Van Metre 1992), 4-aminopyridine (Kitzman et al 1982) and piperoxan (Gross 2001).

Other affects of xylazine in cattle (which are generally undesirable) include bradycardia (which can be prevented by administration of atropine), decreased cardiac output and hypotension (Campbell et al 1979, Hodgson et al 2002), excessive salivation (secondary to decreased swallowing), increased urine production (Thurmon et al 1978), decreased blood insulin, hyperglycaemia (Brearley et al 1990, Eichner et al 1979, Hsu and Hummel 1981) and glycosuria, decreased haematocrit (Brearley et al 1990), hyperthermia (Fayed et al 1989, Young 1979), and reticuloruminal hypomotility (Hikasa et al 1988, Ruckebusch 1983, Ruckebusch & Allal 1987).

Breed differences in the response to xylazine have been observed. Raptopoulos & Weaver (1984) found that Hereford steers became recumbent after injection of xylazine more readily than the Friesian steers and took longer to recover but showed fewer reactions to surgical stimulation than the Friesians. Brahman cattle have been reported to be the most sensitive to xylazine, often responding to one tenth the usual bovine dose (Greene & Thurmon 1988). Other causes of variation in response include temperament (Hopkins 1972, Riebold 2001), similar to the situation with acepromazine.

The pharmacology of xylazine has been described by several authors (Clarke & Hall 1969, Garcia-Villar et al 1981, Greene & Thurmon 1988, Gross 2001, Hopkins 1972, Lemke 2007).

Cattle are the most sensitive of the domestic species to the actions of xylazine (possibly because of a denser population of spinal α_2-adrenoceptors) and generally require only one tenth of the dose required in cats, dogs or horses. Recommended doses for mild sedation are 0.1mg/kg i.m. or 0.03mg/kg i.v.

Absorption of xylazine after i.m. administration is rapid with an absorption half life of 3-5 minutes though the extent of absorption is incomplete and variable between animals. Xylazine is rapidly distributed throughout the body, subjected to extensive hepatic metabolism and excreted in the urine with an elimination half life of approximately 36 minutes. Studies of the use of xylazine as a component of an analgesia protocol for castration or dehorning (see Appendixes 9.3 and 9.5) demonstrated that even at low dose rates some calves became deeply sedated and many remained recumbent throughout the period of observation. The unpredictability of the response to xylazine makes it a poor candidate for routine use in less than ideally supervised field conditions.

The rapid elimination half life of xylazine contrasts notably with the duration of hyperthermia (18h, Young 1979), hyperglycaemia (24h, Eichner et al 1979) and prostration following high doses (36h, Clarke & Hall 1969).

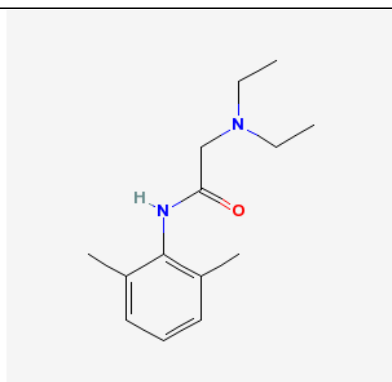
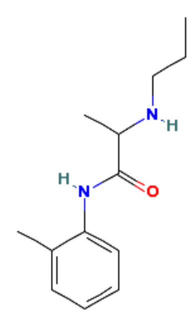
Xylazine is increasingly administered by the epidural route (Caron et al 1989, Caulkett et al 1993a, Chevalier et al 2004, Hiraoka et al 2007, Lee & Yamada 2005, Lee et al 2003a, Lee et al 2004, Lewis et al 1999, Meyer et al 2007, St Jean et al 1990) either alone or in combination with a local anaesthetic agent such as lignocaine. The need for precise delivery and strict asepsis when administering any agent into the central nervous system makes routine field use of epidural injections impractical in groups of animals.

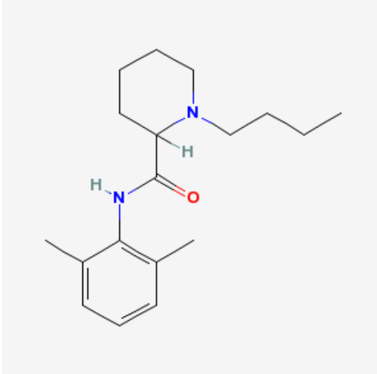
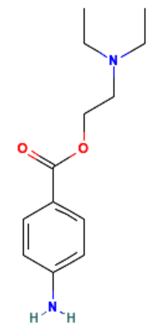
Xylazine is approved for use in cattle in Australia and a number of preparations are available generally containing 20mg/ml xylazine as the hydrochloride.

4.9.2 Agents for local anaesthesia

Local anaesthetic agents are a group of structurally related compounds that reversibly bind to specific receptor sites within voltage gated sodium channels blocking sodium permeability and impulse generation and conduction in nerve fibres.

Structural features shared by local anaesthetics include an unsaturated aromatic group (usually a benzene ring which endows the molecule with lipophilicity) linked by an intermediate chain to a tertiary or secondary amine (which increases hydrophilicity), rendering all local anaesthetics weak bases or proton acceptors. The nature of the intermediate chain divides local anaesthetics into the aminoesters (such as procaine, cocaine and tetracaine) and the aminoamides (which include lignocaine, prilocaine, bupivacaine, mepivacaine, ropivacaine). While the esters can be metabolised by esterases which are present in blood and tissues, the amides require hepatic metabolism for inactivation and excretion. The uncharged base can penetrate biological membranes to the site of action, while the cationic or charged amine moiety is necessary for binding to sodium channel receptors. Thus the biological behaviour and pharmacological effects of local anaesthetics are highly dependent on chemical structure and the balance between lipophilicity and hydrophilicity.

	
Lignocaine (lidocaine) IUPAC: 2-diethylamino-N-(2,6-dimethylphenyl) acetamide **Molecular Weight:** 234.33728 g/mol **Molecular Formula:** $C_{14}H_{22}N_2O$ **XLogP:** 2.1	**Prilocaine** IUPAC: N-(2-methylphenyl)-2-propylamino propanamide **Molecular Weight:** 220.3107 g/mol **Molecular Formula:** $C_{13}H_{20}N_2O$ **XLogP:** 2.1

	
Bupivacaine IUPAC: 1-butyl-N-(2,6-dimethylphenyl) piperidine-2-carboxamide **Molecular Weight:** 288.42772 g/mol **Molecular Formula:** $C_{18}H_{28}N_2O$ **XLogP:** 3.6	**Procaine** IUPAC: 2-diethylaminoethyl 4-aminobenzoate **Molecular Weight:** 236.3101 g/mol **Molecular Formula:** $C_{13}H_{20}N_2O_2$ **XLogP:** 1.8

Potency

Intrinsic anaesthetic potency is related to lipophilicity alone in isolated nerve preparations. However, in clinical situations molecular size and balance between lipophilicity and hydrophilicity are also important.

Speed of onset

There are five principal determinants of the speed of onset of sensory anaesthesia following injection near a nerve (Catterall & Mackie 2006):

- Proximity of local anaesthetic deposition to nerve;
- Concentration and volume of the local anaesthetic;
- Degree of ionisation;
- Tissue environment; and
- Nerve type.

The local anaesthetic agent must diffuse from the injection site to its site of action within individual nerve fibres. The rate of diffusion is dependent on the concentration of the drug, the proportion of drug that is unionised (it is only the more lipophilic unprotonated drug that can cross biological membranes and the proportion available is dependent on the local pH and the drug pKa) and the characteristics of the tissue environment in which the drug is deposited (lipophilic drugs may be bound to tissue fat and abundant connective tissue can delay diffusion). Peripheral nerves typically consist of multiple individual nerves surrounded by epineurium with an inner vascular supply. Outer nerves will be reached first as they require the shortest diffusion distance and will be blocked first, followed progressively by more centrally located nerve fibres. Studies in humans have shown that the sensation of pain disappears first followed by loss of the sensations of temperature, touch, deep pressure and finally motor function. Autonomic fibres, small unmyelinated type C fibres (that mediate pain sensation), and small myelinated Aδ fibres (mediating pain and temperature sensations) are blocked before larger myelinated Aγ, Aβ and Aα fibres (that convey proprioception, touch, pressure and motor information) (Mama & Steffey 2001; Catterall & Mackie 2006). Clearly the anatomical arrangement of the nerve that is the target of block will impact the speed of onset of anaesthesia. Clinically lignocaine has a rapid onset of action (in the order of 2-10 minutes) while prilocaine and bupivacaine have delayed onset (greater than 10 minutes). While it is recommended that the presence of local anaesthesia is confirmed before any painful procedure is initiated, the rapid onset of lignocaine ensures the time between administration and surgery is minimised.

Duration of local anaesthesia

Duration of action is related to the dose and lipophilicity of the local anaesthetic agent administered, depot effects, and rate of removal by enzymatic degradation or the circulation. The higher the liphophilicity the longer the duration of action, related to persistence in the lipid rich environment of nerves. Formulation factors can facilitate the formation of depots and allow the rate of absorption to determine duration of affect. This is particularly evident with topical dosage forms such as patches and gels. Rate of removal can be influenced by the inclusion of a vasoconstrictor which reduces local blood flow. Local enzymatic degradation is only applicable to ester type local anaesthetics such as procaine and tetracaine. In theory, co-administration of an esterase inhibitor (for example an organophosphate or neostigmine) could increase the duration of action of ester type agents.

On the basis of affects on peripheral nerves, local anaesthetic agents have been divided into short acting (20-60 minute action: procaine), intermediate (60-120 minutes: lignocaine, prilocaine, mepivacaine) and long acting (180-480 minutes: bupivacaine, ropivacaine, tetracaine).

Safety

Local anaesthetics are potentially neurotoxic and myotoxic but at clinically used concentrations and volumes for local infiltration, nerve blocks or epidural administration significant toxicity is rarely observed.

Prilocaine in particular is metabolised to ortho-toluidine which can cause oxidation of haemoglobin to methaemoglobin. While this is clinically important in sensitive species such as cats, methaemoglobinaemia has not been associated with local anaesthetic use in cattle.

Hypersensitivity reactions to ester type local anaesthetics (especially procaine) have been commonly described but no confirmed hypersensitivity reactions to amide type local anaesthetics have been reported.

The most clinically significant adverse effects of local anaesthetics are due to overdose and manifest as central nervous system and cardiovascular toxicity. Exposure of the CNS to high concentrations can cause excitement and convulsions followed by CNS depression with respiratory arrest and cardiovascular collapse. Direct cardiovascular toxicity is associated with direct electrophysiological effects on the heart leading to dysrhythmias, fibrillation and cardiac arrest. The maximum tolerated dose of lignocaine has not been described in the literature but in sheep the mean fatal dose of intravenous lignocaine was 31mg/kg (Nancarrow et al 1989). Scarratt & Troutt (1986) observed a variety of neurological signs of toxicity in ewes 15 minutes after a subcutaneous injection of lignocaine at 20mg/kg, with gradual recovery from 90 minutes. No adverse effects were encountered in the same ewes given 10mg/kg subcutaneously 2 weeks later. Dobromylskyj et al (2000) suggest that the maximum safe intravenous dose for most species is 4mg lignocaine/kg bodyweight. Higher doses could presumably be administered subcutaneously as the slower rate of absorption should ensure toxic concentrations are not readily attained. The maximum dose rate administered subcutaneously prior to dehorning or castration (refer to Appendixes 9.3 and 9.5) is usually 4mg/kg, well below the toxic doses described above.

Additives

The duration of activity of local anaesthetics is related to the duration of contact with target nerve fibres. The addition of a vasoconstrictor reduces local blood flow and can reduce the removal of the local anaesthetic, especially those agents that themselves induce vasodilation such as lignocaine. Adrenaline and phenylephrine are two vasoconstrictors that act via α-adrenoceptors and are added to lignocaine to prolong its action. Because adrenaline is also a vasodilator through actions at β_2 adrenoceptors situated in muscle vasculature it can increase absorption of local anaesthetic agents injected into muscle and thereby reduce the normally expected duration of local anaesthesia.

Other additives that have been included in the formulation of local anaesthetics include hyaluronidase (to increase the spread of subcutaneously administered local anaesthetics) and sodium bicarbonate (to increase the pH of the solution and increase the unprotonated form of the local anaesthetic in an attempt to increase the amount of agent available to diffuse to and interact with sodium channel receptors). In practice however neither of these additives has provided any significant benefit (Riebold et al 1992).

Local anaesthetic agents approved for use in cattle in Australia

Lignocaine (lidocaine): is the prototypical amide local anaesthetic. It has a fast onset of action (approximately 3 minutes, depending on site of administration) that lasts around 1-2h without adrenaline and around 2-2.5h with adrenaline (Link & Smith 1956). Lignocaine is dealkylated by hepatic cytochrome P450 enzymes and further metabolised to monoethylglycine and xylidide which are excreted in the urine.

Prilocaine: has a slow onset of action and is an intermediate-acting amide local anaesthetic with a similar pharmacological profile to lignocaine. However, unlike lignocaine if causes little vasodilation and formulations do not benefit from the addition of adrenaline. Prilocaine is metabolised to ortho-toluidine which has the potential, especially at high dose rates, to oxidise haemoglobin to methaemoglobin. The clinical consequences of this adverse affect are minor in healthy animals and there appear to be no reports of prilocaine induced methaemoglobinaemia in cattle.

Local anaesthesia and castration

Techniques of local anaesthesia for surgical castration of cattle have been thoroughly described (Hodgkinson & Dawson 2007, Skarda 1986, Skarda & Tranquilli 2007, Weaver et al 2005) with the most commonly advocated approach being one injection per testicle to combine subcutaneous administration of lignocaine alone the line of intended incision (3-5ml) and intratesticular injection (usually around 10-15ml per 200kg bodyweight). Other analgesia protocols for castration are set out in Appendix 9.3.

Investigations in the pig (Ranheim et al 2005) and horse (Haga et al 2006) have demonstrated that, following intratesticular injection of lignocaine or lignocaine plus adrenaline, lignocaine rapidly flows proximally via the vasculature into the spermatic cord with peak levels present within 3 minutes. However, lignocaine was not found in the cremaster muscle in either species and may explain why pain responses are still evident during castration when the cremaster muscle is severed. Haga & Ranheim (2005) found no difference in the pain response by pigs during castration between intratesticular or intrafunicular (injection into the spermatic cord). This suggests that there could be benefits in improving popular and widely practiced intratesticular local anaesthetic techniques. Similar studies have not been conducted in cattle but in view of the close anatomical similarities there is no reason to dismiss the applicability of these findings in cattle.

Local anaesthesia and dehorning

Desensitisation of the nerve supply to the horn by blocking the cornual nerve has been well known for more than 70 years (Browne 1938, Butler 1967, Edwards 2001, Hodgkinson & Dawson 2007, Jones 1995, Peterson 1951, Skarda 1986, Skarda & Tranquilli 2007, Tufvesson 1963, Weaver et al 2005, Wheat 1950). In adult cattle with well developed horns cutaneous branches of the second cervical nerve can innervate the caudal aspect of the horn necessitating local infiltration around the caudal half of the horn.

The cornual nerve is a branch of the lacrimal (zygomaticotemporal) nerve which in turn arises from the ophthalmic nerve, one of the main trunks of the trigeminal nerve. The cornual nerve passes through the periorbital tissues dorsally then runs along the frontal crest to the base of the horn. As it passes from the orbit to the base of the horn this nerve becomes more and more superficial. The block is therefore most easily performed 2 to 3 cm in front of the horn. Here the nerve is situated just below and only 1-2 mm inside the margin of the frontal crest. When this margin has been palpated the needle can be inserted first directed towards the margin of the crest and then passing it just a few millimetres underneath. The cornual artery and vein are close to the site of nerve block so aspiration (pulling back with the syringe) will identify inadvertent intravascular placement. The horn and the skin around the base of the horn will be anaesthetised, unless the injection is made too deep in the aponeurosis of the temporal muscle. Specific skills related to a working knowledge of the local anatomy and injection technique are required to reliably and repeatedly achieve effective blockade of the cornual nerve. Even with experienced operators the success of blockade should be confirmed (for example by needle pricks to target area) before dehorning is commenced.

In the dehorning analgesia protocols described in Appendix 9.5 horns were desensitised by either cornual nerve blocks using 3-6ml 2% (or in a single case 5%) lignocaine or 0.25% bupivacaine in calves less than 26 weeks old or 20ml in 2-year-old pregnant cows. Less commonly a ring block was performed with 3-20ml 2% lignocaine.

4.9.3 Analgesics: nonsteroidal anti-inflammatory drugs (NSAIDs)

**The NSAIDs are weak organic acids with a diversity of structures (
Table 31) but importantly all share anti-inflammatory, analgesic and antipyretic properties.**

Table 31 Nonsteroidal anti-inflammatory drugs (NSAIDs)

Class	Example	Species in which used
Arylacetic acids	Diclofenac	Human [cattle]
	Indomethacin	Human
	Ketorolac	Human
Arylpropionic acids	Carprofen	Dog, horse [cattle]
	Ibuprofen	Human
	Ketoprofen	**Cattle**, horse
	Naproxen	Human
	Vedaprofen	Dog
Coxibs	Celecoxib	Human
	Deracoxib	Dog
	Firoxoxib	Dog
Fenamates (phenyl anthranilates)	Meclofenamic acid	Horse
	Tolfenamic acid	**Cattle**, horse, pig, dog, cat
Nicotinic acid	Flunixin meglumine	**Cattle**, horse, pig, dog
Oxicams	Meloxicam	**Cattle**, human, dog, cat, pig,
	Piroxicam	Human
Pyrazolones	Dipyrone	Horse, dog, cat
	Phenylbutazone	Horse
Salicylates	Acetylsalicylic acid (aspirin)	Human
	Diflunisal	Human
	Sodium salicylate	Human

Properties

The principal mode of action of the NSAIDs is inhibition of prostaglandin production from arachidonic acid by prostaglandin synthase G/H or cyclooxygenase (COX), which has two isoforms (COX 1 and COX 2). Individual members of the NSAID family exert other effects at a molecular level both peripherally and centrally, contributing to differences in pharmacological, toxicological and therapeutic properties. Examples of effects in addition to COX inhibition include:

- Prostaglandin receptor blockade by meclofenamic acid;
- Scavenging free radicals by phenylbutazone and piroxicam;
- Anti-bradykinin properties of flunixin, ketoprofen and tolfenamic acid;
- Inhibition of enzyme release (for example β-glucuronidase from activated inflammatory cells by flunixin, ketoprofen and tolfenamic acid);
- Inhibition of cytokine release (for example interleukin-6) by carprofen;
- Inhibition of NFκB by aspirin, carprofen and flunixin; and

- Inhibition of 5-lipoxygenase by tepoxalin.

General features of the pharmacokinetic behaviour of the NSAIDS (Lees et al 2004) include:

- Good bioavailability in monogastric species after oral dosing because of medium to high lipid solubility (Kokki et al 2001). Dissolution in stomach impaired by acidic pH. However, absorption may be delayed by binding to fibrous material in the gastrointestinal tract of herbivores (Lees et al 1988, Maitho et al 1986, Welsh et al 1992);

- Good bioavailability after parenteral (intramuscular and subcutaneous) dosing;

- Medium to high lipid solubility, therefore penetrate blood–brain barrier readily;

- As weak acids they penetrate poorly into cells because of relatively acid pH of intracellular fluid (pH 7.40 in plasma vs. pH 7.00 in cells);

- High degree of plasma protein binding of all drugs (except salicylate) in all species limits passage from plasma into interstitial and transcellular fluids but facilitates passage into (and retention by) inflammatory exudate;

- Renal excretion of parent drug markedly limited by plasma protein binding (only free fraction available for ultrafiltration in glomerular capillaries);

- Low volume of distribution but some exceptions where tissue binding predominates over intravascular protein binding (for example for flunixin and tolfenamic acid in calves [Lees et al 1998]);

- Metabolised in liver, usually to inactive compounds, but some metabolites are active (phenylbutazone → oxyphenbutazone, aspirin → salicylate);

- Marked species (and possibly breed and strain) differences in clearance, terminal half-life;

- Reduced clearance, increased elimination half-life in neonates; and

- For NSAIDs with a chiral centre (e.g. ketoprofen) the pharmacology (including biological effects) of each enantiomer is likely to be distinct and not well characterised by studies of the racemate (Evans 1992, Hutt and Caldwell 1983, Landoni et al 1995a,b,c).

<u>Side effects</u>

In the management of acute pain potential adverse effects include allergic reactions, renal failure, coagulation problems, gastrointestinal bleeding and impact on healing processes, particularly of bone. However, single dose or short term use is rarely associated with adverse effects in unanaesthetised healthy animals. Renal toxicity is more likely when blood pressure is significantly reduced but rare with normotension. Gut ulceration and bleeding is more likely with repeated use.

Lengthening of bleeding time has been reported for aspirin which irreversibly inhibits platelet thromboxane production. However, other NSAIDs cause only transient inhibition and impaired haemostasis is not expected. In studies of more than 11,000 human patients having major surgery and given repeated doses of NSAIDs there was a 1% incidence of surgical site bleeding (Forrest et al 2002). In the absence of a group of patients not receiving NSAIDs it is not possible to determine whether or not NSAID use had a positive or negative effect on bleeding but this study does give some idea of what a baseline incidence of bleeding may be. NSAID use after tonsillectomy in humans did not affect the rate of postoperative bleeding but was associated with an increase in reoperation rate in one study (Møiniche et al 2003) and more surgical blood loss in another (Rusy et al 1995) compared with paracetamol. After gynaecological or breast surgery, NSAIDs have been found to cause more blood loss than the selective COX-2 inhibitor rofecoxib (Hegi et al 2004). The presence of a bleeding diathesis or administration of anticoagulants may increase the risk of significant surgical blood loss after NSAID administration (Schafer 1999).

After a comprehensive meta-analysis the Australian and New Zealand College of Anaesthetists (2005) concluded that most types of surgery are not usually associated with clinically significant bleeding in patients taking NSAIDs, making it typically unnecessary to discontinue them and thus delay surgery for the purpose of restoring normal haemostasis. Exceptions may include operations at sites where optimal haemostasis is critical, surgical manipulation of the genitourinary tract and oral cavity, and possibly cardiac surgery. Factors that increase the risk of bleeding with aspirin and other NSAIDs include coexisting coagulation abnormalities and the simultaneous use of alcohol or anticoagulants. Propensity of meloxicam and ketoprofen to influence haemostasis has been investigated in dogs undergoing surgery with observations of whole blood platelet aggregation and buccal mucosal bleeding time. Neither ketoprofen (Lemke et al 2002a) nor meloxicam (Fresno et al 2005, Kazakos et al 2005, Mathews et al 2001) had any effect, a finding that was corroborated by a study of meloxicam in humans (Rinder et al 2002).

In the context of use of NSAIDs in healthy cattle for the relief of pain resulting from dehorning, castration and even ovariectomy (spaying) it is unlikely that prolonged surgical site bleeding will be induced but this is an area that may benefit from specific observations.

The analgesic potency of the NSAIDs and other analgesic agents have been the subject of a large number of studies in humans and have been usefully converted to a comparative ranking in the Oxford league table of analgesic efficacy[23]. In the 2007 table that restricts analysis to only those agents that have data from 3 trials or 200 patients, orally administered NSAIDs and paracetamol combinations occupy the first 17 places, followed by the opioids pethidine (IM), tramadol (PO) and morphine (IM). The high ranking of NSAIDs may seem surprising at first but is consistent with recent studies in dogs (Caulkett et al 2003, Dzikiti et al 2006, Mathews et al 2001) and cats (Carroll et al 2005, Gassel et al 2005) that have shown perioperative NSAIDs provide better analgesia than the opioids butorphanol, buprenorphine or morphine.

Recent studies in cats (Carroll et al 2005, Gassel et al 2005) and dogs (Lascelles et al 1998, Lemke et al 2002b, Mathews et al 2001) have also demonstrated that pre-surgical administration of NSAIDs (meloxicam, ketoprofen or carprofen) provided long lasting preemptive analgesia for periods in excess of 24 hours. This suggests that appropriate use of NSAIDs in cattle may lead to effects beyond the period expected from the pharmacokinetics of the drug alone.

<u>NSAIDs approved for use in cattle</u>

[23] http://www.jr2.ox.ac.uk/bandolier/booth/painpag/acutrev/analgesics/lftab.html

The NSAIDs approved for use in cattle in Australia include ketoprofen, flunixin meglumine, meloxicam and tolfenamic acid (Table 32). Label dose rates and costs of these drugs are shown in Table 33. The only other NSAIDs approved in major markets for use in livestock are carprofen (approved for use in cattle in the UK) and aspirin (permitted but not formally approved for use in cattle in the US).

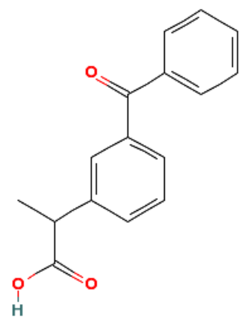
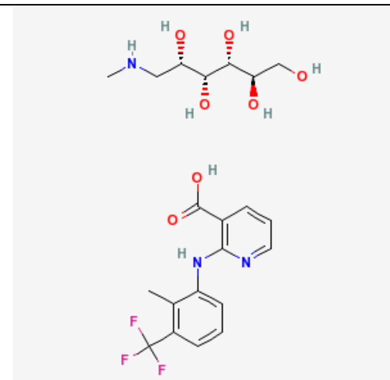
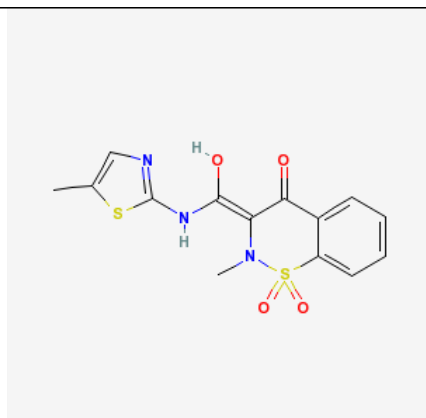
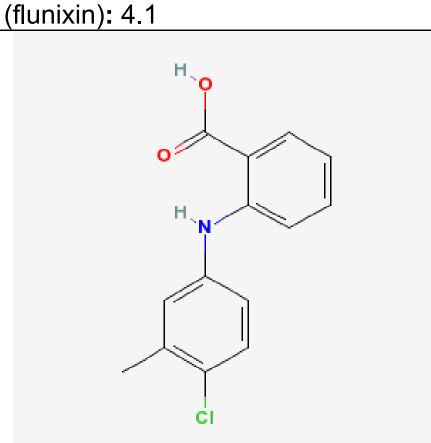
	
Ketoprofen **IUPAC:** 2-[3-(benzoyl)phenyl]propanoic acid **Molecular Weight:** 254.28056 g/mol **Molecular Formula:** $C_{16}H_{14}O_3$ **XLogP:** 3.2	**Flunixin meglumine** **IUPAC:** (2R,3R,4R,5S)-6-methylaminohexane-1,2,3,4,5-pentol; 2-[[2-methyl-3-(trifluoromethyl) phenyl]amino]pyridine-3-carboxylic acid **Molecular Weight:** 491.45813 g/mol **Molecular Formula:** $C_{21}H_{28}F_3N_3O_7$ **XLogP** (flunixin)**:** 4.1
	
Meloxicam **IUPAC:** (3E)-3-[hydroxy-[(5-methyl-1,3-thiazol-2-yl)amino]methylidene]-2-methyl-1,1-dioxobenzo[e] thiazin-4-one **Molecular Weight:** 351.40072 g/mol **Molecular Formula:** $C_{14}H_{13}N_3O_4S_2$ **XLogP:** 1.9	**Tolfenamic acid** **IUPAC:** 2-[(4-chloro-3-methylphenyl) amino] benzoic acid **Molecular Weight:** 261.70358 g/mol **Molecular Formula:** $C_{14}H_{12}ClNO_2$ **XLogP:** 4.3

Table 32 NSAIDs approved for use in cattle in Australia

Active	**Content** (mg/ml)	**Product name** (pioneer products in italics)	**Registrant**	**Approval number**
Ketoprofen	100	*Ketofen 100 Injectable*	Merial	40634
Ketoprofen	100	Ilium Ketoprofen Injection	Troy Laboratories	53423
Ketoprofen	100	Key Injection	Parnell Laboratories	56418
Flunixin	50	*Finadyne Solution*	Schering-Plough	37013
Flunixin	50	Ilium Flunixil Injection	Troy Laboratories	40439
Flunixin	50	Flunix Antiinflammatory Injection	Parnell Laboratories	47802
Flunixin	50	Flumav Flunixin Injection	Mavlab	48183
Flunixin	50	Flunixon Injection	Norbrook Laboratories	50626
Flunixin	50	Flurox Injection	Jurox	50810
Flunixin	50	Fluximine Injection	Bomac Laboratories	51812
Meloxicam	5	*Metacam 5 Solution for Injection*	Boehringer Ingelheim	50674
Meloxicam	20	*Metacam 20mg/ml Solution for Injection*	Boehringer Ingelheim	54061
Tolfenamic acid	40	*Tolfedine CS Injection*	Vetoquinol (Ausrichter)	52850

Table 33 Label dose rates and cost of NSAIDs used in cattle

NSAID	**Dose rate** (mg/kg)	**Route of administration**	**Indicative cost** (to veterinarian, ¢/kg)
Flunixin meglumine	1.1-2.2	IM, IV	1.1-2.1
Ketoprofen	3	IM, IV	1.4
Meloxicam	0.5	SC, IV	4.6
Tolfenamic acid	2-4	IM, IV	2.2-4.4

Ketoprofen: has been available for use by veterinarians in Australia for more than 15 years. The published literature describes the use of ketoprofen in cattle in the reduction of pain associated with castration and dehorning (Stafford et al 2006, and see below) as well as an adjunct in the management of lameness (Whay et al 2005), bovine respiratory disease (Lockwood et al 2003), diarrhoea associated with *E. coli* enterotoxins (Roussel et al 1993), endotoxaemia (Semrad 1993), mastitis (Shpigel et al 1994), pyrexia (Belloli et al 2007), ephemeral fever (Fenwick & Daniel 1996) and PAF-induced respiratory dysfunction (van de Weerdt et al 1999). A study of tissue damage following intramuscular administration of ketoprofen found no clinical signs of pain and minor effect on serum creatine kinase, suggesting that IM administration is an acceptable route of administration (Pyorala et al 1999).

In Australia, ketoprofen is approved for use in cattle at 3mg/kg bodyweight once daily for 3 days by IM injection in the anterior half of the neck or by slow i.v. injection. It is indicated for the suppression of untoward inflammatory reactions, pain and fever associated with a variety of musculoskeletal conditions, surgery, ophthalmological conditions and colic. Its use in animals under 6 weeks of age is specifically contraindicated though the basis of this restriction on use is not provided.

The pharmacokinetic and pharmacodynamic characteristics of ketoprofen in cattle have been investigated in a number of studies (DeGraves et al 1995, 1996, Igarza et al 2002, 2004, Landoni & Lees 1995, Landoni et al 1995c). Key findings include:

- As expected for a highly protein-bound drug, the volume of distribution is in the order of 0.1 l/kg in mature cattle and 0.2 l/kg in 20-week-old calves;

- After i.v. administration the elimination half life from plasma was:
    - 0.3h in cows in the 6^{th} month of gestation
    - 0.5-0.9h in lactating Holstein or Holando Argentino cows weighing 543kg
    - 0.4-2.2 hours in 20 week old Friesian calves with mean bodyweight of 119kg
    - 1.7h in preruminant calves 4-5 days old and weighing 30kg;

- Notably, the elimination half life from exudate and transudate was tenfold and fivefold longer than from plasma;

- Serum TxB_2 synthesis was significantly inhibited for up to 24 hours;

- Exudate PGE_2 synthesis was significantly inhibited for 30 hours;

- β-glucuronidase release into exudate was inhibited for 36 hours;

- Bradykinin-induced swelling was inhibited with an equilibration half-life of 10h; and

- Ketoprofen is available as a racemic mixture of R(-) and S(+) enantiomers with the latter having greatest COX inhibition. After administration R(-)-ketoprofen is converted to S(+)-ketoprofen and the rate of chiral inversion is around 50%, 33% and 26% in newborn calves, cows in early lactation and cows in gestation.

The points listed above demonstrate that unlike the situation with many other drugs, the biological effects of NSAIDs (i.e. anti-inflammatory and analgesic effects) significantly outlast the residence time of the NSAID in plasma.

There is clearly an effect of age on ketoprofen pharmacokinetics and it can be expected that the anti-inflammatory activity of a fixed dose will be significantly higher in young calves than in mature animals. These age-related differences may support a recommendation for dose adjustment in calves rather than an obligatory contraindication.

There have been four studies assessing the role of ketoprofen alone or in combination with local anaesthesia in the alleviation of pain cause by castration (Earley & Crowe 2002, Stafford et al 2002, Ting et al 2003a,b) summarised in Appendix 9.3. All studies have involved Friesian calves from 8-56 weeks of age and weighing from 68 to 307kg. In most cases ketoprofen was administered intravenously at a dose of 3mg/kg approximately 20 minutes prior to castration. In one case, the dose was divided and provided as two 1.5mg/kg doses administered 20 minutes apart and in another situation the initial precastration dose was supplemented with another dose 24 hours after castration. In all cases, with or without concurrent local anaesthesia, and despite the method of castration (Burdizzo, band, rubber ring, surgery with emasculation or surgery with traction) the use of ketoprofen was associated with a significant reduction in blood cortisol concentration and adverse behaviours. A second dose of ketoprofen 24 hours after castration was not associated with any incremental benefit.

Six studies have investigated the benefits of ketoprofen in cattle subjected to dehorning (Faulkner & Weary 2000, McMeekan et al 1998a, 1999, Milligan et al 2004, Stafford et al 2003, Sutherland et al 2002a). Friesian calves that were studied ranged from 0.3 to 16 weeks of age and weighed from 50-171kg. Amongst nine treatment groups ketoprofen was administered i.v. to seven groups and once each i.m. and per os in milk. While i.m. ketoprofen is likely to be equivalent to i.v. ketoprofen, the results of separate pharmacokinetic studies (Caillé et al 1989, Eshra et al 1988, Williams & Upton 1988) suggest that the systemic availability of ketoprofen administered in milk is likely to be characterised by slower rate but similar extent of absorption. Nonetheless, in most groups of treated calves, ketoprofen appeared to provide sustained pain relief, especially if combined with local anaesthesia.

Flunixin:(as the meglumine salt) is the most widely studied of the NSAIDs in cattle and was the first to receive approval in Australia. The anti-inflammatory activity of flunixin has been applied as an adjunctive treatment in puerperal metritis (Drillich et al 2007), bovine respiratory disease (Friton et al 2004, Keita et al 2007, Lockwood et al 2003), diarrhoea (Barnett et al 2003), endotoxaemia (Odensvik & Magnusson 1996) and *E. coli* mastitis (Rantala et al 2002) and may be beneficial in the management of transported cattle (Merrill et al 2007). The pharmacodynamic actions of flunixin have been studied in models of inflammation in cattle (Landoni et al 1995a,b, Lees et al 2004) and the pharmacokinetic behaviour thoroughly documented (Anderson et al 1990, Benitz 1984, Hardee et al 1985, Jedziniak et al 2007, Landoni et al 1995b, Lees et al 2004, Lichtenwalner et al 1986, Neff-Davis et al 1983, Neff-Davis et al 1985, Odensvik 1995, Odensvik & Johansson 1995).

Flunixin is rapidly absorbed and distributed after i.v. or i.m. administration and has an elimination half life that varies from approximately 3 hours in lactating adult cattle (Anderson et al 1990) to 6-8 hours in non-lactating heifers (Hardee et al 1985, Odensvik 1995). The bioavailability of orally administered flunixin granules has been reported as 60% (Odensvik 1995) and of i.m. administration 76% (Anderson et al 1990). Importantly, flunixin concentrates in inflammatory exudates and has been shown to provide long lasting inhibition of serum TXB_2, exudate PFE_2, β-glucuronidase activity and bradykinin induced swelling for up to 24 hours (Landoni et al 1995a).

Label directions for use of flunixin recommend dose rates of 1.1-2.2 mg/kg administered by either i.m. or i.v. routes, depending on the acuteness and seriousness of the condition being treated with an option for daily treatment for up to 3 days.

There are no published reports of the use of flunixin meglumine for the relief of pain associated with routine husbandry practices in cattle.

Tolfenamic acid: is approved for use in cattle and pigs. The pharmacology of tolfenamic acid administered by both i.m. and i.v. routes has been reported (Landoni et al 1995a, 1996, Lees et al

1998, Sidhu et al 2005). The elimination half life is approximately 2 - 8 hours and tolfenamic acid inhibited serum TXB_2 for up to 6 hours and exudate PGE_2 for up to 24 hours.

Meloxicam: is used widely in humans, dogs and cats and has recently become available for use in cattle and pigs. The pharmacology of SC meloxicam in cattle has been described (Dumka & Srivastava 2004, Wojcik et al 2006) as has its use as an adjunct in the management of bovine respiratory disease (Bednarek et al 2003, 2005, Friton et al 2004, 2005), diarrhoea (Todd et al 2007), endotoxaemia (Salamon et al 2000) and mastitis (Milne et al 2003).

The use of meloxicam for the relief of pain associated with dehorning of calves is described in abstract form only (see Section 4.6) though it can be anticipated that a complete description of its activity will be published in the future.

Aspirin and salicylic acid: have not been approved for use in cattle in Australia. Their pharmacology has been evaluated in cattle (Coetzee et al 2007, Gingerich et al 1975, Jenkins 1987, Short and Beadle 1978, Whittem et al 1995, 1996) and it has been observed that, in comparison with other species, absorption following oral administration in cattle is protracted (half life of almost 3 hours), bioavailability is low (70%) and elimination half life is rapid (0.5 hours). Consequently oral dose rates are high (100mg/kg) and must be given frequently (at least every 12 hours) in order to maintain an effective systemic concentration, though the duration of effect has not been investigated and may not require such a frequent dose regimen. Nonetheless, the experimental and clinical applications of aspirin have included bacterial endocarditis (Constable 1991), bovine respiratory disease (Apley 1997, Eyre et al 1976, Kopcha & Ahl 1989, Kopcha et al 1992, Schimmel & Schimmel 1978), *E. coli* heat-stable enterotoxin (Wise et al 1983), mitigation of effects of 3-methylindole in feedlot cattle (Bingham et al 2000, Loneragan et al 2002), and post-calving of dairy cows (Bertoni et al 2004). In addition there is one study describing the affects of aspirin per os or salicylic acid parenterally in castrated calves (Coetzee et al 2007).

Carprofen: has been studied in calves (Delatour et al 1996, Lees et al 1996, Lohuis et al 1991, Thun et al 1989), the results of which have led a number of the investigators to conclude that the mechanism of anti-inflammatory action was unknown and unlikely to involve inhibition of either cyclooxygenase or 12-lipoxygenase. Despite a potentially novel mode of action the clinical applications of carprofen are not dissimilar to those of other NSAIDs and include bovine respiratory disease (Balmer et al 1997, Elitok & Elitok 2004, Lockwood et al 2003) and *E. coli* mastitis (Vangroenweghe et al 2005). In addition there is one report of the use of carprofen to alleviate the pain and stress associated with band and Burdizzo castration (Pang et al 2006).

4.9.4 Opioids and other analgesic agents

Opioids

Although pethidine (meperidine) is approved for use in cattle in Australia with uses as a sedative and for provision of analgesia during parturition and following other major obstetric procedures there is little published information describing the pharmacology of any of the opioids in cattle. No evidence-based dose recommendations for cattle are provided in major textbooks of veterinary pharmacology and anaesthesiology (Branson & Gross 2001, George 2003, Lamont 2007, Nolan 2000, Wagner 2002) or are identified in literature searches of PubMed or CAB. Jenkins (1987) presents the dose rate of pethidine as 3.3-4.4 mg/kg s.c. or i.m. but provides no basis for this recommendation. Effects of butorphanol on ruminoreticular motility in cattle have been described (Guard et al 1988) as well as its effects on sedation (Jones 1972, Lin & Riddell 2003). The analgesic effects and pharmacokinetics of butorphanol have been investigated in the dairy cow (Court et al 1992, Dodman et al 1992) and nociceptive thresholds for morphine described in cattle using a thermal method (Machado et al 1998). Opioids are commonly used as part of a combination approach to epidural (Fierheller et al 2004) or subarachnoid (DeRossi et al 2007) analgesia in cattle. Butorphanol has been used in combination with xylazine as part of an analgesic protocol for castration of weanling bull calves (Faulkner et al 1992) or dehorning of beef calves (Grøndahl-Nielsen et al 1999) but with little effect in either case. Overall there does not appear to be any compelling evidence in support of the utility of pethidine or other opioids in the management of the pain and stress of routine husbandry procedures in cattle.

Ketamine

Ketamine (a controlled drug, possession of which without authority is illegal) is approved for use in cattle in Australia as an intravenously administered dissociative anaesthetic for use alone or in combination with muscle relaxants or tranquillisers (such as xylazine).

An alternative use of ketamine, however, as an analgesic agent has become widespread since it was recognised that ketamine was an NMDA antagonist at subanaesthetic doses (often 1-10% of the anaesthetic dose) (Annetta et al 2005, Argiriadou et al 2004, Bell 1999, Correll et al 2004, Eide 2000, Kohrs & Durieux 1998, Kronenberg 2002, Schmid et al 1999, Subramaniam et al 2004, Woolf & Thompson 1991).

McCartney et al (2004) undertook a qualitative systematic review of the effect of N-methyl D-aspartate antagonists on reducing postoperative pain and analgesic consumption in humans and found that the evidence in favour of preventive analgesia was strongest in the case of dextromethorphan and ketamine, with 67% and 58%, respectively, of studies demonstrating a reduction in pain, analgesic consumption, or both beyond the clinical duration of action of the drug concerned. Other recent studies (including a Cochrane review) have also found strong evidence that analgesic doses of ketamine have a postoperative opioid-sparing effect (Bell et al 2006, Elia & Tramer 2005).

Use of ketamine as an analgesic agent in the management of pain associated with routine husbandry practices has not been investigated but it is likely to provide some benefit. Nonetheless, the controlled status of ketamine (a schedule 8 drug) means that supply and use is unlikely to be permitted other than by veterinarians.

Dexamethasone

A variety of dexamethasone preparations are approved for use in cattle in Australia with claims based on potent anti-inflammatory and gluconeogenic activity including ketosis, arthritis, allergic conditions and stress. However, corticosteroids such as dexamethasone may play a role in the management of pain (Lamont et al 2000, Muir 2002, Nolan 2000) with a mechanism of action that may be related to the inhibition of transcription of COX 2 (Lukiw et al 1998) or reduction in local oedema (Holte & Kehlet 2002). A number of studies in humans have found reductions in pain associated with a variety of surgical procedures including laparoscopic cholecystectomy, tonsillectomy and extraction of molars (Afman et al 2006, Baxendale et al 1993, Bisgaard et al 2003, Breivik et al 2007, Schmelzeisen & Frolich 1993). Other studies in humans have found that corticosteroid use had limited impact in reducing surgical pain (Buvanendran et al 2007) or was ineffective (Bisgaard et al 2008, Laureano Filho et al 2008) or could not be recommended (Lachance et al 2008). It is likely that potential analgesic and other benefits of dexamethasone need to be carefully examined in each clinical situation and such study may identify significant advantages of dexamethasone as part of the approach to pain relief in routine husbandry practices in cattle.

An important consideration if dexamethasone is demonstrated to offer benefits in pain relief is the safety of combined NSAID and dexamethasone use. Combinations of corticosteroid and NSAID have been safe and effective in the management of pain, swelling and trismus following third molar surgery (Bamgbose et al 2005), breast surgery (Hval et al 2007) and postoperative pain and nausea in patients undergoing elective laparoscopic cholecystectomy (Antonetti et al 2007). However, concerns at the increased potential for gastropyloric ulceration, perforation and haemorrhage have been expressed in the veterinary area based on a number of studies in dogs (Boston et al 2003, Dow et al 1990, Narita et al 2007) that identified significant adverse effects of combined treatment. In each of these studies the combination of NSAID and corticosteroid was administered daily for from 3 to 30 days. Unfortunately, the minimum time to adverse effects was not determined, although there was a clear increase in frequency of adverse effects with time. It is likely that a single combined treatment could be administered without clinically significant adverse effects on the gastrointestinal mucosa. Indeed Margolis et al (1987) administered dexamethasone and flunixin meglumine together to treat endotoxin-induced changes in calves and found the combination safe and effective. Nonetheless, if a combination programme is developed for use in calves and cattle it would be prudent to closely examine ulcerogenic activity.

Another potential application of dexamethasone is in combination with lignocaine (Movafegh et al 2006) or bupivacaine (Castillo et al 1996, Curley et al 1996, Dräger et al 1998, Estebe et al 2003, Holte et al 2002, Kopacz et al 2003a,b, Pedersen et al 2004) as such combinations have unexpectedly been found to result in prolonged local anaesthesia.

Magnesium

Magnesium in the form of the metal or as various salts (hypophosphite, carbonate, chloride, oxide and sulfate) is approved for use in cattle by parenteral and enteral routes for the prevention and treatment of hypomagnesaemia (grass tetany), as a purgative or as a rumen neutralizer.

Administration of magnesium has also been investigated as a stress controlling agent (Ali et al 2002) or as an adjuvant in pain management protocols (Dahl & Kehlet 2006, Dubé & Granry 2003, Gaynor 2002).

Kietzmann & Jablonski (1985) found that intramuscular administration of Mg aspartate to pigs one hour before a stressful stimulus significantly reduced catecholamine and cortisol concentrations in blood, a finding that had previously been observed in rats offered diets supplemented with magnesium (Kaemmerer & Kietzmann 1984,Kaemmerer et al 1984).

Magnesium is an N-methyl-D-aspartate (NMDA) receptor antagonist and a physiological antagonist of calcium, both mechanisms associated with potential antinociceptive compounds. Magnesium has been included in a growing number of studies to characterise its use perioperatively. Results from clinical studies have been mixed with a number of investigations finding no benefit (Ko et al 2001, Tramèr & Glynn 2007, Wilder-Smith et al 1997) and others positive contributions to pain alleviation during surgery (Bhatia et al 2004, Kara et al 2002, Koinig et al 1998, Levaux et al 2003, Seyhan et al

2006, Tauzin-Fin et al 2006, Tramèr et al 1996) or in the relief of pain associated with administration of the anaesthetic agent propofol (Honarmand & Safavi 2008). Even though they found no unequivocal benefits in their study of adults undergoing ambulatory ilioinguinal hernia repair or varicose vein operation under general anaesthesia, Tramèr & Glynn (2007) recommended that 'since the NMDA receptor antagonists may potentially decrease chronic postsurgical pain … it would be interesting to examine the potential long-term benefits of magnesium'. Lysakowski et al (2007) reviewed 14 published randomised comparisons of magnesium and placebo in the surgical setting and found that postoperative analgesic requirements were significantly reduced by magnesium in eight (57%) trials and concluded that it may be worthwhile to further study the role of magnesium as a supplement to postoperative analgesia, since this relatively harmless molecule is inexpensive, and the biological basis for its potential antinociceptive effect is promising. In addition to its use intravenously magnesium has also been included in epidural (Arcioni et al 2007, Bilir et al 2007, Birbicer et al 2007) intrathecal (Arcioni et al 2007, Kroin et al 2000, Ozalevli et al 2005), intraarticular (Bondok et al 2006) and intravenous regional anaesthesia (Turan et al 2005) injections, usually in combination with an opioid or local anaesthetic.

In view of the potential benefits and low likelihood of adverse effects it may be of great value to investigate the use of magnesium for alleviation of stress and pain in cattle.

4.9.5 Topical and transdermal analgesia

Topical and transdermal approaches to analgesia and local anaesthesia are the subject of increasing interest and use in veterinary and medical acute and chronic pain management (Ramamurthi & Krane 2007, Riviere & Papich 2001, Speirs et al 2001, Tranquilli et al 2000). Published studies in this area include:

Transdermal analgesic preparations

- Buprenorphine patch (Norspan) (Budd 2003, Evans & Easthope 2003, Sittl 2005);
- Capsaicin cream (Agarwal et al 2007b);
- Diclofenac patch (Agarwal et al 2007a);
- Fentanyl iontophoretic transdermal system (ITS) (Herndon 2007, Koo 2005);
- Fentanyl patch: release at 25-100mcg/h/patch (Egger et al 2007, Glerum et al 2001, Hofmeister & Egger 2004, Jeal & Benfield 1997); and
- Pluronic gel medications: for compounding with analgesic agents (ketamine, NSAIDs, TCAs) (Tranquilli et al 2000).

Topical local anaesthetic preparations

- Amethocaine (4%) gel (Lander et al 2006);

- EMLA: eutectic mixture of lignocaine (2.5%) and prilocaine (2.5%) (Eidelman et al 2005, Hung et al 1997, Wagner et al 2006);
- LET: lignocaine (4%), adrenaline (0.1%), tetracaine (0.5%) (Schilling et al 1995) ;
- Lignocaine patch (Lidoderm®): 5% lignocaine (Gammaitoni et al 2003, 2004) ;
- LMX (ELA Max cream): liposomal encapsulated 4% lignocaine (Smith & Gjellum 2004);
- TAC: tetracaine (0.25-0.5%), adrenaline (0.025-0.05%), cocaine (4-11%) (Schilling et al 1995);
- Synera patch: eutectic mixture of lidocaine (70 mg) and tetracaine (70 mg) (Curry & Finkel 2007); and
- Cryoanaesthesia: ethyl chloride or fluorohydrocarbon (1,1,1,3,3-pentafluoropropane and 1,1,1,2-tetrafluoroethane combinations) (Armstrong et al 1990, Hartstein & Barry 2008, Ramsook et al 2001, Zappa & Nabors 1992).

There are many opportunities to explore effective topical application of local anaesthetic agents (with or without the inclusion of a NSAID or corticosteroid) to allay the pain associated with disbudding/dehorning, castration and branding.

It is recommended that the potential of topical and transdermal analgesia / anaesthesia be the subject of formal evaluation to assess the likelihood of significant alleviation of pain.

4.9.6 Scheduling of drugs: the experience in deer

Just as with dehorning or disbudding of cattle, velvet antler removal from deer requires physical or pharmacological restraint and analgesia. Sedation and chemical restraint of deer has been the subject of a number of investigations (Choi et al 1998, Read et al 2000, Walsh and Wilson 2002a, Wilson et al 1996a,b). Pharmacological agents reviewed or examined experimentally in deer have included the neuroleptics (including phenothiazines, butryophenones and the long acting thioxanthene zuclopenthixol [investigated in deer by Read et al 2000]), the benzodiazepine diazepam, α_2 adrenoceptor agonists (xylazine, detomidine, medetomidine) and reversal agents (4-aminopyridine, yohimbine and atipamezole); opioid agonists (including fentanyl, carfentanil and etorphine) and antagonists (naloxone, naltrexone, nalmefene, deprenorphine) and the dissociative anaesthetics (ketamine in combination with an α_2 adrenoceptor agonist; tiletamine and zolazepam).

The most widely used agent in NZ is reported to be xylazine (Wilson 2002; Wilson & Stafford 2002) though there are two concerns. First, Wilson et al (1996a) described reports from veterinary practitioners (first noted by Fletcher 1974) that responses to xylazine in red deer varied and were unpredictable and encouraged the use of other agents or combinations (such as xylazine/fentanyl citrate/azaperone) in an attempt to attain greater reliability of sedation and restraint. The second concern relates to tissue (velvet) residues of the xylazine metabolite 2,6-xylidine which has been found in toxicology studies in Charles River rats to be carcinogenic. Such residues issues may only be significant for tissues harvested without the benefit of a withholding period immediately after xylazine administration, unlike husbandry procedures in cattle which are not carried out close to the time of slaughter.

Analgesia requirements of velvet harvesting have been comprehensively described (Wilson 2002; Wilson et al 2002). Walsh & Wilson (2002b) noted that control of post-operative pain after velvet removal is not practised routinely. Current and future potential analgesic measures include traditional local anaesthetic agents such lignocaine with and without adrenaline, and in combination with bupivacaine or mepivacaine as well as novel compounds such as the tricyclic antidepressant amitriptyline. Systemic analgesic agents such as the opioids, NSAIDS, α_2 adrenoceptor agonists, NMDA receptor antagonists (ketamine) and various combination approaches are likely to be more widely adopted in the future

The absolute requirement for analgesia is necessitated by a consideration of the nerve supply to the antlers which is very rich and much more complex than that present in cattle (Adams 1979, Woodbury & Haigh 1996). While the horns of cattle are principally supplied by the cornual nerve, Adams (1979) described innervation from the infratrochlear and zygomaticotemporal branches of the ophthalmic division of the trigeminal nerve with possible contributions of the first two cervical nerves to which Woodbury & Haigh (1996) added innervation in some individuals from the dorsal branch from the auriculopalpebral nerve.

Compression bands applied around the base of the antler pedicle are a physical approach to analgesia (Matthews et al 1999, Matthews & Suttie 2001) developed in an attempt to avoid the use of pharmacological agents. However, studies of the pain response to compression bands have found this approach is associated with pain (Woodbury et al 2002, 2005). Local anaesthetics are the most widely used agents to provide analgesia (Johnson et al 2005b, Webster & Matthews 2006, Wilson & Stafford 2002, Wilson et al 1999, 2000, Woodbury et al 2002, 2005) with ring blocks found to be much more reliable than regional nerve blocks. Wilson et al (2000) recommended that the standard for ring block analgesia required 1ml/cm of 2% lignocaine injected circumferentially around each pedicle at least 2 minutes prior to surgical removal of the velvet antler. The most important issue associated with local anaesthesia for velvet collection is the presence of the potentially carcinogenic lignocaine metabolite 2,6-xylidine (also known as 2,6-dimethylaniline) (Chamberlain & Brynes 1998) in harvested velvet. As with residues arising from xylazine use, lignocaine use in cattle during routine husbandry procedures is not likely to share the same concern as there is generally a long interval between administration and slaughter for human consumption. However, because of concern at the potential for velvet residues alternatives to lignocaine are actively being investigated, including the use of the ester chloroprocaine as well as tourniquet application to reduce or eliminate blood supply to the antler after lignocaine use.

New Zealand Minimum Standards for the Welfare of Deer during the Removal of Antlers

Compliance with welfare standards can be greatly enhanced by removal of significant restraints to adoption. The introduction of a deer farmer accreditation scheme in New Zealand in the early 1990s and subsequent schemes in Canada (Church & Church 2001, Weary et al 2006) and Australia appear to have improved pain management in deer and elk.

In New Zealand the harvesting of deer velvet antlers falls within the jurisdiction of a number of acts and regulations including the *Code of Recommendations and Minimum Standards for the Welfare of*

Deer during the Removal of Antlers 1992 (NAWAC 1992) *Animal Welfare Act 1999* and the *Animal Remedies (Develveting) Regulations 1994*, and subsequent amendments.

Drugs used for the harvest of velvet may be administered to a stag only under direct supervision, or in the presence of, a veterinary surgeon, or indirect supervision of trained, National Velveting Standards Body (NVSB) certificated farmers under and according to the authority and prescription of a veterinary surgeon following consultation.

The National Velvetting Standards Body (NVSB) administers a training and certification program for the removal of velvet based on a Code of Practice. The programme is approved under the 1997 Agricultural Compounds and Veterinary Medicines Act (ACVM) and endorsed by the National Animal Welfare Advisory Committee.

The New Zealand Deer Farmers Association (NZDFA) and the New Zealand Veterinary Association (NZVA) each appoint two representatives to the NVSB, and the programme is managed by Deer Industry New Zealand. There are approximately 1,300 farmers certificated under the program, which is audited annually.

Key points of the NVSB certification programme include:

- Velvet is removed using a local anaesthetic so that the stag feels no pain and the whole procedure is designed to minimise stress;
- Hygiene standards are set out for facilities and equipment;
- Farmer training is carried out by a ‘supervising veterinarian’ and covers both the theory and practice of velveting;
- Farmers must pass a written theory exam, an oral test and a practical assessment by an independent veterinarian before gaining certification;
- On-going training and monitoring involves an annual assessment by the supervising veterinarian; and
- Random independent audits are carried out annually by the NVSB on both certified velvetters and veterinarians to test compliance and to ensure the program’s integrity.

The responsibilities of veterinarians in the supervision of persons approved to collect velvet under the Code are described as follows:

- *After initial training and veterinary approval, the approved person must be reassessed annually for both theoretical and practical competence at the start of the velvet harvest season using similar criteria to the initial training and approval. This would include the veterinarian observing a minimum of number of deer being velvetted using the objective criteria of assessment approved by the Chief Veterinary Officer. The veterinarian has a duty to visit more frequently during the velvet season if he/she considers this necessary for the welfare of the animals;*

- *The supervising veterinarian must be satisfied that the equipment and facilities used are sufficient to achieve compliance with this code of practice;*

- *Approved persons may only remove velvet from stags under their direct care. The veterinarian must record the size of the herd and permit only animals from that herd to be velvetted;*

- *The veterinarian must be prepared to certify that to the best of his or her knowledge all stags were velvetted by a supervised person who had been trained to meet the standard of this code of conduct;*

- *The veterinarian and farmer must document any problems observed, including deaths and any other untoward events; and*

- *There will be an annual audit of certificated deer farmers and participating veterinarians by appropriately qualified persons approved by the CVO using standard audit principles at a level required to maintain the integrity and credibility of the scheme. The minimum audit level should be determined by independent statistical advice.*

In addition to the welfare components of veterinary supervision, veterinarians have separate responsibilities for the control of prescription animal remedies governed by the NZ Animal Remedies Board.

NVSB standards and requirements, and Deer Quality Assurance (QA) Farm Programme standards and recommendations can be obtained from the New Zealand Game Industry Board, PO Box 10-702, Wellington.

An Emergency Response Plan (ERP) covers contingencies in the event of accidental administration of xylazine to a human, and is displayed prominently.

Australian National Deer Velveting Accreditation Scheme

The minimisation of the pain and stress of velvet collection has long been a concern of the deer industry with appropriately accredited deer farmers now permitted in each State of Australia to use particular prescription animal remedies, including xylazine and lignocaine.

The first program to train and accredit Australian deer farmers in the harvesting of velvet was developed in Western Australia in 1992 on the basis of a successful program in New Zealand. Similar accreditation courses were conducted in South Australia and Victoria in 1993 and in NSW in 1994 and have now evolved into the National Deer Velveting Accreditation Scheme organised by the Deer Industry Association of Australia (DIAA)[24]. This scheme has been developed with the approval of the veterinary surgeons' board and welfare organisation in each state. All boards now support the Scheme but there is some variation in how each board oversees the way drugs are prescribed.

Important components of the accreditation scheme include:

[24] http://www.diaa.org

- *Veterinary supervision:* an appropriate veterinary-client-patient relationship must exist with a veterinarian who must be able to help with supervision and dispensing of veterinary medicines and be available to help solve problems associated with velveting and general deer medicine;

- *Training:* a 2-day course in deer velveting that includes the handling, storage and use of veterinary medicines must be satisfactorily completed. In addition, a separate practical assessment must be undertaken where the farmer must demonstrate appropriate skills in the entire velveting procedure;

- *Reporting:* farmers who are accredited (those that completed the training courses and have a veterinarian prepared to support them) need to submit an annual report stating the number of deer velveted, the method of velveting used, the species of deer, the number of deaths within 48 hours of velveting and details of drugs used and received;

- *Monitoring:* the supervising veterinarian must make at least one site visit each year to review procedures and assess storage and use of veterinary medicines;

- *Continuing education:* to maintain accreditation, farmers are required to attend a refresher course at the end of 3 years; and

- *Sale of velvet:* all velvet sold through the DIAA or exported must carry the accreditation tag of the farmer or veterinarian who harvested the velvet.

In NSW the Veterinary Practitioners Board administers the accreditation of deer farmers itself. The Board works closely with the NSW Velvet Accreditation Scheme Committee and industry veterinarians to ensure the success of the scheme. In 1994 the Board agreed to approved accredited deer farmers undertaking the procedure of removal of antlers from deer, and using S4 anaesthetic drugs for removal of antlers from deer.

Deer farmers must support their application with proof that they fulfil the requirements of the National Deer Velvet Accreditation Scheme. The Board is to be advised of the name of the supervising veterinarian and the NVAS Accreditation Number. The Board charges the deer farmer a fee of $10 for registration of accreditation.

The Board has the statutory power to refuse to grant, to revoke or to refuse to renew the accreditation of any farmer. The Board retains complete power to determine whether the Velvet Accreditation Scheme continues and under what conditions it continues.

Removing the antlers from deer is an act of veterinary science. Deer farmers may apply to the VPB for permission to remove the antlers from their own deer and to use S4 anaesthetic drugs (supplied by a registered veterinary surgeon) for this purpose.

In addition to the requirements of the *Veterinary Practice Act 2003*, accredited farmers need to observe a number of other pieces of legislation which include (but may not be limited to):

- *Prevention of Cruelty to Animals Act 1979*: Section 5 states that: ‘a person shall not commit an act of cruelty upon an animal or where the person is in charge of an animal, authorise the commission of an act of cruelty upon an animal'. Section 4 states that: 'for the purposes of this Act, a person commits an act of cruelty upon an animal if he unreasonably, unnecessarily or unjustifiably.....inflicts pain upon an animal'. It is generally accepted that velvet antler harvesting without analgesia is a painful procedure and that this pain can be effectively eliminated by use of appropriate drugs;

- *Poisons and Therapeutic Goods Act 1984*: Section 8(2) defines Schedule 4 restricted substances as 'substances which in the public interest should be supplied only upon the written prescription of a medical practitioner, dentist or veterinary surgeon'; and

- *Stock Medicines Act 1986*: Sections 37(2)(3), 38(1), 39(2), 40 require S4 anaesthetic drugs to be supplied by a registered veterinary surgeon to an accredited deer farmer. They may only be used by that farmer for the purpose and according to written instructions which must be given to the deer farmer by that veterinary surgeon.

Accreditation of cattle farmers

The success of the deer farmer accreditation programs in ensuring high rates of adoption of welfare standards could be translated to accreditation programs for farmers and contractors involved in undertaking painful husbandry procedures in cattle. Accreditation training and objectives could focus on both welfare of cattle and the use of veterinary medicines to alleviate stress and pain.

Such an accreditation scheme would require at the outset the commitment and involvement of the veterinary profession (the Australian Veterinary Association), the cattle industry (Cattle Council of Australia and National Farmers Federation), the agency that registers veterinary medicines (Australian Pesticides and Veterinary Medicines Authority), the State bodies that register veterinarians and set and audit standards of practice (veterinary practitioner boards), organisations with a special interest in animal welfare (e.g. RSPCA), and the bodies that are responsible for regulating the use of prescription animal remedies (generally the Departments of Health in each state).

Accreditation programs should ensure that potential adverse impacts on OHS of the use of scheduled drugs are minimised and that injections can be administered safely. Most of the components of an accreditation scheme (for example training, record keeping, auditing) are analogous to components of quality assurance programs and should be very familiar to the cattle industry. The necessity of a supervising veterinarian will be novel in many cases and will incur an additional cost that should be spread over the numbers of animals requiring treatment each year.

4.9.7 Acupuncture

Since the mid 1970s there have been a number of reviews of veterinary acupuncture which included description of its use in cattle (Haltrecht 1999, Hare 1999, Klide 1992, Kothbauer 2002, 2004, Lindley 2006b, Looney 2000, McLeod 1974, Milin 1977, Ramey et al 2001, Rogers et al 1974, 1976, Schwerg 1990, Scott 2001, Skarda & Glowaski 2007) with (Skarda 2002) reviewing the use of electroacupuncture (percutaneous acupoint electrical stimulation or PAES), transcutaneous electrical nerve stimulation (TENS), percutaneous electrical nerve stimulation (PENS), laser therapy and pulsed magnetic field therapy.

Most of the emphasis of veterinary acupuncture research has been on dogs and horses with little attention to cattle in recent textbooks (Lindley 2006a, Xie & Preast 2007). Application of acupuncture for induction of analgesia in cattle undergoing a variety of surgical procedures including laparotomy for Caesarian or displaced abomasum have been described (Arambarri et al 1975, Baumgartner & Kanis 1983, Kanis 1982, Kim et al 2004, Kothbauer et al 1975, 1990, White et al 1985), though analgesia was not reliably induced in cattle (Arambarri et al 1975, Baumgartner & Kanis 1983) or in sheep (Bossut et al 1986). Other applications of acupuncture in cattle have included management of downer cows (Kim et al 2006, Rogers 1979, 1985) as well as principal or adjunctive therapy of parturition, prolapsed uterus, swelling of udder, arthritis, pulmonary disorders, hepatic disorders and oral disorders (Chan et al 2001, Kothbauer 1986, 2002, 2004, Rogers et al 1974, 1976, Weiss et al 2006). Despite many accounts and reports of acupuncture use in cattle the strength and quality of the evidence is low (Rijnberk 1997). The poor quality of the published literature led the authors of the most recent systematic review (Habacher et al 2006) to conclude that there is 'no compelling evidence to recommend or reject acupuncture for any condition in domestic animals'. This situation is not unique to veterinary acupuncture as the authors of a comprehensive review of the medical literature (Barkas & Lundeberg 2006) concluded that 'none of the research evidence at present is able to provide clear clinical guidelines on the usefulness of TENS and acupuncture in the treatment of pain'.

Some key observations relevant to consideration of the use of acupuncture for the relief of pain associated with routine husbandry procedures include:

- *Long induction period*: from placement of needles to detectable analgesia can take up to 50 minutes, with an average time is some case series reported as 20 minutes;

- *Short duration of effect*: pain relief is only apparent during the period of active acupuncture – once needles are removed or current turned off, pain is restored;

- *Narrow sensory block*: when acupuncture analgesia is induced other sensory modalities (touch, pain, movement etc) are unaffected;

- *Non-responding cattle*: the percentage of cattle showing inadequate analgesia following acupuncture in its various forms has ranged from 10-70%;

- *Adjuvant treatment*: in some reports acupuncture provides an effective supplement to local anaesthesia or conventional analgesics but ineffective as a single analgesic treatment;

- *Unhandled cattle*: nervous animals appear less responsive to acupuncture than more sedate animals;

- *Individual customisation of procedure*: needle placement may need to be fine tuned in individual animals to improve efficacy; and

- *Lack of evidence*: as mentioned above, there is no strong evidence to support the use of acupuncture for the relief of acute pain.

While it is possible that acupuncture could find a role in cattle practice as an analgesic procedure there is too little evidence available at present to recommend consideration as an option. Even if acupuncture is demonstrated to provide pain relief during husbandry procedures, many of the limitations summarised above are likely to remain and render the approach impractical.

4.9.8 Conclusions and recommendations

This section of the report was built upon interviews with medical and veterinary pain experts as well as a comprehensive literature review. In summary, it has found that there are no undiscovered ‘silver bullets’ for managing the pain associated with husbandry procedures in cattle, although there may be some prospects for the future.

Currently available sedative agents (acepromazine and xylazine) can be very effective in improving the tractability of calves and cattle. However, with both agents there is a need for individualisation of the dose to accommodate the variability in response between animals. Variability in response can be manifested as complete absence of response at one extreme and substantial oversedation at the other that may, in the case of xylazine, result in sustained recumbency and prolonged recovery. Wherever possible it would be useful to develop non-pharmacological approaches to restraint that are consistent with the objective of minimising the stress of handling.

Amongst the analgesic agents available, lignocaine and the NSAIDs have the potential to provide significant alleviation of pain and inflammation. The quick onset of action of lignocaine is very useful but the duration of action may not be ideal. In addition, lignocaine preparations approved for use in cattle must be injected and there is pain associated with injection. There are four NSAIDs available for use in cattle and each would appear to have the potential to provide 12-24 hours of action following a single injection. Ketoprofen is the most widely investigated in husbandry procedures but each of the other three agents may provide similar benefits. In most cases only short courses of treatment (and usually only a single administration) will be needed which should ensure that the commonly encountered adverse effects reported in dogs and humans – especially gastropyloric ulceration, renal dysfunction, and cardiovascular toxicity – do not limit safe use in cattle.

There is insufficient evidence in support of a role for the opioids in pain alleviation in cattle and they are unlikely to find a place in analgesia protocols. Ketamine may have value as an analgesic agent in cattle, but it is highly unlikely ketamine would be made available except through veterinarians given its controlled status. Further characterisation of the contribution of dexamethasone and magnesium to pain mitigation may be justified on the basis of a plausible mechanism of action and the results of clinical studies in humans. There are currently no controlled studies of either agent in cattle. No specific recommendation has been made to pursue these agents because other priorities prevail.

There is a very significant research effort in the field of topical and transdermal analgesia. This could feasibly deliver, in the longer term, products that obviate the use of needles on-farm and hence improve the occupational health and safety implications of injecting cattle. However, the development of products for cattle would require significant R&D expenditure and is likely to be some years away. Again, this report does not recommend specific investment by MLA in transdermal analgesia because there is a shorter-term imperative simply to bed down effective and minimum-cost pain relief protocols based on existing technologies.

However, MLA should maintain a watching brief on this area. A topically applied analgesic or anaesthetic agent might, for example, offer particular value if applied to a branding site and could be developed by an interested pharmaceutical company. The market size would need to be considered adequate to offer a return on an investment likely to be in the order of $200,000.

The Australian National Deer Velveting Accreditation Scheme and its New Zealand equivalent offer a model for the accreditation of cattle producers to gain access to veterinary drugs for use during on-farm husbandry procedures. Such a scheme would require the cooperation of a large number of professional and regulatory bodies and a significant initial investment in design before implementation. The cost to farmers will include additional time (training, record keeping) and the development of a professional relationship with a veterinarian but is not expected to exceed the separate cost of the analgesic agents used.

One final consideration in a possible move to using pain relief agents is that meat (and milk) withholding periods will need to be observed. This should not be a major problem for conventional systems where a period of wound healing will be required before sale anyway. Meat withholding periods are generally short for the products discussed here (lignocaine has a nil withholding period, ketoprofen 4 days). Using pharmaceutical agents may be an issue for organic producers.

There is little evidence to support the use of acupuncture even if it were a practical option in the field.

5 Success in achieving objectives

This report meets the objectives of the project as described in Section 2.

6 Impact on meat and livestock industry

This report is expected to assist the cattle industry in dealing with the transition from model codes of practice to animal welfare standards in Australia. The value of the report will be in the industry's improved capacity to make R&D and policy decisions informed by a strong understanding of the relevant animal welfare science as well the stances taken by other countries in respect of cattle welfare.

7 Conclusions and recommendations

An intense scientific effort has gone into understanding the welfare impacts of surgical husbandry procedures of cattle in the last 20 years. Castration and dehorning have received particular attention because they are major procedures and they are practised worldwide. There has been some work on branding. Spaying has been little studied, only because of its limited use outside Australia, while ear marking has probably been passed over as a relatively minor procedure.

Assessing the pain felt by animals is not a perfect science and there are some inconsistencies on detail in the literature. However, the science has developed sufficiently that there is now good agreement among researchers on the usefulness of plasma cortisol, behavioural changes and other indicators of pain. The findings of research using these indicators are starting to be taken up internationally in animal welfare standard-setting processes (by New Zealand in particular).

It is clear from the science that all of the procedures under consideration cause pain, because the same responses are not seen in animals either *not* experiencing the procedure or experiencing the procedure but with the benefit of some form of anaesthesia or analgesia. The science has also demonstrated that options are available to greatly reduce or eliminate the pain of these procedures.

The means to manage the pain of surgical husbandry procedures in cattle has been available for many years primarily in the form of lignocaine applied by local or regional blocking approaches (branding is an exception). However, lignocaine and the skill of applying it has only been available to veterinarians and there has been little expectation that it should be applied to accepted farming practices.

This picture is changing, for several reasons. First, the large research effort into animal welfare described above has objectively demonstrated the adverse effects of husbandry procedures of cattle and sheep. Second, attitudes towards animal welfare are evolving, and in Europe at least this is being increasingly reflected in legislation that recognises animals as sentient beings with intrinsic rights that transcend their status as the property of humans. There is a move worldwide to redraft animal welfare standards based on science rather than the 'realities' of farm management, although the latter still hold considerable sway, especially in North America.

A third factor is the growing range of analgesic drugs available for use in cattle. Until recently there have been few options for pain management in cattle apart from local anaesthesia, xylazine, flunixin and possibly butorphanol. None of these has been extensively researched for its usefulness with the common minor surgeries performed on farms. Since the mid-1990s ketoprofen has been investigated for use in castration in particular, while carprofen and more recently meloxicam (for dehorning) have also received some attention.
The difficulty in developing recommendations from this report is that there is a fundamental question of philosophy in how the industry and governments address the issues raised. The first test will be the content of the proposed animal welfare standards. There appear to be interventions available that virtually abolish the pain response to several procedures, at least in the acute phase, but they come at a cost, either from restrictions on the use of certain methods or from the use of drugs (there may also be implications for meat and milk residues). The question is whether 'virtual abolition' of pain is the necessary end-point and, if not, what should be considered an acceptable degree of pain.

'Virtual abolition' of pain would appear to be the philosophy of northern European countries and perhaps in time the entire European Community. New Zealand has been more pragmatic in its approach but gives the sense that total pain management is a matter of time. North America appears the most reluctant to place any additional impost on its farmers.

The industry can choose to follow any of these paths or a different one. The challenge is to carefully judge how the expectations of the public and politicians, but just as importantly consumers, will evolve over the next 20 years and to adequately prepare for that evolution. Research and development, particularly that required to develop new technologies such hormonal fertility control, has a lead time measured in decades. Registering new pharmaceutical products or even changing the registration of existing ones also takes several years. Taking a forward view of animal welfare standards is clearly in the cattle industry's interests. On the other hand, issues of practicality and cost must also be weighed up.

With those thoughts in mind, the following recommendations are made:

1. MLA commissions a comprehensive survey of castration, dehorning and branding practices across Australia, so that solid data is available to guide R&D, extension and policy. There is some information on the uptake of different practices but it is limited and this makes it difficult to judge the impact of possible changes in standards.

2. MLA commissions a study of the use of ketoprofen under field conditions to manage the pain associated with castration, dehorning, ear marking, branding and other procedures undertaken concurrently. At least two production systems should be included: a southern system involving *Bos taurus* breeds, and a northern system with *Bos indicus* cattle, the ages of which should be determined in consultation with an industry reference group. The study should quantify the costs and benefits of ketoprofen use for each system. It should be conducted in complete confidence and the results retained for future reference.

3. MLA commissions a feasibility and cost study for a scheme to license lay people to administer local anaesthesia for castration and dehorning in calves. The study would be preceded by a discussion between MLA and APVMA on the likelihood of success for such a scheme. This study would include the identification of shielded-needle, needleless and possibly other technologies that could be used to deliver local anaesthetic with reasonable operator safety as well as the regulatory changes that would be required to permit the use of local anaesthetics, and also non-steroidal anti-inflammatory drugs, by lay people. As with the recommended ketoprofen study, this study should be conducted in complete confidence and the results retained for future reference.

4. If castration using high-tension bands (as distinct from rubber rings) is shown to be a widespread practice in Australia, MLA considers research to clarify the welfare implications of this method. New Zealand may already be undertaking or planning such research in which case Australia may be able to benefit from the results. Alternatively, a collaboration on such research with Meat & Wool New Zealand may be appropriate.

5. MLA continues to support research into hormonal technologies for suppression of fertility in female cattle.

6. MLA commissions research on pain relief options for WDOT spaying. A preliminary study might focus on the welfare benefit of an NSAID such as ketoprofen administered shortly after spaying using the WDOT. If there is evidence that local anaesthesia will be required, surgical instrument engineers might be approached to develop a modification to the Willis instrument that allows the injection or spray of a local anaesthetic into or onto the ovarian pedicle at the time it is transected. A mucoadhesive formulation of lignocaine is another option for consideration.

7. MLA uses the findings from AHW.094 to promote the uptake of polled breeds of cattle. It is recognised, however, that there are negative perceptions about polled cattle in some parts of industry and that these may need to be addressed first.

8. MLA maintains a watching brief on the development and uptake of newer identification management systems with a view to identifying opportunities for branding to be dispensed with as a management tool. Alternatively, MLA could take a proactive stance on R&D to

develop new identification systems, although branding is a lower welfare priority than other procedures.

9. MLA considers conducting research to quantify the welfare impacts of ear tagging and notching given the dearth of information currently available. This is a relatively low priority, however, as ear tagging and notching are second-order welfare issues compared with castration, spaying and dehorning.

10. MLA reviews the potential of NLIS to take over the role of identifying HGP-treated and spayed animals and thereby obviate the need for ear notches in these circumstances. This is a lower priority given the relative unimportance of ear notching as a welfare issue.

8 Bibliography

8.1 Scientific / technical papers and articles

Adams JL 1979, 'Innervation and blood supply of the antler pedicle of the Red deer', *New Zealand Veterinary Journal*, vol. 27, pp. 200-201.

Afman CE, Welge JA & Steward DL 2006, 'Steroids for post-tonsillectomy pain reduction: meta-analysis of randomized controlled trials', *Otolaryngology – Head and Neck Surgery*, vol. 134, pp. 181-186.

Agarwal A, Gautam S, Gupta D & Singh U 2007a, 'Transdermal diclofenac patch vs eutectic mixture of local anesthetics for venous cannulation pain', *Canadian Journal of Anesthesia*, vol. 54, pp. 196-200.

Agarwal A, Yadav G, Gupta D, Tandon M, Dhiraaj S & Singh PK 2007b, 'Comparative evaluation of myolaxin and EMLA cream for attenuation of venous cannulation pain: a prospective, randomised, double blind study', *Anaesthesia and Intensive Care*, vol. 35, pp. 726-729.

Alexander JI 1997, 'Pain after laparoscopy', *British Journal of Anaesthesia*, vol. 79, no. 3, pp. 369-378.

Ali BH & Al-Qarawi AA 2002, 'An evaluation of drugs used in the control of stressful stimuli in domestic animals: a review', *Acta Veterinaria Brno*, vol. 71, pp. 205-216.

Alldredge JG & Hendrickson DA 2004, 'Use of high-power ultrasonic shears for laparoscopic ovariectomy in mares', *Journal of the American Veterinary Medical Association*, vol. 225, pp. 1578-1580.

Anderson DE & Muir WW 2005, 'Pain management in ruminants', *Veterinary Clinics of North America Food Animal Practice*, vol. 21, pp. 19-31.

Anderson KL, Neff-Davis CA, Davis LE & Bass VD 1990, 'Pharmacokinetics of flunixin meglumine in lactating cattle after single and multiple intramuscular and intravenous administrations', *American Journal of Veterinary Research*, vol. 51, no. 9, pp. 1464-1467.

Annetta MG, Iemma D, Garisto C, Tafani C & Proietti R 2005, 'Ketamine: new indications for an old drug', *Current Drug Targets*, vol. 6, pp. 789-794.

Antonetti M, Kirton O, Bui P, Ademi A, Staff I, Hudson-Civetta JA & Lilly R 2007, 'The effects of preoperative rofecoxib, metoclopramide, dexamethasone, and ondansetron on postoperative pain and nausea in patients undergoing elective laparoscopic cholecystectomy', *Surgical Endoscopy*, vol. 21, no. 10, pp. 1855-1861.

Apley M 1997, 'Ancillary therapy of bovine respiratory disease', *Veterinary Clinics of North America Food Animal Practice*, vol. 13, no. 3, pp. 575-592.

Arambarri R, Cazieux A, Dickele G & Genevois JP 1975, 'De l'analgesie acupuncturale en chirugie veterinaire', *Revue de Medecine Veterinaire*, vol. 126, pp. 1231-1236.

Arcioni R, Palmisani S, Tigano S, Santorsola C, Sauli V, Romanò S, Mercieri M, Masciangelo R, De Blasi RA, & Pinto G 2007, 'Combined intrathecal and epidural magnesium sulfate supplementation of spinal anesthesia to reduce post-operative analgesic requirements: a prospective, randomized, double-blind, controlled trial in patients undergoing major orthopedic surgery', *Acta Anaesthesiologica Scandinavica*, vol. 51, pp. 482-489.

Argiriadou H, Himmelseher S, Papagiannopoulou, Georgiou M, Kanakoudis F, Giala M & Kochs E 2004, 'Improvement of pain treatment after major abdominal surgery with intravenous S+ ketamine', *Anesthesia and Analgesia*, vol. 98, pp. 1413-1418.

Armstrong P, Young C & McKeown D 1990, 'Ethyl chloride and venepuncture pain: a comparison with intradermal lidocaine', *Canadian Journal of Anesthesia*, vol. 37, pp. 656–658.

Arnemo JM & Søli NE 1993, 'Reversal of xylazine-induced sedation in dairy calves with atipamezole: a field trial', *Veterinary Research Communications*, vol. 17, pp. 305-312.

Aslani MR, Bazargani TT, Ashkar AA, Movasaghi AR, Raoofi A & Atiabi N 1998, 'Outbreak of tetanus in lambs', *The Veterinary Record*, vol. 142, no. 19, pp. 518-519.

Australian and New Zealand College of Anaesthetists 2005, *Acute pain management: scientific evidence*, Guidelines approved by the National Health and Medical Research Council at its 157th Session on 9 June 2005.

AVMA (American Veterinary Medical Association) 2006a, *Welfare implications of dehorning and disbudding of cattle*, October 10, 6 pp., accessed 10 January 2008, http://www.avma.org/issues/policy/default.asp.

AVMA (American Veterinary Medical Association) 2006b, *Welfare implications of the castration of cattle*, October 10, 7 pp., accessed 10 January 2008, http://www.avma.org/issues/policy/default.asp.

Bagley CP, Morrison DG, Feazel JI & Saxton AM 1989, 'Growth and sexual characteristics of suckling beef calves as influenced by age at castration and growth implants', *Journal of Animal Science,* vol. 67, pp. 1258-1264.

Baker AM & Gonyou HW 1986, 'Effects of zeranol implementation and late castration on sexual, agonistic and handling behavior in male feedlot cattle', *Journal of Animal Science,* vol. 62, pp. 1224-1232.

Balmer TV, Williams P & Selman IE 1997, 'Comparison of carprofen and flunixin meglumine as adjunctive therapy in bovine respiratory disease, *The Veterinary Journal*, vol. 154, no. 3, pp. 233-241.

Bamgbose BO, Akinwande JA, Adeyemo WL, Ladeinde AL, Arotiba GT & Ogunlewe MO 2005, 'Effects of co-administered dexamethasone and diclofenac potassium on pain, swelling and trismus following third molar surgery', *Head & Face Medicine*, vol. 1, p. 11.

Barkas P & Lundeberg T 2006, ‘Transcutaneous electrical nerve stimulation and acupuncture’, in SB McMahon & M Koltzenburg (eds), *Wall and Melzack's textbook of pain*, 5th edn, Elsevier/Churchill Livingstone, Philadelphia, pp 583-590.

Barnett SC, Sischo WM, Moore DA & Reynolds JP 2003, ’Evaluation of flunixin meglumine as an adjunct treatment for diarrhea in dairy calves’, *Journal of the American Veterinary Medical Association*, vol. 223, no. 9, pp. 1329-1333.

Baumgartner W & Kanis A 1983, ‘Die Anwendung der Akupunkturanalgesie bei Laparotomien an Kuhen’, *Wiener Tierarztliche Monatsschrift,* vol. 70, pp. 88-93.

Baxendale BR, Vater M & Lavery KM 1993, ‘Dexamethasone reduces pain and swelling following extraction of third molar teeth’, *Anaesthesia*, vol. 48, pp. 961–964.

Bednarek D, Kondracki M, Friton GM, Trela T & Niemczuk K 2005, ’Effect of steroidal and non-steroidal antiinflammatory drugs on inflammatory markers in calves with experimentally-induced bronchopneumonia’, *Berliner und Munchener Tierarztliche Wochenschrift*, vol. 118, no. 7/8, pp. 305-308.

Bednarek D, Zdzisinska B, Kondracki M & Kandefer-Szerszen M 2003, ‘Effect of steroidal and non-steroidal anti-inflammatory drugs in combination with long-acting oxytetracycline on non-specific immunity of calves suffering from enzootic bronchopneumonia’, *Veterinary Microbiology*, vol. 96, no. 1, pp. 53-67.

Bell RF 1999, ‘Low dose subcutaneous ketamine infusion and morphine tolerance’, *Pain*, vol. 83, pp. 101-103.

Bell RF, Dahl JB, Moore RA & Kalso E 2006, ‘Perioperative ketamine for acute postoperative pain’, *Cochrane Database of Systematic Reviews* (1): CD004603

Belloli A, Bertagnoli A, Morandi N, Bacchetta S, Pravettoni D 2007, ‘NSAIDs in cattle and pig practices: survey of clinical experiences on the use of ketoprofen’, *Rivista di Zootecnia e Veterinaria,* vol. 36, no. 1, pp. 19-27.

Bengtsson B, Menzel A, Holtenius P & Jacobsson S-O 1996, ‘Cryosurgical dehorning of calves: a preliminary study’, *The Veterinary Record,* no. 138, pp. 234-237.

Benitz AM 1984, ‘Pharmacology and pharmacokinetics of flunixin meglumine in cattle’, *Proceedings of the 13th World Congress on Diseases of Cattle*, Durban, South Africa, vol. 2, pp. 928-930.

Bertoni G, Trevisi E & Piccioli-Cappelli F 2004, ‘Effects of acetyl-salicylate used in post-calving of dairy cows’, *Veterinary Research Communications,* vol. 28 (supp 1), pp. 217-219.

Bhatia A, Kashyap L, Pawar DK & Trikha A 2004, ‘Effect of intraoperative magnesium infusion on perioperative analgesia in open cholecystectomy’, *Journal of Clinical Anesthesia*, vol. 16, pp. 262-265.

Bilir A, Gulec S, Erkan A & Ozcelik A 2007, 'Epidural magnesium reduces postoperative analgesic requirement', *British Journal of Anaesthesia,* vol. 98, no. 4, pp. 519-523.

Bingham HR, Wittum TE, Morley PS, Bray TM, Sarver CF, Queen WG & Shulaw WP 2000, 'Evaluation of the ability of orally administered aspirin to mitigate effects of 3-methylindole in feedlot cattle', *American Journal of Veterinary Research,* vol. 61, no. 10, pp. 1209-1213.

Birbicer H, Doruk N, Cinel I, Atici S, Avlan D, Bilgin E & Oral U 2007, 'Could adding magnesium as adjuvant to ropivacaine in caudal anaesthesia improve postoperative pain control?', *Pediatric Surgery International*, vol. 23, pp. 195-198.

Bisgaard T, Schulze S, Christian HN, Rosenberg J & Bjerregaard KV 2008, 'Randomized clinical trial comparing oral prednisone (50 mg) with placebo before laparoscopic cholecystectomy', *Surgical Endoscopy*, vol. 22, no. 2, pp. 566-572.

Bleul U, Hollenstein K & Kähn W 2005, 'Laparoscopic ovariectomy in standing cows', *Animal Reproduction Science*, vol. 90, pp. 193-200.

Boandl KE, Wohlt JE & Carsia RV 1989, 'Effects of handling, administration of a local anesthetic, and electrical dehorning on plasma cortisol in Holstein calves', *Journal of Dairy Science,* vol. 72, no. 8, pp. 2193-2197.

Bondok RS & Abd El-Hady AM 2006, 'Intra-articular magnesium is effective for postoperative analgesia in arthroscopic knee surgery', *British Journal of Anaesthesia*, vol. 97, pp. 389-392.

Bossut DF, Stromberg MW & Malven PV 1986, 'Electroacupuncture-induced analgesia in sheep: measurement of cutaneous pain thresholds and plasma concentrations of prolactin and beta-endorphin immunoreactivity', *American Journal of Veterinary Research, vol.* 47, pp. 669-676.

Boston SE, Moens NM, Kruth SA & Southorn EP 2003, 'Endoscopic evaluation of the gastroduodenal mucosa to determine the safety of short-term concurrent administration of meloxicam and dexamethasone in healthy dogs', *American Journal of Veterinary Research*, vol. 64, pp. 1369-1375.

Branson KR & Gross ME 2001, 'Opioid agonists and antagonists', in HR Adams (ed), *Veterinary pharmacology and therapeutics*, 8th edition, Iowa State Press, Ames IA, pp. 268-298.

Brearley JC, Dobson H & Jones RS 1990, 'Investigations into the effect of two sedatives on the stress response in cattle', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 13, pp. 367-377.

Breivik H, Curatolo M, Niemi HH, Kvarstein G, Romundstad L & Stubhaug A 2007, 'How to implement an acute postoperative pain service: an update', in H Breivik and M Shipley (eds), *Pain. Best practice & research compendium*, Elsevier, Edinburgh, pp 255-270.

Bretschneider G 2005, 'Effects of age and method of castration on performance and stress response of beef male cattle: A review', *Livestock Production Science*, vol. 97, pp. 89-100.

Brown K undated, *Branding cattle for identification and theft prevention*, Texas Longhorn Breeders Association of America, accessed 23 January 2008, http://www.tlbaa.org/faq/Branding-article.pdf.

Browne TG 1938, 'The technique of nerve-blocking for dehorning cattle', *The Veterinary Record*, vol. 50, pp. 1136-1137

Browning Jr. R, Landry SC & Wakefield T 1997, 'Evaluation of live animal and carcass yield traits in Holstein crossbred calves castrated at birth or weaning', *Journal of Animal Science,* vol. 75 (supp 1), p. 174.

Budd K 2003, 'Buprenorphine and the transdermal system: the ideal match in pain management', *International Journal of Clinical Practice*, vol. 133 (supp), pp. 9-14.

Butler WF 1967, 'Innervation of the horn region in domestic ruminants', *The Veterinary Record*, vol. 80, pp. 480-492.

Buvanendran A & Kroin JS 2007, 'Useful adjuvants for postoperative pain management', *Best Practice & Research Clinical Anaesthesiology*, vol. 21, no. 1, pp. 31-49.

Caillé G, du Souich P, Besner JG, Gervais P & Vézina M 1989, 'Effects of food and sucralfate on the pharmacokinetics of naproxen and ketoprofen in humans', *American Journal of Medicine*, vol. 86, no.6A, pp. 38-44.

Campbell KB, Klavano PA, Richardson P & Alexander JE 1979, 'Hemodynamic effects of xylazine in the calf', *American Journal of Veterinary Research*, vol. 40, pp. 1777-1780.

Caron JP & LeBlanc PH 1989, 'Caudal epidural analgesia in cattle using xylazine', *Canadian Journal of Veterinary Research*, vol. 53, pp. 486-489.

Carragher JF, Knight TW, Death AF, Fisher AD & Matthews LR 1997, 'Measures of stress and growth suppression in surgically castrated bulls', *Proceedings of the New Zealand Society of Animal Production,* vol. 57, pp. 100-104.

Carroll MA, Pearce JM, Basset JM, Gillard PB & Lawrence TLJ 1963, 'The effects of age of calves at castration on growth rate, carcass composition and feed efficiency', *Journal of Agriculture Science,* vol. 61, pp. 19-25.

Carroll GL, Howe LB & Peterson KD 2005, 'Analgesic efficacy of preoperative administration of meloxicam or butorphanol in onychectomized cats', *Journal of the American Veterinary Medical Association*, vol. 226, pp. 913-919.

Carter PD, Johnston NE, Corner LA & Jarrett RG 1983, 'Observations on the effect of electro-immobilisation on the dehorning of cattle', *Australian Veterinary Journal,* vol. 60, January, pp.17-19.

Castillo J, Curley J, Hotz J, Uezono M, Tigner J, Chasin M, Wilder R, Langer R & Berde C 1996, 'Glucocorticoids prolong rat sciatic nerve blockade in vivo from bupivacaine microspheres', *Anesthesiology*, vol. 85, pp. 1157-1166.

Catterall WA & Mackie K 2006, ‘Local anesthetics’, in LL Brunton, JS Lazo & KL Parker (eds), *Goodman & Gilman's The pharmacological basis of therapeutics*, 11th edn, McGraw-Hill, New York.

Caulkett N, Cribb PH & Duke T 1993a, ‘Xylazine epidural analgesia for cesarian section in cattle’, *Canadian Veterinary Journal*, vol. 34, pp. 674-676.

Caulkett NA, MacDonald DG, Janzen ED, Cribb PN & Fretz PB 1993b, ‘Xylazine hydrochloride epidural analgesia: a method of providing sedation and analgesia to facilitate castration of mature bulls’, *The Compendium on Continuing Veterinary Education for the Practicing Veterinarian*, vol. 15, no. 8, pp. 1155-1159.

Caulkett N, Read M, Fowler D & Waldner C 2003, ‘A comparison of the analgesic effects of butorphanol with those of meloxicam after elective ovariohysterectomy in dogs’, *Canadian Veterinary Journal,* vol. 44, pp. 565-570.

Chamberlain PL & Brynes SD 1998, ’The regulatory status of xylazine for use in food-producing animals in the United States’, *Journal of Veterinary Pharmacology and Therapeutics*, vol. 21, pp. 322–329.

Champagne JR, Carpenter JW, Hentges JF Jr, Palmer AZ & Koger M 1969, ‘Feedlot performance and carcass characteristics of young bulls and steers castrated at four ages’, *Journal of Animal Science*, vol. 29, pp. 887-890.

Chan WW, Chen KY, Liu H, Wu LS & Lin JH 2001, ‘Acupuncture for general veterinary practice’, *Journal of Veterinary Medical Science*, vol. 63, pp.1057-1062.

Chase CC Jr, Larsen RE, Randel RD, Hammond AC & Adams EL 1995, ‘Plasma cortisol and white blood cell responses in different breeds of bulls: a comparison of two methods of castration’, *Journal of Animal Science*, vol. 73, pp. 975-980.

Chen ACN, Dworkin SF & Haug J, 1989, ‘Topographic brain measures of human pain and pain responsivity’, *Pain,* vol. 37, pp. 129–41.

Chevalier HM, Provost PJ & Karas AZ 2004, ‘Effect of caudal epidural xylazine on intraoperative distress and post-operative pain in Holstein heifers’, *Veterinary Anaesthesia and Analgesia*, vol. 31, pp. 1-10.

Choi SH, Kang SS, Choi HS & Cho SK 1998, ‘The effect of fentazine-induced sedation in farmed elk (Cervus elaphus canadensis)’, *Korean Journal of Veterinary Clinical Medicine*, vol. 15, pp. 394-398.

Church JS & Church TL 2001, ‘Development of training programmes for velvet antler production and removal in Canada’, in JS Sim, HH Sunwoo , RJ Hudson & BT Jeong (eds), *Antler science and product technology*, Antler Science and Product Technology Research Centre, Edmonton, Canada, pp 427–432.

Clarke KW & Hall LW 1969, ‘Xylazine-a new sedative for horses and cattle’, *The Veterinary Record*, vol. 85, pp. 512-517.

Clarke-Lewis AV 1977, 'Bloodless castrator', *The Veterinary Record,* vol. 100, September, p. 215.

Coetzee JF, Gehring R, Bettenhausen AC, Lubbers BV, Toerber SE, Thomson DU, Kukanich B & Apley MD 2007, 'Attenuation of acute plasma cortisol response in calves following intravenous sodium salicylate administration prior to castration', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 30, no. 4, pp. 305-313.

Cokelaere SM, Martens AMJG & Wiemer P 2005, 'Laparoscopic ovariectomy in mares using a polyamide tie-rap', *Veterinary Surgery*, vol. 34, pp. 651-656.

Cohen RDH, King BD, Thomas LR & Janzen ED 1990, 'Efficacy and stress of chemical versus surgical castration of cattle', *Canadian Journal of Animal Science,* vol. 70, December, pp. 1063-1072.

Colbern GT & Reagan WJ 1987, 'Ovariectomy by colpotomy in mares', *The Compendium on Continuing Veterinary Education for the Practicing Veterinarian*, vol. 9, pp. 1035-1041.

Colbert ST, Moran K, O'Hanlon DM, Chambers F, Moriarty DC & Blunnie WP 2000, 'An assessment of the value of intraperitoneal meperidine for analgesia postlaparoscopic tubal ligation', *Anesthesia and Analgesia*, vol. 91, no.3, pp. 667-670.

Constable P 1991, 'Treatment of bacterial endocarditis in cattle', *Journal of the American Veterinary Medical Association*, vol 199, no. 3, pp. 299-301.

Cooper C, Evans ACO, Cook S & Rawlings NC 1995, 'Cortisol, progesterone and beta-endorphin response to stress in calves', *Canadian Journal of Animal Science,* vol. 95, pp. 197–201.

Cooper DW & Larsen E 2006, 'Immunocontraception of mammalian wildlife: ecological and immunogenetic issues', *Reproduction*, vol. 132, no. 6, pp. 821-828.

Correll GE, Maleki J, Gracely EJ, Muir JJ & Harbut RE 2004, 'Subanaesthetic ketamine infusion therapy: a retrospective analysis of a novel therapeutic approach to complex regional pain syndrome', *Pain Medicine*, vol. 5, pp. 26-75.

Court MH, Dodman NH, Levine HD, Richey MT, Lee JW & Hustead DR 1992, 'Pharmacokinetics and milk residues of butorphanol in dairy cows after single intravenous administration', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 15, no. 1, pp. 28-35.

Coventry J, McEwan D & Bertram JD 1989, 'Sterilisation of bulls with lactic acid', *Australian Veterinary Journal,* vol. 66, no. 5, pp. 156-157.

Cox JE 1977, 'Bloodless castrators', *The Veterinary Record*, vol. 100, November, pp. 431-432.

Crowe M 2006, *Review of literature on the relief of pain in livestock undergoing husbandry procedures*, final report of project AHW.120, Meat & Livestock Australia, North Sydney, December.

Curley J, Castillo J, Hotz J, Uezono M, Hernandez S, Lim JO, Tigner J, Chasin M, Langer R & Berde C 1996, 'Prolonged regional nerve blockade. Injectable biodegradable bupivacaine/polyester microspheres', *Anesthesiology*, vol. 84, pp. 1401-1410.

Curry SE & Finkel JC 2007, 'Use of the Synera patch for local anesthesia before vascular access procedures: a randomized, double-blind, placebo-controlled study', *Pain Medicine*, vol. 8, no. 6, pp. 497-502.

Dahl JB & Kehlet H 2006, 'Postoperative pain and its management', in SB McMahon & M Koltzenburg (eds), *Wall and Melzack's textbook of pain*, 5th edition, Elsevier/Churchill Livingstone, Philadelphia, pp 635-651.

Dechant JE & Hendrickson DA 2000, 'Standing female equine urogenital endoscopic surgery', *Veterinary Clinics of North America Equine Practice*, vol. 16, pp. 301-315.

DeGraves FJ, Riddel GM & Schumacher J 1995, 'Pharmacokinetics of ketoprofen in lactating dairy cows', *Proceedings of the Twenty Seventh Annual Convention American Association of Bovine Practitioners*, pp. 226-228.

DeGraves FJ, Riddell GM & Schumacher J 1996, 'Ketoprofen concentrations in plasma and milk after intravenous administration in dairy cattle', *American Journal of Veterinary Research,* vol. 57, no. 7, pp. 1031-1033.

Delatour P, Foot R, Foster AP, Baggot D & Lees P 1996, 'Pharmacodynamics and chiral pharmacokinetics of carprofen in calves', *British Veterinary Journal*, vol. 152, pp.183-198.

DeRossi R, Almeida RG, Medeiros U, Righetto FR & Frazílio FO 2007 'Subarachnoid butorphanol augments lidocaine sensory anaesthesia in calves', *The Veterinary Journal*, vol. 173, no. 3, pp. 658-663.

Denooy PP 1992, 'Clinical use of a bloodless castrator', *Canadian Veterinary Journal*, vol. 33, April, p. 218.

Dinniss AS, Stafford KJ, Mellor DJ, Bruce RA & Ward RN 1999, 'The behaviour pattern of lambs after castration using a rubber ring and/or castrating clamp with or without local anaesthetic', *New Zealand Veterinary Journal,* vol. 47, pp. 198-203.

Disney H 1999, *Meagher ovary flute*, United States patent no. 5,997,551, 7 December.

Dobromylskyj P, Flecknell PA, Lascelles BD, Pascoe PJ, Taylor P & Waterman-Pearson A 2000, 'Management of postoperative and other acute pain', in P Flecknell & A Waterman-Pearson (eds), *Pain management in animals*, WB Saunders, London, pp. 81-145.

D'Occhio MJ, Fordyce G, Whyte TR, Jubb TF, Fitzpatrick LA, Cooper NJ, Aspden WJ, Bolam MJ & Trigg TE 2002, 'Use of GnRH agonist implants for long-term suppression of fertility in extensively managed heifers and cows', *Animal Reproduction Science,* vol. 74, pp. 151-162.

Dodman NH, Levine H & Court MH 1992, 'Clinical assessment of analgesic effects of butorphanol in cattle', in CE Short and A van Poznak (eds), *Animal pain*, Churchill Livingstone, New York, pp. 396-399.

Doherty TJ, Kattesh HG, Adcock RJ, Welborn MG, Saxton AM, Morrow JL & Dailey JW 2007, 'Effects of concentrated lidocaine solution on the acute phase stress response to dehorning in dairy calves', *Journal of Dairy Science,* vol. 90, no. 9, pp. 4232-4239.

Dow SW, Rosychuk RA, McChesney AE & Curtis CR 1990, 'Effects of flunixin and flunixin plus prednisone on the gastrointestinal tract of dogs', *American Journal of Veterinary Research*, vol. 51, pp. 1131-1138.

Dräger C, Benziger D, Gao F & Berde CB 1998, 'Prolonged intercostal nerve blockade in sheep using controlled-release of bupivacaine and dexamethasone from polymer microspheres', *Anesthesiology*, vol. 89, pp. 969-979.

Drillich M, Voigt D, Forderung D & Heuwieser W 2007, 'Treatment of acute puerperal metritis with flunixin meglumine in addition to antibiotic treatment', *Journal of Dairy Science,* vol. 90, no.8, pp. 3758-3763.

Dubé L & Granry JC 2003, 'The therapeutic use of magnesium in anesthesiology, intensive care and emergency medicine: a review', *Canadian Journal of Anesthesia,* vol. 50, pp. 732-746.

Dumka VK & Srivastava AK 2004, 'Disposition kinetics, urinary excretion and dosage regimen of meloxicam in crossbred calves after single subcutaneous injection', *Indian Journal of Animal Sciences*, vol. 74, no. 6, pp. 586-589.

Düsterdieck KF, Pleasant RS, Lanz OI, Saunders G & Howard RD 2003, 'Evaluation of the harmonic scalpel for laparoscopic bilateral ovariectomy in standing horses', *Veterinary Surgery*, vol. 32, pp. 242-250.

Dzikiti TB, Joubert KE, Venter LJ & Dzikiti LN 2006, 'Comparison of morphine and carprofen administered alone or in combination for analgesia in dogs undergoing ovariohysterectomy', *Journal of the South African Veterinary Association*, vol. 77, pp. 120-126.

Earley B & Crowe MA 2002, 'Effects of ketoprofen alone or in combination with local anesthesia during the castration of bull calves on plasma cortisol, immunological, and inflammatory responses', *Journal of Animal Science*, vol. 80, pp. 1044-1052.

Edwards B 2001, 'Regional anaesthesia techniques in cattle' *In Practice*, vol. 23, pp. 142-149.

Edwards DS & Johnston AM 1999, 'Welfare implications of sheep ear tags', *The Veterinary Record,* vol. 144, pp. 603-606.

Egger CM, Glerum L, Michelle Haag K & Rohrbach BW 2007, 'Efficacy and cost-effectiveness of transdermal fentanyl patches for the relief of post-operative pain in dogs after anterior cruciate ligament and pelvic limb repair', *Veterinary Anaesthesia and Analgesia*, vol. 34, no. 3, pp. 200-208.

Eichner RD, Prior RL & Kvasnicka WG 1979, 'Xylazine-induced hyperglycemia in beef cattle', *American Journal of Veterinary Research*, vol. 40, pp. 127-129.

Eide PK 2000, 'Wind-up and the NMDA receptor complex from a clinical perspective', *European Journal of Pain*, vol. 4, pp. 5-15.

Eidelman A, Weiss JM, Lau J & Carr DB 2005, 'Topical anesthetics for dermal instrumentation: a systematic review of randomized, controlled trials', *Annals of Emergency Medicine*, vol. 46, no. 4, pp. 343-351.

Elia N & Tramer MR 2005, 'Ketamine and postoperative pain - a quantitative systematic review of randomised trials' *Pain*, vol. 113, pp. 61-70.

Elitok B & Elitok OM 2004, 'Clinical efficacy of carprofen as an adjunct to the antibacterial treatment of bovine respiratory disease', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 27, no. 5, pp. 317-320.

Embertson RM & Bramlage LR 1992, 'Clinical uses of the laparoscope in general equine practice', *Proceeding of the American Association of Equine Practice*, vol. 38, pp. 165-169.

Eshra AG, Etman MA & Naggar VF 1988, 'Effect of milk and food on the bioavailability of ketoprofen in man', *International Journal of Pharmaceutics,* vol. 44, nos. 1-3, pp. 9-14.

Estebe JP, Le Corre P, Clément R, Du Plessis L, Chevanne F, Le Verge R & Ecoffey C 2003, 'Effect of dexamethasone on motor brachial plexus block with bupivacaine and with bupivacaine-loaded microspheres in a sheep model', *European Journal of Anaesthesiology,* vol. 20, pp. 305-310.

Evans AM 1992, 'Enantioselective pharmacodynamics and pharmacokinetics of chiral non-steroidal anti-inflammatory drugs', *European Journal of Clinical Pharmacology*, vol. 42, pp. 237–256.

Evans HC & Easthope SE 2003, 'Transdermal buprenorphine', *Drugs*, vol. 63, no. 19, pp. 1999-2010.

Eyre P, Nymeyer DH, McCraw BM & Deline TR 1976, 'Protection by acetylsalicylic acid and other agents in experimental acute interstitial pneumonia of calves', *The Veterinary Record*, vol. 98, no. 4, pp. 64-66.

Ezeh UO, Shoulder VS, Martin JL, Breeson AJ, Lamb MD & Vellacott ID 1995, 'Local anaesthetic on Filshie clips for pain relief after tubal sterilisation: a randomised double-blind controlled trial', *Lancet* , vol. 346, no. 8967, pp. 82-85.

Falk M 2004, 'Pain-free castration: solutions in sight', *SFVO* [Swiss Federal Veterinary Office] *Magazine*, no. 2, pp. 24-26, accessed 30 November 2007, http://www.bvet.admin.ch.

Farm Sanctuary undated, *The welfare of cattle in beef production: a summary of the scientific evidence*, Watkins Glen, New York, 18 pp.

Farstvedt EG & Hendrickson DA 2005, ‘Intraoperative pain responses following intraovarian versus mesovarian injection of lidocaine in mares undergoing laparoscopic ovariectomy’, *Journal of the American Veterinary Medical Association,* vol. 227, pp. 593-596.

Faulkner DB, Eurell T, Tranquilli WJ, Ott RS, Ohl MW, Cmarik GF & Zinn G 1992, ‘Performance and health of weanling bulls after butorphanol and xylazine administration at castration’, *Journal of Animal Science*, vol. 70, pp. 2970-2974.

Faulkner PM & Weary DM 2000, ‘Reducing pain after dehorning in dairy calves’, *Journal of Dairy Science,* vol. 83, no. 9, pp 2037-2041.

Fayed AH, Abdalla EB, Anderson RR, Spencer K & Johnson HD 1989, ‘Effect of xylazine in heifers under thermoneutral or heat stress conditions’, *American Journal of Veterinary Research,* vol. 50, pp. 151-153.

Fell LR, Wells R & Shutt DA 1986, ‘Stress in calves castrated surgically or by the application of rubber rings’, *Australian Veterinary Journal,* vol. 63, no. 1, pp. 16-18.

Fenton BK, Elliot J & Campbell RC 1958, ‘The effects of different castration methods on the growth and well-being of calves’, *The Veterinary Record*, vol. 70, no. 5, pp. 101-103.

Fenwick DC & Daniel RCW 1996, ‘Evaluation of the effect of ketoprofen on experimentally induced ephemeral fever in dairy heifers’ *Australian Veterinary Journal*, vol. 74, no. 1, pp. 37-41.

Fierheller EE, Caulkett NA & Bailey JV 2004, ‘A romifidine and morphine combination for epidural analgesia of the flank in cattle’, *Canadian Veterinary Journal,* vol. 45, pp. 917-923.

Fiddes TM, Williams HW & Herbison GP 1996, ‘Evaluation of post-operative analgesia following laparoscopic application of Filshie clips’, *British Journal of Obstetrics and Gynaecology* , vol. 103, no. 11, pp. 1143-1147.

Fisher AD, Crowe MA, Alonso de la Varga ME & Enright WJ 1996, ‘Effect of castration method and the provision of local anesthesia on plasma cortisol, scrotal circumference, growth, and feed intake of bull calves’, *Journal of Animal Science,* vol. 74, pp. 2336-2343.

Fisher AD, Crowe MA, Ó’Nualláin EM, Monaghan ML, Larkin JA, O’Kiely P & Enright WJ 1997a, ‘Effects of cortisol on in vitro interferon-γ production, acute-phase proteins, growth, and feed intake in a calf castration model’, *Journal of Animal Science,* vol. 75, pp. 1041-1047.

Fisher AD, Crowe MA, Ó’Nualláin EM, Monaghan ML, Prendiville DJ, O’Kiely P & Enright WJ 1997b, ‘Effects of suppressing cortisol following castration of bull calves on adrenocorticotropic hormone, in vitro interferon-γ production, leukocytes, acute-phase proteins, growth, and feed intake’, *Journal of Animal Science,* vol. 75, 1899-1908.

Fisher AD, Knight TW, Cosgrove GP, Death AF, Anderson CB, Duganzich DM & Matthews LR 2001, ‘Effects of surgical or banding castration on stress responses and behaviour of bulls’, *Australian Veterinary Journal*, vol. 79, no. 4, pp. 279-284.

Fitzgerald M & Howard RF 2002, 'The neurobiologic basis of paediatric pain', in NL Schecter, CB Berde & M Yaster (eds), *Pain in infants, children and adolescents,* Lippincott Williams and Wilkins, Baltimore, pp. 19–42.

Fitzgerald M & Walker S 2003, 'The role of activity in developing pain pathways', in JO Dostrovsky, DB Carr & M Koltzenburg (eds), *Proceedings of the 10th World Congress on Pain. Progress in pain research and management*, vol. 24, IASP Press, Seattle, pp185-196.

Fletcher J 1974, 'Hypersensitivity of an isolated population of red deer (Cervus elaphus) to xylazine', *The Veterinary Record*, vol. 94, pp. 85-86.

Fordyce G, Hodge PB, Beaman NJ, Lang AR, Campero C & Shepherd RK 1989, 'An evaluation of calf castration by intra-testicular injection of lactic acid solution', *Australian Veterinary Journal,* vol. 66, no. 9, pp. 272-276.

Forrest JB, Camu F, Greer IA, Kehlet H, Abdalla M, Bonnet F, Ebrahim S, Escolar G, Jage J, Pocock S, Velo G, Langman MJ, Bianchi PG, Samama MM & Heitlinger E; POINT Investigators 2002, 'Ketorolac, diclofenac, and ketoprofen are equally safe for pain relief after major surgery', *British Journal of Anaesthesia*, vol. 88, no. 2, vol. 227-233.

Friend TH, Lay DC, Bushong DM & Pierce DW 1994, 'Wisconsin's 'stale calf' issue and a study designed to resolve some of the animal welfare concerns', *Journal of Animal Science,* vol. 72, pp. 2260-2263.

Fresno L, Moll J, Peñalba B, Espada Y, Andaluz A, Prandi D, Ruiz de Gopegui R & García F 2005, 'Effects of preoperative administration of meloxicam on whole blood platelet aggregation, buccal mucosal bleeding time, and haematological indices in dogs undergoing elective ovariohysterectomy' *The Veterinary Journal,* vol. 170, pp. 138-140.

Frisch JE, Nishimura H, Cousins KL & Turner HG 1980, 'The inheritance and effect on production of polledness in four crossbred lines of beef cattle', *Animal Production,* vol. 31, pp. 119-126.

Friton GM, Cajal C & Ramirez-Romero R 2005, 'Long-term effects of meloxicam in the treatment of respiratory disease in fattening cattle', *The Veterinary Record*, vol. 156, no. 25, pp. 809-811.

Friton GM, Cajal C, Ramirez Romero R & Kleemann R 2004, 'Clinical efficacy of meloxicam (Metacam(R)) and flunixin (Finadyne(R)) as adjuncts to antibacterial treatment of respiratory disease in fattening cattle', *Berliner und Munchener Tierarztliche Wochenschrift,* vol. 117, no. 7/8, pp. 304-309.

Gammaitoni AR, Alvarez NA & Galer BS 2003, 'Safety and tolerability of the lidocaine patch 5%, a targeted peripheral analgesic: a review of the literature', *Journal of Clinical Pharmacology*, vol. 43, no. 2, pp. 111-117.

Gammaitoni AR, Galer BS, Onawola R, Jensen MP & Argoff CE 2004, 'Lidocaine patch 5% and its positive impact on pain qualities in osteoarthritis: results of a pilot 2-week, open-label study using the Neuropathic Pain Scale', *Current Medical Research and Opinion*, vol. 20 Suppl 2, pp. S13-S19.

Garber MJ, Roeder RA, Combs JJ, Eldridge L, Miller JC, Hinman DD & Ney JJ 1990, ‘Efficacy of vaginal spaying and anabolic implants on growth and carcass characteristics in beef heifers’, *Journal of Animal Science,* vol. 68, pp. 1469-1475.

Garcia-Villar R, Toutain PL, Alvinerie M & Ruckebusch Y 1981, ‘The pharmacokinetics of xylazine hydrochloride: an interspecific study’, *Journal of Veterinary Pharmacology and Therapeutics*, vol. 4, pp. 87-92.

Garwood S, Reeder M, Mackenzie IZ & Guillebaud J 2002 ‘Tubal surface lidocaine mediates pre-emptive analgesia in awake laparoscopic sterilization: a prospective, randomized clinical trial’, *American Journal of Obstetrics and Gynecology*, vol. 186, no. 3, pp. 383-388.

Gassel AD, Tobias KM, Egger CM & Rohrbach BW 2005, ‘Comparison of oral and subcutaneous administration of buprenorphine and meloxicam for preemptive analgesia in cats undergoing ovariohysterectomy’, *Journal of the American Veterinary Medical Association*, vol. 227, no. 12, pp. 1937-1944.

Gaynor JS 2002, ‘Other drugs used to treat pain’, in JS Gaynor and WW Muir (eds), *Handbook of veterinary pain management*, Mosby, St Louis, pp 251-260.

George LW 2003, ‘Pain control in food animals’, in EP Steffey (ed), *Recent advances in anesthetic management of large domestic animals*, International Veterinary Information Service (IVIS), Ithaca NY.

Gibson TJ, Johnson CB, Stafford KJ, Mitchinson SL & Mellor DJ 2007, ‘Validation of the acute electroencephalographic responses of calves to noxious stimulus with scoop dehorning’, *New Zealand Veterinary Journal,* vol. 55, no. 4, pp. 152-157.

Gingerich DA, Baggot JD & Yeary RA 1975, ‘Pharmacokinetics and dosage of aspirin in cattle’, *Journal of the American Veterinary Medical Association*, vol. 167, no. 10, pp. 945-948.

Glerum LE, Egger CM, Allen SW & Haag M 2001, ’Analgesic effect of the transdermal fentanyl patch during and after feline ovariohysterectomy’, *Veterinary Surgery*, vol. 30, no. 4, pp. 351-358.

Goonewardene LA & Hand RK 1991, ‘Studies on dehorning steers in Alberta feedlots’, *Canadian Journal of Animal Science*, vol. 71, December, pp. 1249-1252.

Goonewardene LA, Price MA, Okine E & Berg RT 1999, ‘Behavioural responses to handling and restraint in dehorned and polled cattle’, *Applied Animal Behaviour Science,* vol. 64, pp. 159-167.

Graf B & Senn M 1999, ‘Behavioural and physiological responses of calves to dehorning by heat cauterization with or without local anaesthesia’, *Applied Animal Behavioural Science,* vol. 62, pp. 153-171.

Greene SA & Thurmon JC 1988, ‘Xylazine – a review of its pharmacology and use in veterinary medicine’, *Journal of Veterinary Pharmacology and Therapeutics*, vol. 11, pp. 295-313.

Grøndahl-Nielsen C, Simonsen HB, Damkjer Lund J & Hesselholt M 1999, 'Behavioural, endocrine and cardiac responses in young calves undergoing dehorning without and with use of sedation and analgesia', *The Veterinary Journal,* vol. 158, pp. 14-20.

Gross ME 2001, 'Tranquilizers, α_2-adrenergic agonists, and related agents', in HR Adams (ed), *Veterinary pharmacology and yherapeutics*, 8th edn, Iowa State Press, Ames IA, pp 299-342.

Grunau RV 2000, 'Long-term consequences of pain in human neonates', in KJS Anand, BJ Stevens & PJ McGrath (eds), *Pain research and clinical management*, vol. 10, Elsevier, Amsterdam, pp 55-76.

Guard CL & Schwark WS 1984, 'Influence of yohimbine on xylazine-induced depression of central nervous, gastrointestinal and cardiovascular function in the calf', *The Cornell Veterinarian*, vol. 74, pp. 312-321.

Guard C, Schwark W, Kelton D & Dobson A 1988, 'Effects of metoclopramide, clenbuterol and butorphanol on ruminoreticular motility of calves', *The Cornell Veterinarian,* vol. 78, no. 1, pp. 89-98.

Guyton AC 1986, *Textbook of medical physiology,* 7th edition, Igaku-Shoin/Saunders International Edition, Philadelphia.

Habacher G, Pittler MH & Ernst E 2006, 'Effectiveness of acupuncture in veterinary medicine: systematic review', *Journal of Veterinary Internal Medicine*, vol. 20, pp. 480-488.

Habermehl NL 1993, 'Heifer ovariectomy using the Willis spay instrument: Technique, morbidity and mortality', *Canadian Veterinary Journal,* vol. 34, pp. 664-667.

Haga HA & Ranheim B 2005, 'Castration of piglets; the analgesic effect of an intratesticular or intrafunicular injection of lidocaine', *Veterinary Anaesthesia and Analgesia,* vol. 32, pp. 1–9.

Haga HA, Lykkjen S, Revold T & Ranheim B 2006, 'Effect of intratesticular injection of lidocaine on cardiovascular responses to castration in isoflurane-anesthetized stallions', *American Journal of Veterinary Research*, vol. 67, pp. 403-408.

Haltrecht H 1999, 'Veterinary acupuncture', *Canadian Veterinary Journal*, vol. 40, pp. 401-403.

Hand R, Rakestraw P & Taylor T 2002, 'Evaluation of a vessel-sealing device for use in laparoscopic ovariectomy in mares', *Veterinary Surgery,* vol. 31, pp. 240-244.

Hanson CA & Galuppo LD 1999, 'Bilateral laparoscopic ovariectomy in standing mares: 22 cases', *Veterinary Surgery*, vol. 28, pp. 106-112.

Hardee GE, Smith JA & Harris SJ 1985, 'Pharmacokinetics of flunixin meglumine in the cow', *Research in Veterinary Science,* vol. 39, no. 1, pp. 110-112.

Hardy CM & Braid AL 2007, 'Vaccines for immunological control of fertility in animals', *Revue Scientifique et Technique*, vol. 26, no. 2, pp. 461-470.

Hare D 1999, ‘Complementary and alternative veterinary medicine’, *Canadian Veterinary Journal,* vol. 40, pp. 376-377.

Hartstein BH & Barry JD 2008, ‘Mitigation of pain during intravenous catheter placement using a topical skin coolant in the emergency department’, *Emergency Medicine Journal*, vol. 25, pp. 257-261.

Hegi TR, Bombeli T, Seifert B, Baumann PC, Haller U, Zalunardo MP, Pasch T & Spahn DR 2004, ‘Effect of rofecoxib on platelet aggregation and blood loss in gynaecological and breast surgery compared with diclofenac’, *British Journal of Anaesthesia,* vol. 92, pp. 523–531.

Heinrich A, Duffield T, Lissemore K & Millman ST 2007, ‘Behaviour and pain sensitivity of dairy calves following dehorning and the efficacy of meloxicam in relieving the pain response’ (abstract of oral paper), *Proceedings of the 41st international Congress of the ISAE*, International Society for Applied Ethology, Edinburgh, p. 35.

Heinrich A, Duffield T, Lissemore K, Squires EJ & Millman ST 2007, ‘The efficacy of meloxicam at relieving the pain response to dehorning in dairy calves’, abstract submitted for American Dairy Science Association Conference, supplied by Suzanne Millman 22 January 2008.

Heinrich A, Millman ST, Duffield TF, Lissemore KD & Squires EJ 2008, ‘An investigation of meloxicam for pain relief following dehorning of dairy calves’, abstract submitted for XXVth World Buiatrics Conference, supplied by Suzanne Millman 22 January 2008.

Herndon CM 2007, ‘Iontophoretic drug delivery system: focus on fentanyl’, *Pharmacotherapy,* vol. 27, no. 5, pp. 745-754.

Hikasa Y, Takase K, Emi S & Ogasawara S 1988, ‘Antagonistic effects of alpha-adrenoceptor blocking agents on reticuloruminal hypomotility induced by xylazine in cattle’, *Canadian Journal of Veterinary Research*, vol. 52, pp. 411-415.

Hill GM, Neville Jr. WE, Richardson KL, Utley PR & Stewart RL 1985, ‘Castration method and progesterone-estradiol implant effects on growth rate of suckling calves’, *Journal of Dairy Science,* vol. 68, pp. 3059-3061.

Hinch GN & Lynch JJ 1987, ‘A note on the effect of castration on the ease of movement and handling of young cattle in yards’ *Animal Production,* vol. 45, pp. 317-320.

Hinton M 1977, ‘Bloodless castrators’, *The Veterinary Record,* vol. 100, October, pp. 351-352.

Hiraoka M, Miyagawa T, Kobayashi H, Takahashi T, Kishi H, Kobayashi H & Lee I 2007, ‘Successful introduction of modified dorsolumbar epidural anesthesia in a bovine referral center’, *Journal of Veterinary Science*, vol. 8, pp. 181-184.

Hodgkinson O & Dawson L 2007, ‘Practical anaesthesia and analgesia in sheep, goats and calves’, *In Practice,* vol. 29, November/December, pp. 596-603.

Hodgson DS, Dunlop CI, Chapman PL & Smith JA 2002, 'Cardiopulmonary effects of xylazine and acepromazine in pregnant cows in late gestation', *American Journal of Veterinary Research*, vol. 63, pp. 1695-1699.

Hofmeister EH & Egger CM 2004, 'Transdermal fentanyl patches in small animals', *Journal of the American Animal Hospital Association*, vol. 40, no. 6, pp. 468-478.

Holte K, Werner MU, Lacouture PG & Kehlet H 2002, 'Dexamethasone prolongs local analgesia after subcutaneous infiltration of bupivacaine microcapsules in human volunteers', *Anesthesiology* , vol. 96, pp. 1331-1335.

Honarmand A & Safavi M 2008, 'Magnesium sulphate pre-treatment to alleviate pain on propofol injection: a comparison with ketamine or lidocaine', *Acute Pain*, vol. 10, pp. 23-29.

Hooper RN, Taylor TS, Varner DD & Blanchard TL 1993, 'Effects of bilateral ovariectomy via colpotomy in mares: 23 cases (1984-1990)', *Journal of the American Veterinary Medical Association*, vol. 203, pp. 1043-1046.

Hopkins TJ 1972, 'The clinical pharmacology of xylazine in cattle', *Australian Veterinary Journal*, vol. 48, pp. 109-112.

Hosie B 1995, 'Problems with the use of ear tags in sheep', *The Veterinary Record,* vol. 137, no. 22, p. 571.

Hsu WH & Hummel SK 1981, 'Xylazine-induced hyperglycemia in cattle: a possible involvement of alpha 2-adrenergic receptors regulating insulin release', *Endocrinology,* vol. 109, pp. 825-829.

Hung OR, Comeau L, Riley MR, Tan S, Whynot S & Mezei M 1997, 'Comparative topical anaesthesia of EMLA and liposome-encapsulated tetracaine', *Canadian Journal of Anesthesia*, vol. 44, pp.707-711.

Hutt AJ & Caldwell J 1983, 'The metabolic chiral inversion of 2-arylpropionic acids – a novel route with pharmacological consequences', *Journal of Pharmacy and Pharmacology*, vol. 35, pp. 693-704.

Hval K, Thagaard KS, Schlichting E & Raeder J 2007, 'The prolonged postoperative analgesic effect when dexamethasone is added to a nonsteroidal antiinflammatory drug (rofecoxib) before breast surgery', *Anesthesia and Analgesia*, vol. 105, no. 2, pp. 481-486.

Igarza L, Soraci A, Auza N & Zeballos H 2002, 'Chiral inversion of (R)-ketoprofen: influence of age and differing physiological status in dairy cattle', *Veterinary Research Communications,* vol. 26, no. 1, pp. 29-37.

Igarza L, Soraci A, Auza N & Zeballos H 2004, 'Some pharmacokinetic parameters of R-(-)- and S-(+)-ketoprofen: the influence of age and differing physiological status in dairy cattle', *Veterinary Research Communications*, vol. 28, no. 1, pp. 81-87.

Irwin J & Walker B 1998, *Dehorning cattle*, agfact series A0.2.4 second edition, last updated 1 September 1998, Department of Primary Industries, Sydney.

Jago JG, Matthews L, Bass JJ & Knight TW 1996, 'A comparison of two methods of castration of post-pubertal beef cattle and their effect on behaviour, growth and ultimate pH', *Proceedings of the New Zealand Society of Animal Production,* vol. 56, pp. 394-397.

Jago JG, Cox NR, Bass JJ & Matthews L 1997, 'The effect of prepubertal immunization against gonadotropin-releasing hormone on the development of sexual and social behavior of bulls', *Journal of Animal Science,* vol. 75, pp. 2609-2619.

Jeal W & Benfield P 1997, 'Transdermal fentanyl. A review of its pharmacological properties and therapeutic efficacy in pain control', *Drugs*, vol. 53, no. 1, pp. 109-138.

Jedziniak P, Szprengier-Juszkiewicz T, Olejnik M & Jaroszewski J 2007, 'Determination of flunixin and 5-hydroxyflunixin in bovine plasma with HPLC-UV-method development, validation and verification', *Bulletin of the Veterinary Institute in Pulawy,* vol. 51, no. 2, pp. 261-266.

Jeffery M, Loxton I, Van der Mark S, James T, Shorthose R, Bell K & D'Occhio M 1997, 'Liveweight gains, and carcass and meat characteristics of entire, surgically spayed or immunologically spayed beef heifers', *Australian Journal of Experimental Agriculture,* vol. 37, pp. 719-726.

Jenkins WJ 1987, 'Pharmacological aspects of analgesic drugs in animals: an overview', *Journal of the American Veterinary Medical Association,* vol. 191, pp. 1231-1240.

Johnson CB, Stafford KJ, Sylvester SP, Ward RN, Mitchinson S & Mellor DJ 2005a, 'Effects of age on the electroencephalographic response to castration in lambs anaesthetised using halothane in oxygen', *New Zealand Veterinary Journal*, vol. 53, pp. 433-437.

Johnson CB, Wilson PR, Woodbury MR & Caulkett NA 2005b, 'Comparison of analgesic techniques for antler removal in halothane-anaesthetized red deer (Cervus elaphus): electroencephalographic responses', *Veterinary Anaesthesia and Analgesia*, vol.32, pp. 61-71.

Johnston JD & Buckland RB 1976, 'Response of male Holstein calves from seven sires to four management stresses as measured by plasma corticoid levels', *Canadian Journal of Animal Science,* vol.56, December, pp. 727-732.

Johnston AM & Edwards DS 1996, 'Welfare implications of identification of cattle by ear tags', *The Veterinary Record,* vol. 138, no. 25, pp.612-614.

Jones RS 1972, 'A review of tranquillisation and sedation in large animals', *The Veterinary Record*, vol. 90, no. 22, pp. 613-617.

Jones RS 1995, 'Anaesthesia in cattle (II) – regional and local analgesia', *Bovine Practitioner*, vol. 29, pp. 13-21.

Jubb TF, Fordyce G, Bolam MJ, Hadden DJ, Cooper NJ, Whyte TR, Fitzpatrick LA, Hill F & D'Occhio MJ 2003, 'Trial introduction of the Willis dropped ovary technique for spaying cattle in northern Australia', *Australian Veterinary Journal,* vol. 81, no. 1 & 2, pp. 66-70.

Kaemmerer K & Kietzmann M 1984, ‘Studies on magnesium. 3. Influence of magnesium aspartate hydrochloride on the stress reactions in animals with magnesium deficiency’, *Zentralbl Veterinarmed A*, vol. 31, pp. 334-339.

Kaemmerer K, Kietzmann M & Kreisner M 1984, ’Studies on magnesium. 2. Effect of magnesium chloride and magnesium aspartate hydrochloride on stress reactions’, *Zentralbl Veterinarmed A*, vol. 31, pp. 321-333.

KAHD (Kansas Animal Health Department) undated, *Helpful information about brands and branding*, accessed 20 January 2008, http://www.kansas.gov/kahd/pdf/forms/brands/brands_hints.pdf.

Kanis A 1982, ‘Ein Beitrag zur Anwendung der Akupunkturanalgesia bei Laparotomie an Kuhen’, *Wiener Tierarztliche Monatsschrift*, vol. 69, pp.171-172.

Kara H, Sahin N, Ulusan V & Aydogdu T 2002, ’Magnesium infusion reduces perioperative pain’, *European Journal of Anaesthesiology*, vol.19, pp. 52-56.

Kazakos GM, Papazoglou LG, Rallis T, Tsimopoulos G, Adamama-Moraitou K & Tea A 2005, ‘Effects of meloxicam on the haemostatic profile of dogs undergoing orthopaedic surgery’, *The Veterinary Record*, vol. 157, pp. 444-446.

Keane MG 1999, ‘Effects of time of complete or split castration on performance of beef cattle’, *Irish Journal of Agricultural and Food Research*, vol. 38, no. 1, pp. 41-51.

Keita A, Pommier P, Pagot E, Couper A & Cromie L 2007, ‘A combination oxytetracycline/flunixin treatment of respiratory infections in cattle’, *Revue de Médecine Vétérinaire*, vol. 158, no. 2, pp. 86-91.

Kelly MC 1996, ‘An assessment of the value of intraperitoneal bupivacaine for analgesia after laparoscopic sterilisation’, *British Journal of Obstetrics and Gynaecology*, vol. 103, no. 8, pp.837-839.

Kent JE, Molony V & Robertson IS 1995, ‘Comparison of Burdizzo and rubber ring castration and tail docking of lambs’, *The Veterinary Record,* vol. 136, pp. 192-196.

Kent JE, Thursfield MV, Robertson IS & Molony V 1996, ‘Castration of calves: a study of methods used by farmers in the United Kingdom’, *The Veterinary Record,* vol. 138, April, pp.384-387.

Kietzmann K & Jablonski H 1985, ‘Zur Stressabschirmung mit magnesiumaspartat hydrochlorid beim Schwein’, *Prakt Tierarzt*, vol. 66, pp. 331-335.

Kihurani DO, Mbiuki SM & Ngatia TA 1989, ‘Healing of dehorning wounds’, *British Veterinary Journal,* vol. 145, no. 6, pp.580-585.

Kim DH, Cho SH, Song KH, Lee SE, Lee SH, Kwon GO, Kim IB, Kim YC, Cho JH, Kwon YY & Kim JW 2004, ‘Electroacupuncture analgesia for surgery in cattle’, *American Journal of Chinese Medicine,* vol. 32, pp. 131-140.

Kim DH, Liu JZ, MacManus P, Jennings P, Darcy K, Burke F, Slattery G & Rogers PAM 2006, 'Injection-acupuncture with dexamethasone and modified moxibustion treatment of a downer cow', *Journal of Veterinary Clinics*, vol. 23, pp. 69-71.

Kimberling CV & Rupp GP 1980, *Apparatus for spaying large animals*, United States patent no. 4,220,155, 2 September.

King BD, Cohen RDH, Guenther CL & Janzen ED 1991, 'The effect of age and method of castration on plasma cortisol in beef calves', *Canadian Journal of Animal Science*, vol. 71, June, pp. 257-263.

Kitzman JV, Booth NH, Hatch RC & Wallner B 1982, 'Antagonism of xylazine sedation by 4-aminopyridine and yohimbine in cattle', *The American Journal of Veterinary Research*, vol. 43, pp. 2165-2169.

Klide AM 1992, 'Acupuncture-produced surgical analgesia. Physiology, indications, techniques, and limitations', *Problems in Veterinary Medicine*, vol. 4, pp. 200-206.

Knight TW, Cosgrove GP, Death AF & Anderson CB 1999, 'Effect of interval from castration of bulls to slaughter on carcass characteristics and meat quality', *New Zealand Journal of Agricultural Research,* vol. 42, pp. 269-277.

Knight TW, Cosgrove GP, Death AF & Anderson CB 2000, 'Effect of method of castrating bulls on their growth rate and liveweight', *New Zealand Journal of Agricultural Research,* vol. 43, pp. 187-192.

Ko SH, Lim HR, Kim DC, Han YJ, Choe H & Song HS 2001, 'Magnesium sulfate does not reduce postoperative analgesic requirements', *Anesthesiology,* vol. 95, pp. 640-646.

Koetsawang S, Srisupandit S, Apimas SJ & Champion CB 1984, 'A comparative study of topical anesthesia for laparoscopic sterilization with the use of the tubal ring', *American Journal of Obstetrics and Gynecology*, vol. 150, no. 8, pp. 931-933.

Koger LM 1976, 'Dehorning by injection of calcium chloride', *Veterinary Medicine, Small Animal Clinician*, vol. 71, p. 824.

Kohrs R & Durieux ME 1998, 'Ketamine: teaching an old drug new tricks', *Anesthesia and Analgesia,* vol. 87, pp. 1186-1193.

Koinig H, Wallner T, Marhofer P, Andel H, Hörauf K & Mayer N 1998, 'Magnesium sulfate reduces intra- and postoperative analgesic requirements', *Anesthesia and Analgesia*, vol. 87, pp. 206-210.

Kokki H, Tuomilehto H & Karvinen M 2001, 'Pharmacokinetics of ketoprofen following oral and intramuscular administration in young children', *European Journal of Clinical Pharmacology*, vol. 57, no. 9, pp. 643-647.

Koo PJ 2005, 'Postoperative pain management with a patient-controlled transdermal delivery system for fentanyl', *American Journal of Health-System Pharmacy*, vol. 62, no. 11, pp. 1171-1176.

Kopacz DJ, Bernards CM, Allen HW, Landau C, Nandy P, Wu D & Lacouture PG 2003a, 'A model to evaluate the pharmacokinetic and pharmacodynamic variables of extended-release products using in vivo tissue microdialysis in humans: bupivacaine-loaded microcapsules', *Anesthesia and Analgesia*, vol. 97, no. 124-131.

Kopacz DJ, Lacouture PG, Wu D, Nandy P, Swanton R & Landau C 2003b, 'The dose response and effects of dexamethasone on bupivacaine microcapsules for intercostal blockade (T9 to T11) in healthy volunteers', *Anesthesia and Analgesia*, vol. 96, pp. 576-582.

Kopcha M & Ahl AS 1989, 'Experimental uses of flunixin meglumine and phenylbutazone in food-producing animals', *Journal of the American Veterinary Medical Association*, vol. 194, no. 1, pp. 45-49.

Kopcha M, Kaneene JB, Shea ME, Miller R & Ahl AS 1992, 'Use of nonsteroidal anti-inflammatory drugs in food animal practice', *Journal of the American Veterinary Medical Association*, vol. 201, no. 12, pp.1868-1872.

Kothbauer O 1975, 'Ein Kaiserschnitt bei einer Kuh unter Akupunkturanalgesie', *Wiener Tierarztliche Monatsschrift*, vol. 62, pp. 394-396.

Kothbauer O 1986, 'Studie zur Ohrakupunktur des Rindes', *Wiener Tierarztliche Monatsschrift*, vol. 73, pp. 177-180.

Kothbauer O & Zohmann A 1990, 'Laparotomie bei Labmagenverflagerung eines Rindes unter Akupunkturanalesie', *Wiener Tierarztliche Monatsschrift*, vol. 77, pp. 330-332.

Kothbauer O 2002, 'A general introduction to cattle acupuncture', *Cattle Practice*, vol. 10, pp. 81-88.

Kothbauer O 2004, 'Anatomical verification of acupuncture in cattle: a review', *Wiener Tierarztliche Monatsschrift,* vol. 91, pp. 4-13.

Kutzler M & Wood A 2006, 'Non-surgical methods of contraception and sterilization', *Theriogenology*, vol. 66, no. 3, pp. 514-525.

Kroin JS, McCarthy RJ, Von Roenn N, Schwab B, Tuman KJ & Ivankovich AD 2000, 'Magnesium sulfate potentiates morphine antinociception at the spinal level', *Anesthesia and Analgesia*, vol. 90, pp. 913-917.

Kronenberg RH 2002, 'Ketamine as an analgesic: parenteral, oral, rectal, subcutaneous, transdermal and intranasal administration', *Journal of Pain and Palliative Care Pharmacotherapy*, vol. 16, pp. 27-35.

Lachance M, Lacroix Y, Audet N, Savard P & Thuot F 2008, 'The use of dexamethasone to reduce pain after tonsillectomy in adults: a double-blind prospective randomized trial', *The Laryngoscope,* vol. 118, no. 2, pp. 232-236.

Laden SA, Wohlt JE, Zajac PK & Carsia RV 1985, 'Effects of stress from electrical dehorning on feed intake, growth, and blood constituents of Holstein heifer calves', *Journal of Dairy Science,* vol. 68, pp. 3062-3066.

La Fontaine D 2002, *Dehorning and castration of calves under six months of age*, Agnote No. J83, 4 February 2002, Department of Primary Industry, Darwin.

Lamont LA & Mathews KA 2007, 'Opioids, nonsteroidal anti-inflammatories, and analgesic adjuvants', in WJ Tranquilli, JC Thurmon, KA Grimm (eds), *Lumb & Jones' veterinary anesthesia and Analgesia,* 4th edn, Blackwell Publishing, Ames IA, pp 241-271.

Lamont LA, Tranquilli WJ & Mathews KA 2000, 'Adjunctive analgesic therapy', *Veterinary Clinics of North America: Small Animal Practice*, vol. 30, pp. 805-813.

Lander JA, Weltman BJ & So SS 2006, 'EMLA and amethocaine for reduction of children's pain associated with needle insertion', *Cochrane Database of Systematic Reviews* 3: CD004236.

Landoni MF & Lees P 1995, 'Pharmacokinetics and pharmacodynamics of ketoprofen enantiomers in calves', *Chirality*, vol. 7, no. 8, pp. 586-597.

Landoni MF, Cunningham FM & Lees P 1995a, 'Comparative pharmacodynamics of flunixin, ketoprofen and tolfenamic acid in calves', *The Veterinary Record*, vol. 137, no. 17, pp. 428-431.

Landoni MF, Cunningham FM & Lees P 1995b, 'Determination of pharmacokinetics and pharmacodynamics of flunixin in calves by use of pharmacokinetic/ pharmacodynamic modelling', *American Journal of Veterinary Research,* vol. 56, no. 6, pp. 786-794.

Landoni MF, Cunningham FM & Lees P 1995c, 'Pharmacokinetics and pharmacodynamics of ketoprofen in calves applying PK/PD modelling', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 18, no. 5, pp. 315-324.

Landoni MF, Cunningham FM & Lees P 1996, 'Pharmacokinetics and pharmacodynamics of tolfenamic acid in calves', *Research in Veterinary Science,* vol. 61, no. 1, pp. 26-32.

Lascelles BD, Cripps PJ, Jones A & Waterman-Pearson AE 1998, 'Efficacy and kinetics of carprofen, administered preoperatively or postoperatively, for the prevention of pain in dogs undergoing ovariohysterectomy', *Veterinary Surgery*, vol. 27, pp. 568-582.

Laureano Filho JR, Maurette PE, Allais M, Cotinho M & Fernandes C 2008, 'Clinical comparative study of the effectiveness of two dosages of dexamethasone to control postoperative swelling, trismus and pain after the surgical extraction of mandibular impacted third molars', *Medicina Oral Patalogia Oral Y Cirugia Bucal*, vol. 13, no. 2, pp. E129-E132.

Lay DC, Friend TH, Bowers CL, Grissom KK & Jenkins OC 1992a, 'A comparative physiological and behavioral study of freeze and hot-iron branding in dairy cows', *Journal of Animal Science,* vol. 70, pp. 1121-1125.

Lay DC, Friend TH, Randel RD, Bowers CL, Grissom KK & Jenkins OC 1992b, 'Behavioural and physiological effects of freeze or hot-iron branding on crossbred cattle', *Journal of Animal Science,* vol. 70, pp. 330-336.

Lay DC, Friend TH, Grissom KK, Bowers CL & Mal ME 1992c, 'Effects of freeze or hot-iron branding of Angus calves on some physiological and behavioral indicators of stress', *Applied Animal Behaviour Science,* vol. 33, pp. 137-147.

Lee I, Yamagishi N, Oboshi K & Yamada H 2003a, 'No effect of epidural fat on xylazine-induced dorsolumbar epidural analgesia in cattle', *The Veterinary Journal,* vol. 165, pp. 330-332.

Lee I, Yamagishi N, Oboshi K & Yamada H 2003b, 'Antagonistic effects of intravenous or epidural atipamezole on xylazine-induced dorsolumbar epidural analgesia in cattle', *The Veterinary Journal*, vol. 166, pp. 194-197.

Lee I, Yamagishi N, Oboshi K, Ayukawa Y, Sasaki N & Yamada H 2004, 'Comparison of xylazine, lidocaine and the two drugs combined for modified dorsolumbar epidural anaesthesia in cattle', *The Veterinary Record*, vol. 155, pp. 797-799.

Lee I & Yamada H 2005, 'Epidural administration of fixed volumes of xylazine and lidocaine for anesthesia of dairy cattle undergoing flank surgery', *Journal of the American Veterinary Medical Association*, vol. 227, pp. 781-784.

Lee M & Hendrickson DA 2008, 'A review of equine standing laparoscopic ovariectomy', *Journal of Equine Veterinary Science*, vol. 28, pp. 105-111.

Lees P, Taylor JBO, Higgins AJ & Sedgwick AD 1988, 'In vitro and in vivo studies on the binding of phenylbutazone and related drugs to equine feeds and digesta', *Research in Veterinary Science*, vol. 44, pp. 50–56.

Lees P, Delatour, P, Foster, AP, Foot R & Baggot D 1996, 'Evaluation of carprofen in calves using a tissue cage model of inflammation', *British Veterinary Journal*, vol. 152, pp. 199-211.

Lees P, McKellar QA, Foot R & Gettinby G 1998, 'Pharmacodynamics and pharmacokinetics of tolfenamic acid in ruminating calves: evaluation in models of acute inflammation', *The Veterinary Journal,* vol. 155, no. 3, pp. 275-288.

Lees P, Giraudel J, Landoni MF &Toutain PL 2004, 'PK-PD integration and PK-PD modelling of nonsteroidal anti-inflammatory drugs: principles and applications in veterinary pharmacology', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 27, no. 6, pp. 491-502.

Lemke KA 2007, 'Anticholinergics and sedatives', in WJ Tranquilli, JC Thurmon, KA Grimm (eds), *Lumb & Jones' veterinary anesthesia and analgesia*, 4th edn, Blackwell Publishing, Ames IA, pp 203-239.

Lemke KA, Runyon CL & Horney BS 2002a, 'Effects of preoperative administration of ketoprofen on whole blood platelet aggregation, buccal mucosal bleeding time, and hematologic indices in dogs undergoing elective ovariohysterectomy', *Journal of the American Veterinary Medical Association*, vol. 220, pp. 1818-1822.

Lemke KA, Runyon CL & Horney BS 2002b, 'Effects of preoperative administration of ketoprofen on anesthetic requirements and signs of postoperative pain in dogs undergoing elective ovariohysterectomy', *Journal of the American Veterinary Medical Association*, vol. 221, no.9, pp. 1268-1275.

Lents CA, White FJ, Floyd LN, Wettemann RP & Gay DL 2001, 'Method and timing of castration influences performance of bull calves', *2001 Animal science research report,* Department of Animal Science, Oklahoma State University, accessed 9 October 2007, http://www.ansi.okstate.edu/research/2001rr/48/48.htm.

Levaux Ch, Bonhomme V, Dewandre PY, Brichant JF & Hans P 2003, 'Effect of intra-operative magnesium sulphate on pain relief and patient comfort after major lumbar orthopaedic surgery', *Anaesthesia*, vol. 58, pp. 131-135.

Lewis CA, Constable PD, Huhn JC & Morin DE 1999, 'Sedation with xylazine and lumbosacral epidural administration of lidocaine and xylazine for umbilical surgery in calves', *Journal of the American Veterinary Medical Association*, vol. 214, pp. 89-95.

Lichtenwalner DM, Cameron BD & Young C 1986, 'The metabolism and pharmacokinetics of flunixin in cows and steers', *Proceedings of the 14th World Congress on Diseases of Cattle, Dublin,* vol. 2, pp. 1179-1183.

Lin HC & Riddell MG 2003, 'Preliminary study of the effects of xylazine or detomidine with or without butorphanol for standing sedation in dairy cattle'*, Veterinary Therapeutics*, vol. 4, no. 3, pp. 285-291.

Lindley S & Cummings M 2006a, *Essentials of western veterinary acupuncture*, Blackwell Publishing, Ames, IA.

Lindley S 2006b, 'Veterinary acupuncture: a Western, scientific approach', *In Practice*, vol. 28, pp. 544-547.

Link RP & Smith JC 1956, 'Comparison of some local anesthetics in cattle', *Journal of the American Veterinary Medical Association*, vol. 29, pp. 306-309.

Lockwood PW, Johnson JC & Katz TL 2003, 'Clinical efficacy of flunixin, carprofen and ketoprofen as adjuncts to the antibacterial treatment of bovine respiratory disease', *The Veterinary Record*, vol. 152, pp. 392-394.

Lohuis JACM, VanWerven T, Brand A , van Miert ASJPAM, Rohde E, Ludwig B, Heizmann P & Rehm WF 1991, 'Pharmacodynamics and pharmacokinetics of carprofen, a non-steroidal antiinflammatory drug, in healthy cows and cows with Escherichia coli endotoxin-induced mastitis', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 14, pp. 219-229.

Loneragan GH, Morley PS, Wagner JJ, Mason GL, Yost GS, Thoren MA, Wittum TE & Bray TM 2002, 'Effects of feeding aspirin and supplemental vitamin E on plasma concentrations of 3-methylindole, 3-methyleneindolenine-adduct concentrations in blood and pulmonary tissues, lung lesions, and growth performance in feedlot cattle', *American Journal of Veterinary Research*, vol. 63, no.12, pp. 1641-1647.

Longair JA 1992a, 'CVMA Animal Welfare Committee Chair replies', *Canadian Veterinary Journal*, vol. 33, April, pp. 218-219.

Longair JA 1992b, 'Rationale for the CVMA's position on elastrators', *Canadian Veterinary Journal*, vol. 33, October, p. 628 and December, p. 774.

Looney AL 2000, 'Using acupuncture in veterinary practice', *Veterinary Medicine*, vol. 95, pp. 615-631.

Loxton ID, Toleman MA & Holmes AE 1982, 'The effects of dehorning Brahman crossbred animals of four age groups on subsequent bodyweight gain', *Australian Veterinary Journal,* vol. 58, May, pp. 191-193.

Lukiw WJ, Pelaez RP, Martinez J & Bazan NG 1998, 'Budesonide epimer R or dexamethasone selectively inhibit platelet-activating factor-induced or interleukin 1beta-induced DNA binding activity of cis-acting transcription factors and cyclooxygenase-2 gene expression in human epidermal keratinocytes', *Proceedings of the National Academy of Sciences USA*, vol. 95, pp. 3914-3919.

Lysakowski C, Dumont L, Czarnetzki C & Tramèr MR 2007, 'Magnesium as an adjuvant to postoperative analgesia: a systematic review of randomized trials', *Anesthesia and Analgesia*, vol. 104, pp. 1532-1539.

Macaulay AS, Friend TH & LaBore JM 1986, 'Behavioural and physiological responses of dairy calves to different methods of castration', *Journal of Animal Science*, vol. 63 (supplement), pp. 166.

McCartney CJ, Sinha A & Katz J 2004, 'A qualitative systematic review of the role of N-methyl-D-aspartate receptor antagonists in preventive analgesia', *Anesthesia and Analgesia*, vol. 98, pp. 1385-1400.

McCosker K, Petherick C, Mayer D, Venus B, Letchford P & McGowan M 2007, *Evaluation of the impact on animal welfare of various manipulative and surgical procedures performed on the reproductive tract of female cattle in the northern beef industry*, draft final report of project AHW.143, Meat & Livestock Australia, North Sydney, July.

Machado Filho LC, Hurnik JF & Ewing KK 1998, 'A thermal threshold assay to measure the nociceptive response to morphine sulphate in cattle', *Canadian Journal of Veterinary Research*, vol. 62, no. 3, pp. 218-223.

McLeod JG 1974, 'Acupuncture', *Australian Veterinary Journal*, vol. 50, no. 6, pp. 237-238.

McMeekan CM, Mellor DJ, Stafford KJ, Bruce RA, Ward RN & Gregory NG 1997, ‘Effects of shallow scoop and deep scoop dehorning on plasma cortisol concentrations in calves’, *New Zealand Veterinary Journal,* vol. 45, pp. 72-74.

McMeekan CM, Mellor DJ, Stafford KJ, Bruce RA, Ward RN & Gregory NG 1998a, ‘Effects of local anaesthesia of 4 to 8 hours’ duration on the acute cortisol response to scoop dehorning in calves’, *Australian Veterinary Journal,* vol. 76, no. 4, pp. 281-285.

McMeekan CM, Stafford KJ, Mellor DJ, Bruce RA, Ward RN & Gregory NG 1998b, ‘Effects of regional analgesia and/or a non-steroidal anti-inflammatory analgesic on the acute cortisol response to dehorning in calves’, *Research in Veterinary Science,* vol. 64, pp. 147-150.

McMeekan C, Stafford KJ, Mellor DJ, Bruce RA, Ward RN & Gregory N 1999, ‘Effects of a local anaesthetic and a non-steroidal anti-inflammatory analgesic on the behavioural responses of calves to dehorning’, *New Zealand Veterinary Journal,* vol. 47, pp. 92-96.

MacMillan LB, Lakhlani PP, Hein L, Piascik M, Guo TZ, Lovinger D, Maze M & Limbird LE 1998, ‘In vivo mutation of the alpha 2A-adrenergic receptor by homologous recombination reveals the role of this receptor subtype in multiple physiological processes’, *Advances in Pharmacology*, vol. 42, pp. 493-496.

Maitho TE, Lees P & Taylor JB 1986, ‘Absorption and pharmacokinetics of phenylbutazone in Welsh Mountain ponies’, *Journal of Veterinary Pharmacology and Therapeutics*, vol. 9, pp. 26-39.

Mama KR & EP Steffey 2001, ‘Local anesthetics’, in HR Adams (ed), *Veterinary pharmacology and therapeutics*, 8th edn, Iowa State Press, Ames IA, pp 343-359.

Margolis JH, Bottoms GD & Fessler JF 1987, ‘The efficacy of dexamethasone and flunixin meglumine in treating endotoxin-induced changes in calves’, *Veterinary Research Communications*, vol. 11, pp. 479-491.

Mathews KA, Pettifer G, Foster R & McDonell W 2001, ‘Safety and efficacy of preoperative administration of meloxicam, compared with that of ketoprofen and butorphanol in dogs undergoing abdominal surgery’, *American Journal of Veterinary Research*, vol. 62, pp. 882-888.

Matthews LR, Bremner K & Morrow C 1999, ‘Non-chemical techniques for inducing analgesia before velveting: 2. The effect of the Natur-O technique on subsequent antler production’, *Proceedings of a deer course for veterinarians No. 16*, Hastings, New Zealand, pp 193–194.

Matthews LR & Suttie JM 2001, ‘Research progress in nonchemical techniques for inducing analgesia before velvet antler removal’, in JS Sim, HH Sunwoo , RJ Hudson & BT Jeong (eds), *Antler science and product technology*, Antler Science and Product Technology Research Centre, Edmonton, Canada, pp 411–426.

Maze M & Fujinaga M 2000, ‘Alpha2 adrenoceptors in pain modulation: which subtype should be targeted to produce analgesia?’, *Anesthesiology*, vol. 92, no. 4, pp. 934-936.

Mbiuki SM 1981, 'Xylazine analgesia in cattle', *Veterinary Medicine, Small Animal Clinician,* vol. 76, pp. 1463-1464.

Meeusen ENT, Walker J, Peters A, Pastoret P-P & Jungersen G 2007, 'Current status of veterinary vaccines', *Clinical Microbiology Reviews*, vol. 20, no. 3, pp. 489-510.

Mellor DJ, Molony V & Robertson IS 1991, 'Effects of castration on behaviour and plasma cortisol concentrations in young lambs, kids and calves', *Research in Veterinary Science,* vol. 51, pp. 149-154.

Mellor DJ & Stafford KJ 1997, 'Interpretation of cortisol responses in calf disbudding studies', *New Zealand Veterinary Journal,* vol. 45, pp. 126-127.

Mellor DJ & Stafford KJ 1999, 'Assessing and minimising the distress caused by painful husbandry procedures in ruminants', *In Practice,* September, pp. 436-446.

Mellor DJ, Stafford KJ, Todd SE, Lowe TE, Gregory NG, Bruce RA & Ward RN 2002, 'A comparison of catecholamine and cortisol responses of young lambs and calves to painful husbandry procedures', *Australian Veterinary Journal,* vol. 80, no. 4, pp. 228-233.

Merrill ML, Ansotegui RP, Burns PD, MacNeil MD & Geary TW 2007, 'Effects of flunixin meglumine and transportation on establishment of pregnancy in beef cows', *Journal of Animal Science,* vol. 85, no. 6, pp. 1547-1554.

Meyer D 2004, 'Spaying heifers', in *Cattle Producer's Library, Management Section*, Cooperative Extension Systems, Western Beef Resource Committee, USA, pp. 752-1 – 752-3, accessed 20 December 2008, http://www.csubeef.com/index.php?option=com_csu_cattle&Itemid=36&action=download&pdf=212.

Meyer H, Starke A, Kehler W & Rehage J 2007, 'High caudal epidural anaesthesia with local anaesthetics or alpha(2)-agonists in calves', *Journal of Veterinary Medicine. A, Physiology, Pathology and Clinical Medicine*, vol. 54, pp. 384-389.

Milin J 1977, 'L'acupuncture en médicine vétérinaire', *Recueil de médecine vétérinaire*, vol.153, pp. 363-367.

Milligan BN, Duffield T & Lissemore K 2004, 'The utility of ketoprofen for alleviating pain following dehorning in young dairy calves', *Canadian Veterinary Journal,* vol. 45, February, pp.140-143.

Millman S, Duffield T, Lissemore K, James S & Misch L 2005, 'Does ketoprofen alleviate acute pain during dehorning?', *Journal of Animal Science,* vol. 83, supp. 1/J, pp. 374-375.

Milne MH, Nolan AM, Cripps PJ & Fitzpatrick JL 2003, 'Assessment and alleviation of pain in dairy cows with clinical mastitis', *Cattle Practice*, vol. 11, no. 4, pp. 289-293.

Molony V, Kent JE & Robertson IS 1995, 'Assessment of acute and chronic pain after different methods of castration of calves', *Applied Animal Behaviour Science,* vol. 46, pp. 33-48.

Møiniche S, Rømsing J, Dahl J & Tramèr MR 2003, 'Nonsteroidal antiinflammatory drugs and the risk of operative site bleeding after tonsillectomy: a quantitative systematic review', *Anesthesia and Analgesia*, vol. 96, pp. 68–77.

Morisse JP, Cotte JP & Huonnic D 1995, 'Effect of dehorning on behavioural and plasma cortisol responses in young calves', *Applied Animal Behaviour Science,* vol. 43, pp. 239-247.

Mormède P, Andanson S, Aupérin B, Beerda B, Guémené D, Malmkvist J, Manteca X, Manteuffel G, Prunet P, van Reenen CG, Richard S & Veissier I 2007, 'Exploration of the hypothalamic–pituitary–adrenal function as a tool to evaluate animal welfare', *Physiology & Behavior*, vol. 92, pp. 317-339.

Movafegh A, Razazian M, Hajimaohamadi F, & Meysamie A 2006, 'Dexamethasone added to lidocaine prolongs axillary brachial plexus blockade', *Anesthesia and Analgesia*, vol. 102, no. 1, pp. 263-267.

Muir WW 2002, 'Drugs used to treat pain', in JS Gaynor & WW Muir (eds), *Handbook of veterinary pain management*, Mosby, St Louis, pp 142-163.

Mullen PA 1964, 'Some observations on the effects of the method and time of castration of calves for barley beef production', *British Veterinary Journal,* vol. 120, pp. 518-523.

Murata H 1997, 'Effects of burdizzo castration on peripheral blood lymphocyte parameters in calves', *The Veterinary Journal,* vol. 153, pp. 229-231.

Nancarrow C, Rutten AJ, Runciman WB, Mather LE, Carapetis RJ, McLean CF & Hipkins SF 1989, 'Myocardial and cerebral drug concentrations and the mechanisms of death after fatal intravenous doses of lidocaine, bupivacaine, and ropivacaine in the sheep', *Anesthesia and Analgesia,* vol. 69, pp. 276-283.

Narita T, Sato R, Motoishi K, Tani K, Naito Y & Hara S 2007, 'The interaction between orally administered non-steroidal anti-inflammatory drugs and prednisolone in healthy dogs', *The Journal of Veterinary Medical Science,* vol. 69, pp. 353-363.

Naz RK, Gupta SK, Gupta JC, Vyas HK & Talwar AG 2005, 'Recent advances in contraceptive vaccine development: a mini-review', *Human Reproduction*, vol. 20, no. 12, pp. 3271-3283.

Neff-Davis CA, Anderson KA, Bosch K & Davis LE 1983, 'The pharmacokinetics of flunixin meglumine (banamine) in lactating cows', *Abstracts of Papers presented at the Annual Meeting of the Conference of Research Workers in Animal Disease*, Chicago, November 1983, vol. 64, p. 15.

Neff-Davis CA & Bosch K 1985, 'An HPLC method for the determination of flunixin in bovine plasma and milk', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 8, no. 3, pp. 331-334.

Newman R 2007, *A guide to best practice husbandry in beef cattle. Branding, castrating and dehorning*, Meat & Livestock Australia, North Sydney, 43pp.

Ng A, Habib A, Swami A, Smith G, Nunns D & Davidson AC 2002, 'Randomized controlled trial investigating the effect of transcervical papaverine and bupivacaine on postoperative analgesia following laparoscopic sterilization', *European Journal of Anaesthesiology*, vol. 19, no. 11, pp. 803-807.

Ng A & Smith G 2002, 'Editorial I: Intraperitoneal administration of analgesia: is this practice of any utility?', *British Journal of Anaesthesia*, vol. 89, no. 4, pp. 535-537.

Niethe GE & Holmes WE 2008, 'Modeled female sale options demonstrate improved profitability in northern beef herds', *Australian Veterinary Journal*, in press.

Nolan AM 2000, 'Pharmacology of analgesic drugs', in P Flecknell and A Waterman-Pearson (eds), *Pain management in animals*, WB Saunders, London, pp 21-52.

Odensvik K 1995, 'Pharmacokinetics of flunixin and its effect on prostaglandin F2 alpha metabolite concentrations after oral and intravenous administration in heifers', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 18, no. 4, pp. 254-259.

Odensvik K & Johansson IM 1995, 'High-performance liquid chromatography method for determination of flunixin in bovine plasma and pharmacokinetics after single and repeated doses of the drug', *American Journal of Veterinary Research,* vol. 56, no. 4, pp. 489-495.

Odensvik K & Magnusson U 1996, 'Effect of oral administration of flunixin meglumine on the inflammatory response to endotoxin in heifers', *American Journal of Veterinary Research*, vol. 57, no. 2, pp. 201-204.

O'Sullivan D 2007, *Freeze branding horses and cattle*, DPI&F Note, accessed 23 January 2008, http://www2.dpi.qld.gov.au/beef/3463.html.

O'Toole D & Fox JD 2003, 'Chronic hyperplastic and neoplastic cutaneous lesions (Marjolin's ulcer) in hot-brand sites in adult beef cattle', *Journal of Veterinary Diagnostic Investigation,* vol. 15, pp. 64-67.

Ozalevli M, Cetin TO, Unlugenc H, Guler T & Isik G 2005, 'The effect of adding intrathecal magnesium sulphate to bupivacaine-fentanyl spinal anaesthesia', *Acta Anaesthesiologica Scandinavica*, vol. 49, pp. 1514-1519.

Paech MJ, Ilett KF, Hackett LP, Page-Sharp M & Parsons RW 2008, 'Disposition and clinical outcome after intraperitoneal meperidine and ropivacaine administration during laparoscopic surgery', *Anesthesia and Analgesia*, vol. 106, pp. 278-286.

Palmer SE 1993, 'Standing laparoscopic laser technique for ovariectomy in five mares', *Journal of the American Veterinary Medical Association* , vol. 203, pp. 279-283.

Pang WY, Earley B, Sweeney T & Crowe MA 2006, 'Effect of carprofen administration during banding or burdizzo castration of bulls on plasma cortisol, in vitro interferon-γ production, acute-phase proteins, feed intake, and growth', *Journal of Animal Science,* vol. 84, pp. 351-359.

Parsons C & Jensen S 2004, 'Dehorning cattle', in *Cattle Producer's Library, Management Section*, Cooperative Extension Systems, Western Beef Resource Committee, USA, pp. 750-1 – 750-4, accessed 20 December 2008, http://www.csubeef.com/index.php?option=com_csu_cattle&Itemid=36&action=download&pdf=211.

Pedersen JL, Lillesø J, Hammer NA, Werner MU, Holte K, Lacouture PG & Kehlet H 2004, 'Bupivacaine in microcapsules prolongs analgesia after subcutaneous infiltration in humans: a dose-finding study', *Anesthesia and Analgesia*, vol. 99, pp. 912-918.

Peters JW, Koot HM, de Boer JB, Passchier J, Bueno-de-Mesquita JM, de Jong FH, Duivenvoorden HJ & Tibboel D 2003, 'Major surgery within the first 3 months of life and subsequent biobehavioral pain responses to immunization at later age: a case comparison study', *Pediatrics*, vol. 111, pp. 129-135.

Peterson DR 1951, 'Nerve block of the eye and associated structures', *Journal of the American Veterinary Medical Association*, vol. 118, pp. 145-148.

Petherick JC 2005, 'Animal welfare issues associated with extensive livestock production: The northern Australian beef cattle industry', *Applied Animal Behaviour Science,* vol. 92, pp. 211-234.

Petrie NJ, Mellor DJ, Stafford KJ, Bruce RA, and Ward RN 1996, 'Cortisol responses of calves to two methods of disbudding used with or without local anaesthetic', *New Zealand Veterinary Journal,* vol. 44, pp. 9-127.

Phillips A & Coventry J 2005, *Breeding polled cattle*, Agnote No. J80, Department of Primary Industry, 11 May 2005, Department of Primary Industry, Darwin.

Pinner KKR 2006, 'Lack of animal welfare assessment regarding trans-vaginal spaying of heifers', *Canadian Veterinary Journal,* vol. 47, March, pp. 266-274.

Ponvijay KS 2007, 'Pinhole castration: a novel minimally invasive technique for in situ spermatic cord ligation', *Veterinary Surgery*, vol. 36, no. 1, pp. 74-79.

Powell JD, Denhart JW & Lloyd WE 1998, 'Effectiveness of tolazoline in reversing xylazine-induced sedation in calves', *Journal of the American Veterinary Medical Association*, vol. 212, pp. 90-92.

Prayaga KC 2005, *Genetic options to replace dehorning of beef cattle in Australia,* final report of project AHW.094, Meat & Livestock Australia, North Sydney, July.

Prayaga KC 2007, 'Genetic options to replace dehorning in beef cattle – a review', *Australian Journal of Agricultural Research*, vol. 58, pp. 1-8.

Purswell BJ & Kolster KA 2006, 'Immunocontraception in companion animals', *Theriogenology*, vol. 66, no.3, pp. 510-513.

Pyorala S, Laurila T, Lehtonen S, Leppa S & Kaartinen L 1999, 'Local tissue damage in cows after intramuscular administration of preparations containing phenylbutazone, flunixin, ketoprofen and metamizole', *Acta Veterinaria Scandinavica*, vol. 40, no. 2, pp. 145-150.

Ramamurthi RJ & Krane EJ 2007, 'Local anesthetic pharmacology in pediatric anesthesia', *Techniques in Regional Anesthesia and Pain Management*, vol. 11, pp. 229-234.

Ramey DW, Imrie RH & Buell PD 2001, 'Veterinary acupuncture and traditional Chinese medicine: facts and fallacies', *Compendium on Continuing Education for the Practicing Veterinarian*, vol. 23, pp. 188-193.

Ramsook C, Kozinetz CA & Moro-Sutherland D 2001, 'Efficacy of ethyl chloride as a local anesthetic for venipuncture and intravenous cannula insertion in a pediatric emergency department', *Pediatric Emergency Care*, vol. 17, pp. 341–343.

Ranheim B, Haga HA & Ingebrigtsen K 2005, 'Distribution of radioactive lidocaine injected into the testes in piglets', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 28, pp. 481-483.

Rantala M, Kaartinen L, Valimaki E, Stryrman M, Hiekkaranta M, Niemi A, Saari L, & Pyorala S 2002, 'Efficacy and pharmacokinetics of enrofloxacin and flunixin meglumine for treatment of cows with experimentally induced Escherichia coli mastitis', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 25, no. 4, pp. 251-258.

Raptopoulos D & Weaver BM 1984, 'Observations following intravenous xylazine administration in steers', *The Veterinary Record*, vol. 114, pp. 567-569.

Read M, Caulkett N & McCallister M 2000, 'Evaluation of zuclopentchixol acetate to decrease handling stress in wapiti', *Journal of Wildlife Diseases*, vol. 36, pp. 450–459.

Riebold TW, Hawkins JK & Crisman RO 1992, 'Effect of buffered lidocaine on epidural anesthesia in cattle', in CE Short and A van Poznak (eds), *Animal pain*, Churchill Livingstone, New York, pp 303-306.

Riebold TW 2001, 'Anesthetic management in cattle', in EP Steffey (ed), *Recent advances in anesthetic management of large domestic animals*, International Veterinary Information Service (IVIS), Ithaca NY.

Rijnberk A 1997, 'Modes of treatment', *Australian Veterinary Journal*, vol. 75, pp. 260-261.

Rinder HM, Tracey JB, Souhrada M, Wang C, Gagnier RP & Wood CC 2002, 'Effects of meloxicam on platelet function in healthy adults: a randomized, double-blind, placebo-controlled trial', *Journal of Clinical Pharmacology*, vol. 42, pp. 881-886.

Riviere JE & Papich MG 2001, 'Potential and problems of developing transdermal patches for veterinary applications', *Advanced Drug Delivery Reviews*, vol. 50, no. 3, pp. 175-203.

Robertson IS, Kent JE & Molony V 1994, 'Effect of different methods of castration on behaviour and plasma cortisol in calves of three ages', *Research in Veterinary Science,* vol. 56, pp. 8-17.

Rocken M 2000, 'Laparoscopic cryptorchidectomy and ovariectomy in the standing horse. 2. Laparoscopic ovariectomy', *Praktische Tierarzt,* vol. 81, pp. 34-42.

Rodgerson DH, Belknap JK & Wilson DA 2001, 'Laparoscopic ovariectomy using sequential electrocoagulation and sharp transection of the equine mesovarium', *Veterinary Surgery*, vol. 30, pp. 572-579.

Rogers PAM & Ottaway CW 1974, 'Success claimed for acupuncture in domestic animals', *Irish Veterinary Journal,* vol. 28, pp. 182-191.

Rogers PAM, White SS and Ottaway CW 1976, 'Stimulation of the acupuncture points in relation to therapy of analgesia and clinical disorders in animals', *Veterinary Annual*, vol. 17, pp. 258-279.

Rogers PAM 1979, 'Treatment of the downer syndrome', *Irish Veterinary Journal*, vol. 33, pp. 179.

Rogers PAM 1985, 'Therapy of milk fever and downer cows', *Nordisk Veterinaermedicin*, vol. 37, pp. 109-110.

Rollin BE 2003, 'An ethicist's commentary on the elastrator for older bulls', *Canadian Veterinary Journal,* vol. 44, August, p. 624.

Roming LG 1984, 'Tolazoline as a xylazine antagonist in cattle', *Deutsche tierärztliche Wochenschrift*, vol. 91, pp. 154-157.

Roussel AJ, Dodson SL, Brumbaugh GW, Sriranganathan N & Overbay TD 1993, 'Effect of ketoprofen on Escherichia coli heat-stable enterotoxin-induced diarrhea of calves', *American Journal of Veterinary Research*, vol. 54, no.12, pp. 2088-2090.

Ruckebusch Y 1983, 'Pharmacology of reticulo-ruminal motor function', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 6, pp. 245-272.

Ruckebusch Y & Allal C 1987, 'Depression of reticulo-ruminal motor functions through the stimulation of alpha 2-adrenoceptors', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 10, pp. 1-10.

Rupp GP & Kimberling CV 1982, 'A new approach for spaying heifers', *Veterinary Medicine*, vol. 77, pp. 561-565.

Russell WMS & Burch RL 1959, *The principles of humane experimental technique*, Universities Federation of Animals Welfare, England, 238 pp, accessed 3 April 2008, http://altweb.jhsph.edu/publications/humane_exp/het-toc.htm.

Rusy LM, Houck CS, Sullivan L, Ohlms LA, Jones DT, McGill TJ, & Berde CB 1995, 'A double-blind evaluation of ketorolac tromethamine versus acetaminophen in pediatric tonsillectomy: analgesia and bleeding', *Anesthesia and Analgesia*, vol. 80, pp. 226–229.

St Jean G, Skarda RT, Muir WW & Hoffsis GF 1990, 'Caudal epidural analgesia induced by xylazine administration in cows', *American Journal of Veterinary Research*, vol. 51, pp. 1232-1236.

Salamon E, Schmidt H, Henderson A & Okkinga K 2000, 'Effects of meloxicam on thromboxane levels in calves with experimentally induced endotoxaemia', *Cattle Practice*, vol. 8, no. 1, pp. 37-38.

Scarratt WK & Troutt HF 1986, 'Iatrogenic lidocaine toxicosis in ewes', *Journal of the American Veterinary Medical Association*, vol. 188, pp. 184-185.

Schafer AI 1999, 'Effects of nonsteroidal anti-inflammatory therapy on platelets'*, American Journal of Medicine,* vol. 106, pp. 25S–36S.

Schilling CG, Bank DE, Borchert BA, Klatzko MD & Uden DL 1995, 'Tetracaine, epinephrine (adrenalin), and cocaine (TAC) versus lidocaine, epinephrine, and tetracaine (LET) for anesthesia of lacerations in children', *Annals of Emergency Medicine*, vol.25, pp.203-208.

Schimmel I & Schimmel D 1978, 'Effect of aspirin and indomethacin on changes caused by Pasteurella multocida toxins in calves', *Archiv für experimentelle Veterinärmedizin*, vol. 32, no. 2, pp. 247-250.

Schmelzeisen R & Frolich JC 1993, 'Prevention of post operative swelling and pain by dexamethasone after operative removal of impacted third molar teeth', *European Journal of Clinical Pharmacology*, vol. 44, pp. 275–277.

Schmid RL, Sandler AN & Katz J 1999, 'Use and efficacy of low dose ketamine in the management of acute postoperative pain: a review of current techniques and outcomes', *Pain,* vol. 82, pp. 111-125.

Schwartzkopf KS, Stookey JM, Hull PR & Clark EG 1994, 'Screening of depigmenting compounds for the development of an alternate method of branding beef cattle', *Journal of Animal Science,* vol. 72, pp. 1393-1398.

Schwartzkopf-Genswein KS & Stookey JM 1997a, 'The use of infrared thermography to assess inflammation associated with hot-iron and freeze branding in cattle', *Canadian Journal of Animal Science,* vol. 77, August, pp. 577-583.

Schwartzkopf-Genswein KS, Stookey JM, Janzen ED & McKinnon J 1997b, 'Effects of branding on weight gain, antibiotic treatment rates and subsequent handling ease in feedlot cattle', *Canadian Journal of Animal Science,* vol. 77, March, pp. 361-367.

Schwartzkopf-Genswein KS, Stookey JM, de Passillé AM & Rushen J 1997c, 'Comparison of hot-iron and freeze branding on cortisol levels and pain sensitivity in beef cattle', *Canadian Journal of Animal Science,* vol. 77, April, pp. 369-374.

Schwartzkopf-Genswein KS, Stookey JM & Welford R 1997d, 'Behaviour of cattle during hot-iron and freeze branding and the effects on subsequent handling ease', *Journal of Animal Science,* vol. 75, pp. 2064-2072.

Schwartzkopf-Genswein KS, Stookey JM, Crowe TG & Genswein BMA 1998, 'Comparison of image analysis, exertion force, and behavior measurements for use in the assessment of beef cattle responses to hot-iron and freeze branding', *Journal of Animal Science,* vol. 76, pp. 972-979.

Schwerg HP 1990, 'Akupunktur in der Veterinarmedizin', *Mh Vet Med***,** vol.45, pp. 10-13.

Schytte T, Soerensen JA, Hauge B & Andersen B 2003, ‘Preoperative transcervical analgesia for laparoscopic sterilization with Filshie clips. A double blind randomized trial’, *Acta Obstetricia Gynecologica Scandinavica,* vol. 82, no.1, pp. 57-60.

Scott S 2001, ‘Developments in veterinary acupuncture’, *Acupuncture in Medicine*, vol. 19, pp. 27-31.

Semrad SD 1993, ‘Comparative efficacy of flunixin, ketoprofen, and ketorolac for treating endotoxemic neonatal calves’, *American Journal of Veterinary Research*, vol. 54, no. 9, pp. 1511-1516.

Seyhan TO, Tugrul M, Sungur MO, Kayacan S, Telci L, Pembeci K, & Akpir K 2006, ‘Effects of three different dose regimens of magnesium on propofol requirements, haemodynamic variables and postoperative pain relief in gynaecological surgery’, *British Journal of Anaesthesia*, vol. 96, pp. 247-252.

Short CR & Beadle RE 1978, ‘Pharmacology of antiarthritic drugs’, *Veterinary Clinics of North America*, vol. 8, no. 3, pp. 401-17.

Shpigel NY, Chen R, Winkler M, Saran A, Ziv G & Longo F 1994, ‘Anti-inflammatory ketoprofen in the treatment of field cases of bovine mastitis’, *Research in Veterinary Science*, vol. 56, no. 1, pp. 62-68.

Shutt DA, Fell LR, Connell R & Bell AK 1988, ‘Stress responses in lambs docked and castrated surgically or by application of rubber rings’, *Australian Veterinary Journal,* vol. 65, pp. 5-7.

Sidhu PK, Landoni MF & Lees P 2005, ’Influence of marbofloxacin on the pharmacokinetics and pharmacodynamics of tolfenamic acid in calves’, *Journal of Veterinary Pharmacology and Therapeutic*s, vol. 28, pp. 109-119.

Sittl R 2005, ‘Transdermal buprenorphine in the treatment of chronic pain’, *Expert Review of Neurotherapeutics*, vol. 5, no. 3, pp. 315-323.

Skarda RT 1986, ‘Techniques of local analgesia in ruminants and swine’, *Veterinary Clinics of North America Food Animal Practice*, vol. 2, pp. 621-663.

Skarda RT, Jean GS & Muir WW 1990, ‘Influence of tolazoline on caudal epidural administration of xylazine in cattle’, *American Journal of Veterinary Research*, vol. 51, pp. 556-560.

Skarda RT 2002, ‘Complementary and alternative (integrative) pain therapy’, in JS Gaynor and WW Muir (eds), *Handbook of veterinary pain management*, Mosby, St Louis, pp 281-326.

Skarda RT & Glowaski M 2007, ’Acupunture’, in WJ Tranquilli, JC Thurmon and KA Grimm (eds), *Lumb & Jones’ veterinary anesthesia and analgesia*, 4th edn, Blackwell Publishing, Ames, IA, pp. 683-696.

Skarda RT & Tranquilli WJ 2007, 'Local and regional anesthetic and analgesic techniques: ruminants and swine', in WJ Tranquilli, JC Thurmon and KA Grimm (eds), *Lumb & Jones' veterinary anesthesia and analgesia*, 4th edn, Blackwell Publishing, Ames, IA, pp. 643-681.

Smith DP & Gjellum M 2004, 'The efficacy of LMX versus EMLA for pain relief in boys undergoing office meatotomy', *Journal of Urology*, vol. 172, pp. 1760-1761.

Spielman FJ, Hulka JF, Ostheimer GW & Mueller RA 1983, 'Pharmacokinetics and pharmacodynamics of local analgesia for laparoscopic tubal ligations', *American Journal of Obstetrics and Gynecology*, vol. 146, no. 7, pp. 821-824.

Speirs AF, Taylor KH, Joanes DN & Girdler NM 2001, 'A randomised, double-blind, placebo-controlled, comparative study of topical skin analgesics and the anxiety and discomfort associated with venous cannulation', *British Dental Journal*, vol. 190, pp. 444-449.

Stafford KJ, Mellor DJ & McMeekan CM 2000a, 'A survey of the methods used by farmers to castrate calves in New Zealand', *New Zealand Veterinary Journal,* vol. 48, pp. 16-19.

Stafford KJ, Mellor DJ, Ward RN & Cann B 2000b, 'Behavioural responses of calves to amputation dehorning with or without local anaesthesia', *Proceedings of the New Zealand Society of Animal Production,* vol. 60, pp. 234-236.

Stafford KJ, Mellor DJ, Todd SE, Bruce RA & Ward RN 2002, 'Effects of local anaesthesia or local anaesthesia plus a non-steroidal anti-inflammatory drug on the acute cortisol response of calves to five different methods of castration', *Research in Veterinary Science,* vol. 73, pp. 61-70.

Stafford KJ, Mellor DJ, Todd SE, Ward RN & McMeekan CM 2003, 'The effect of different combinations of lignocaine, ketoprofen, xylazine and tolazoline on the acute cortisol response to dehorning in calves', *New Zealand Veterinary Journal,* vol. 51, no. 5, pp. 219-226.

Stafford KJ & Mellor DJ 2005a, 'The welfare significance of the castration of cattle: a review', *New Zealand Veterinary Journal*, vol. 53, no. 5, pp. 271-278.

Stafford KJ & Mellor DL 2005b, 'Review. Dehorning and disbudding distress and its alleviation in calves', *The Veterinary Journal,* vol. 169, pp. 337-349.

Stafford KJ, Mellor DJ, Dooley AE, Smeaton D & McDermott A 2005c, 'The cost of alleviating the pain caused by the castration of beef calves', *Proceedings of the New Zealand Society of Animal Production,* vol. 65, pp. 123-126.

Stafford KJ & Mellor DJ 2006, 'The assessment of pain in cattle: a review', *CAB reviews: perspectives in agriculture, veterinary science, nutrition, and natural resources*, CABI, Wallingford, UK, 7 pp.

Stafford K 2007, 'Alleviating the pain caused by the castration of cattle', *The Veterinary Journal*, vol. 173, pp. 245-247.

Steinhardt M 2006, ‘Effects of sex, age and body weight on physiological responses in young suckler calves from a cow-calf operation undergoing dehorning with use of sedation by xylazine’ (German), *Tierarztliche Praxis,* vol. 34, no. 3, pp. 155-164. (Note: English abstract only obtained.)

Stilwell G, Lima MS, Capitão E & Nunes T 2004, ‘Evaluation of the effect of local anaesthesia and local anaesthesia associated with analgesia on the levels of cortisol after hot-iron, chemical or scoop dehorning’, *Proceedings XXIII World Buiatrics Congress,* Quebec, Canada. (Note: abstract only).

Stilwell G, Lima MS & Broom DM 2008, ‘Comparing plasma cortisol and behaviour of calves dehorned with caustic paste after non-steroidal-anti-inflammatory analgesia’, *Livestock Science,* in press.

Stookey JM 1992, ‘An animal behaviorist’s opinion of the CVMA’s position on elastrators’, *Canadian Veterinary Journal*, vol. 33, October, pp. 627-628.

Stookey JM & Goonewardene LA 1995, ‘A comparison of production traits and welfare implications between horned and polled beef bulls’, *Canadian Journal of Animal Science,* vol. 76, pp. 1-5.

Stookey JM c2000, ‘Dehorning beef cattle via genetics is welfare friendly’, accessed 11 December 2007, http://www.usask.ca/wcvm/herdmed/applied-ethology/articles/dehorn.html.

Stookey JM, Campbell J, Janzen E, McKinnon J, Watts J & Haley D c2001, *Effects of castration technique and anesthesia on behaviour and weight gain in the feedlot*, technical report, accessed 2 January 2008, http://www.usask.ca/wcvm/herdmed/applied-ethology/2000%20Effects%20of%20Delayed%20Castration%20Study%20from%20WCVM.pdf.

Subramaniam K, Subramaniam B & Steinbrook RA 2004, ‘Ketamine as adjuvant analgesic to opioids: a quantitative and qualitative systematic review’, *Anesthesia and Analgesia,* vol. 99, pp. 489-495.

Sutherland MA, Mellor DJ, Stafford KJ, Gregory NG, Bruce RA & Ward RN 2002a, ‘Cortisol responses to dehorning of calves given a 5-h local anaesthetic regimen plus phenylbutazone, ketoprofen, or adrenocorticotropic hormone prior to dehorning’, *Research in Veterinary Science,* vol. 73, pp. 115-123.

Sutherland MA, Mellor DJ, Stafford KJ, Gregory NG, Bruce RA & Ward RN 2002b, ‘Effect of local anaesthetic combined with wound cauterisation on the cortisol response to dehorning in calves’, *Australian Veterinary Journal,* vol. 80, no. 3, March, pp. 165-167.

Sylvester SP, Mellor DJ, Stafford KJ, Bruce RA & Ward RN 1998a, ‘Acute cortisol responses of calves to scoop dehorning using local anaesthesia and/or cautery of the wound’, *Australian Veterinary Journal,* vol. 76, no. 2, pp. 118-122.

Sylvester SP, Mellor DJ, Stafford KJ, Bruce RA & Ward RN 1998b, ‘Acute cortisol responses of calves to four methods of dehorning by amputation,’ *Australian Veterinary Journal,* vol. 76, no. 2, pp. 123-126.

Sylvester SP, Stafford KJ, Mellor DJ, Bruce RA & Ward RN 2004, 'Behavioural responses of calves to amputation dehorning with and without local anaesthesia', *Australian Veterinary Journal,* vol. 82, no. 11, pp. 697-700.

Tauzin-Fin P, Sesay M, Delort-Laval S, Krol-Houdek MC & Maurette P 2006, 'Intravenous magnesium sulphate decreases postoperative tramadol requirement after radical prostatectomy', *European Journal of Anaesthesiology*, vol. 23, no 12, pp. 1055-1059.

Taddio A, Katz J, Ilersich AL & Koren G 1997, 'Effect of neonatal circumcision on pain response during subsequent routine vaccination', *Lancet*, vol. 349, no. 9052, pp. 599-603.

Taschke AC & Fölsche DW 1993, 'Effects of electrical dehorning on behaviour and salivary cortisol in calves', in M Nichelmann, HK Wierenga & S Braun (eds), *Proceedings of the International Congress of Applied Ethology*, pp. 326-329.

Thompson JR, Kersting KW & Hsu WH 1991, 'Antagonistic effect of atipamezole on xylazine-induced sedation, bradycardia, and ruminal atony in calves', *American Journal of Veterinary Research*, vol. 52, pp. 1265-1268.

Thüer S, Mellema S, Doherr MG, Wechsler B, Nuss K & Steiner A 2007a, 'Effect of local anaesthesia on short- and long-term pain induced by two bloodless castration methods in calves', *The Veterinary Journal,* vol. 173, pp. 333-342.

Thüer S, Doherr MG, Wechsler B, Mellema SC, Nuss K, Kirchhofer M & Steiner A 2007b, 'Influence of local anaesthesia on short- and long-term pain induced in calves by three bloodless castration methods', *Schweizer Archiv für Tierheilkunde*, vol. 149, no. 5, pp. 201-211.

Thun R, Eggenberger E, Zerobin K, Rehm WF & Ludwig B 1989, 'Carprofen in veterinary medicine. II. Inhibitory effect on the release of PGF2 alpha in the early postpartum cow', *Schweizer Archiv für Tierheilkunde*, vol. 131, no. 4, pp. 205-212.

Thurmon JC, Nelson DR, Hartsfield SM & Rumore CA 1978, 'Effects of xylazine hydrochloride on urine in cattle', *Australian Veterinary Journal*, vol. 54, pp.178-180.

Ting STL, Earley B & Crowe MA 2003a, 'Effect of repeated ketoprofen administration during surgical castration of bulls on cortisol, immunological function, feed intake, growth, and behavior', *Journal of Animal Science,* vol. 81, pp. 1253-1264.

Ting STL, Earley B, Hughes JML & Crowe MA 2003b, 'Effect of ketoprofen, lidocaine local anesthesia, and combined xylazine and lidocaine caudal epidural anesthesia during castration of beef cattle on stress responses, immunity, growth, and behaviour', *Journal of Animal Science,* vol. 81, pp. 1281-1293.

Ting STL, Earley B, Veissier I, Gupta S & Crowe MA 2005, 'Effects of age of Holstein-Friesian calves on plasma cortisol, acute-phase proteins, immunological function, scrotal measurements and growth in response to Burdizzo castration', *Animal Science,* vol. 80, pp. 377-386.

Todd C, McKnight D, Millman S, Duffield T & Leslie K 2007, 'An investigation of meloxicam (Metacam(R)) for the relief of pain associated with diarrhea in dairy calves', *Challenge your heart, challenge your mind conference proceedings*, Ontario Veterinary Medical Asociation, Toronto, Ontario, pp. 289-293.

Tool AL, Kammerer-Doak DN, Nguyen CM, Cousin MO & Charsley M 1997, 'Postoperative pain relief following laparoscopic tubal sterilization with silastic bands', *Obstetrics and Gynecology*, vol. 90, no. 5, pp. 731-734.

Tramèr MR & Glynn CJ 2007, 'An evaluation of a single dose of magnesium to supplement analgesia after ambulatory surgery: randomized controlled trial', *Anesthesia and Analgesia*, vol. 104, no. 1374-1379.

Tramèr MR, Schneider J, Marti RA & Rifat K 1996, 'Role of magnesium sulfate in postoperative analgesia', *Anesthesiology*, vol. 84, pp. 340-347.

Tranquilli WJ, Grimm KA & Lamont LA 2000, *Pain management for the small animal practitioner*,. Teton NewMedia , Jackson, Wyoming.

Tufvesson G 1963, *Local anaesthesia in veterinary medicine*, Astra International, Sweden.

Turan A, Memiş D, Karamanlioğlu B, Güler T & Pamukçu Z 2005, 'Intravenous regional anesthesia using lidocaine and magnesium', *Anesthesia and Analgesia*, vol. 100, pp.1189-1192.

USDA (United States Department of Agriculture) undated, *Alternatives and the Animal Welfare Act* (brochure), accessed 10 January 2008, http://labanimals.stanford.edu/resources/AlternativesBrochure.pdf.

USDA (United States Department of Agriculture) 1997, *Beef '97: Part I: Reference of 1997 beef cow-calf management practices,* June, Veterinary Services, Animal Plant Health Inspection Service (APHIS), USDA, Fort Collins, Colorado, 60 pp.

USDA (United States Department of Agriculture) 1998, *Beef '97: Part III: Reference of 1997 beef cow-calf production management and disease control,* January, Veterinary Services, Animal Plant Health Inspection Service (APHIS), USDA, Fort Collins, Colorado, 48 pp.

USDA (United States Department of Agriculture) 2000, *Feedlot '99: Part I: Baseline reference of feedlot management practices 1999,* May, Veterinary Services, Animal Plant Health Inspection Service (APHIS), USDA, Fort Collins, Colorado, 70 pp.

Van de Weerdt ML, Coghe J, Uystepruyst C, Deby-Dupont G & Lekeux P 1999, 'Ketoprofen and phenylbutazone attenuation of PAF-induced lung inflammation in calves', *The Veterinary Journal* , vol. 157, no. 1, pp. 39-49.

Van Donkersgoed J, Jewison G, Mann M, Cherry B, Altwasser B, Lower R, Wiggins K, Dejonge R, Thorlakson B, Moss E, Mills C & Grogan H 1997, 'Canadian beef quality audit', *Canadian Veterinary Journal*, vol. 38, pp. 217-225.

Vangroenweghe F, Duchateau L, Boutet P, Lekeux P, Rainard P, Paape MJ & Burvenich C 2005, 'Effect of carprofen treatment following experimentally induced Escherichia coli mastitis in primiparous cows', *Journal of Dairy Science*, vol. 88, no. 7, pp. 2361-2376.

Van Hoogmoed LM & Galuppo LD 2005, 'Laparoscopic ovariectomy using the endo-GIA stapling device and endo-catch pouches and evaluation of analgesic efficacy of epidural morphine sulfate in 10 mares', *Veterinary Surgery*, vol. 34, pp. 646-650.

Van Metre DC 1992, 'A case report of the treatment of an overdose of xylazine in a cow', *Cornell Veterinarian*, vol. 82, pp. 287-291.

Vickers KJ, Niel L, Kiehlbauch LM & Weary DM 2005, 'Calf response to caustic paste and hot-iron dehorning using sedation with and without local anesthetic', *Journal of Dairy Science,* vol. 88, pp. 1454-1459.

Viňuela-Fernandez I, Jones E, Welsh EM & Fleetwood-Walker SM 2007, 'Review: Pain mechanisms and their implication for the management of pain in farm and companion animals', *The Veterinary Journal,* vol. 174, pp. 227-239.

Wagner AE 2002, 'Opioids', in JS Gaynor and WW Muir (eds), *Handbook of veterinary pain management*, Mosby, St Louis, pp 164-183.

Wagner KA, Gibbon KJ, Strom TL, Kurian JR & Trepanier LA 2006, 'Adverse effects of EMLA (lidocaine/prilocaine) cream and efficacy for the placement of jugular catheters in hospitalized cats', *Journal of Feline Medicine and Surgery*, vol. 8, no. 2, pp. 141-144.

Walker SM, Meredith-Middleton J, Cooke-Yarborough C & Fitzgerald M 2003, 'Neonatal inflammation and primary afferent terminal plasticity in the rat dorsal horn', *Pain*, vol. 105, pp. 185-195.

Walsh V & Wilson PR 2002a, 'Sedation and chemical restraint of deer', *New Zealand Veterinary Journal*, vol. 50, pp. 228-236.

Walsh VP & Wilson PR 2002b, 'Chemical analgesia for velvet antler removal in deer', *New Zealand Veterinary Journal*, vol. 50, pp. 237-243.

Wardrope DD 1995, 'Problems with the use of ear tags in cattle', *The Veterinary Record,* vol. 137, no. 26, p. 675.

Watts JM & Stookey JM 1999, 'Effects of restraint and branding on rates and acoustic parameters of vocalization in beef cattle', *Applied Animal Behaviour Science,* vol. 62, pp. 125-135.

Weary DM, Niel L, Flower FC & Fraser D 2006, 'Identifying and preventing pain in animals', *Applied Animal Behaviour Science*, vol.100, pp. 64-76.

Weaver AD, St Jean G & Steiner A 2005, *Bovine surgery and lameness*, second edition, Blackwell Publishing, Oxford, UK.

Webster JR & Matthews LR 2006, 'Behaviour of red deer following antler removal with two methods of analgesia', *Livestock Science,* vol. 100, pp. 150-158.

Weiss A & Egel-Weiss W 2006, 'Use of acupuncture for the treatment of bovine dystocia. Einsatz der Akupunktur bei der Dystokie des Rindes', *Tierarztliche Umschau,* vol. 61, pp. 303-310.

Welsh JCM, Lees P, Stodulski G, Cambridge H & Foster AP 1992, 'Influence of feeding schedule on the absorption of orally administered flunixin in the horse', *Equine Veterinary Journal Supplement,* vol. 11, pp. 62–65.

Whay HR, Webster AJF & Waterman-Pearson AE 2005, 'Role of ketoprofen in the modulation of hyperalgesia associated with lameness in dairy cattle', *The Veterinary Record*, vol.157, no. 23, pp. 729-732.

Wheat JD 1950, 'New landmark for cornual nerve block', *Veterinary Medicine*, vol. 45, pp. 29-30.

White SS, Bolton JR & Fraser DM 1985, 'Use of electroacupuncture as an analgestic for laparotomies in two dairy cows', *Australian Veterinary Journal*, vol. 62, no. 2, pp. 52-54.

Whittem T, Freeman DA, Hanlon D & Parton K 1995, 'The effects on the pharmacokinetics of intravenous ceftiofur sodium in dairy cattle of simultaneous intravenous acetyl salicylate (aspirin) or probenecid', *Journal of Veterinary Pharmacology and Therapeutics*, vol.18, no. 1, pp. 61-67.

Whittem T, Freeman DA, Parton K & Hanlon DW 1996, 'The pharmacokinetics of salicylate in dairy cattle are not altered by simultaneous intravenous ceftiofur sodium and DL-lysine-acetyl salicylate (aspirin)', *Journal of Veterinary Pharmacology and Therapeutics*, vol. 19, no. 2, pp. 104-108.

Wiersma K 1985, 'Dehorning with Chem-Cast', *Canadian Veterinary Journal*, vol. 26, no. 5, p. 176.

Wilder-Smith CH, Knöpfli R & Wilder-Smith OH 1997, 'Perioperative magnesium infusion and postoperative pain', *Acta Anaesthesiologica Scandinavica*, vol. 41, pp. 1023-1027.

Williams RL & Upton RA 1988, 'The clinical pharmacology of ketoprofen', *Journal of Clinical Pharmacology*, vol. 28, no.12, Suppl, pp. S13-22.

Wilson PR, Beimans J, Stafford KJ, Veltman CJ & Spoorenberg J 1996a, 'Xylazine and a xylazine/fentanyl citrate/azaperone combination in farmed deer. I: dose rate comparison', *New Zealand Veterinary Journal*, vol. 44, pp. 81-87.

Wilson PR, Biemans J, Stafford KJ, Veltman CJ & Spoorenberg J 1996b, 'Xylazine and a xylazine/fentanyl citrate/azaperone combination in farmed deer. II: velvet antler removal and reversal combinations', *New Zealand Veterinary Journal,* vol. 44, pp. 88-94.

Wilson PR, Thomas DG, Stafford KJ & Mellor DJ 1999, 'Routes and doses of lignocaine hydrochloride for analgesia of the velvet antler of stags', *New Zealand Veterinary Journal*, vol. 47, pp. 167-174.

Wilson PR, Stafford KJ, Thomas DG and Mellor DJ 2000, 'Evaluation of techniques for lignocaine hydrochloride analgesia of the velvet antler of adult stags', *New Zealand Veterinary Journal,* vol. 48, pp. 182-187.

Wilson PR 2002, 'Advances in health and welfare of farmed deer in New Zealand', *New Zealand Veterinary Journal,* vol. 50, Suppl, pp.105-109.

Wilson PR, Bartels MM, Stafford KJ & Mellor DJ 2002, 'Analgesia for velvet antler removal', *Proceedings of the New Zealand Society of Animal Production*, vol. 62, pp. 372-375.

Wilson PR & Stafford KJ 2002, 'The welfare of farmed deer in New Zealand. 2. Velvet antler removal', *New Zealand Veterinary Journal*, vol. 50, pp. 221-227.

Winks L, Holmes AE & O'Rourke PK 1977, 'Effect of dehorning and tipping on liveweight gain of mature Brahman crossbred steers', *Australian Journal of Experimental Agriculture and Animal Husbandry,* vol. 17, February, pp. 16-19.

Wise CM, Knight AP, Lucas MJ, Morris CJ, Ellis RP & Phillips RW 1983, 'Effect of salicylates on intestinal secretion in calves given (intestinal loops) Escherichia coli heat-stable enterotoxin', *American Journal of Veterinary Research*, vol. 44, no. 12, pp. 2221-2225.

Wohlt JE, Allyn ME, Zajac PK & Katz LS 1994, 'Cortisol increases in plasma of Holstein heifer calves from handling and method of electrical dehorning', *Journal of Dairy Science,* vol. 77, pp. 3725-3729.

Wojcik R, Markiewicz W, Malaczewska J, Chrostowska M, Maslanka T, Rotkiewicz Z, Jaroszewski J & Siwicki AK 2006, 'Influence of meloxicam on cellular and humoral defense mechanisms', *Medycyna Weterynaryjna,* vol. 62, no. 12, pp. 1400-1402.

Woodbury MR & Haigh JC 1996, 'Innervation and anaesthesia of the antler pedicle in wapiti and fallow deer', *Canadian Veterinary Journal*, vol. 37, pp. 486-489.

Woodbury MR, Caulkett NA & Wilson PR 2002, 'Comparison of lidocaine and compression for velvet antler analgesia in wapiti', *Canadian Veterinary Journal*, vol. 43, pp. 869-875.

Woodbury MR, Caulkett NA, Johnson CB & Wilson PR 2005, 'Comparison of analgesic techniques for antler removal in halothane-anaesthetized red deer (Cervus elaphus): cardiovascular and somatic responses', *Veterinary Anaesthesia and Analgesia*, vol. 32, pp. 72-82.

Woolf CJ & Thompson SW 1991, 'The induction and maintenance of central sensitization is dependent on N-methyl-D-aspartic acid receptor activation; implications for the treatment of post-injury pain hypersensitivity states', *Pain,* vol. 44, pp. 293-299.

Worrell MA, Clanton DC & Calkins CR 1987, 'Effect of weight at castration on steer performance in the feedlot', *Journal of Animal Science,* vol. 64, pp. 343-347.

Wrigley LC, Howard FM & Gabel D 2000, ‘Transcervical or intraperitoneal analgesia for laparoscopic tubal sterilization: a randomized controlled trial’, *Obstetrics and Gynecology*, vol. 96, no. 6, pp. 895-898.

Xie H & Preast V 2007, *Xie’s veterinary acupuncture*, Blackwell Publishing, Ames, IA.

Yeruham I, Perl S & Nyska A 1996, ‘Skin tumours in cattle and sheep after freeze- or heat-branding’, *Journal of Comparative Pathology*, vol. 114, no. 1, pp. 101-106. (Note: abstract only obtained.)

Young PL 1979, ‘The effect of xylazine on the body temperature of cattle’, *Australian Veterinary Journal*, vol. 55, pp. 442-443.

Zappa SC & Nabors SB 1992, ‘Use of ethyl chloride topical anesthetic to reduce procedural pain in pediatric oncology patients’, *Cancer Nursing*, vol. 15, pp. 130–136.

Zilberstein LF, Moens YP & Leterrier E 2007, ‘The effect of local anaesthesia on anaesthetic requirements for feline ovariectomy’, *The Veterinary Journal* [Online ahead of print Nov 23]

ZoBell DR, Goonewardene LA, Bertagnolli C & Ziegler K 1993a, ‘The effects of spaying and anabolic implants on the average daily weight gain of heifers on pasture’, *Canadian Veterinary Journal,* vol. 34, December, pp. 727-730.

ZoBell DR, Goonewardene LA & Ziegler K 1993b, ‘Evaluation of the bloodless castration procedure for feedlot bulls’, *Canadian Journal of Animal Science,* vol. 73, December, pp. 967-970.

Zulauf M, Gutzwiller A, Steiner A & Hirsbrunner G 2003, ‘The influence of an analgesic drug in clamp-castrated male calves on concentrate intake, weight gain and serum cortisol concentration’, *Schweizer Archiv fur Tierheilkunde*, vol. 145, no. 6, pp. 283-290. (Note: abstract only obtained.)

Zweiacher ER, Durham RM, Boren BD & Gaskins CT 1979, ‘Effects of method and time of castration of feeder calves’, *Journal of Animal Science,* vol. 49, no. 1, pp. 5-9.

8.2 Legislative instruments, codes of practice, standards and policies

8.2.1 Australia

Australian Government Department of Agriculture, Fisheries and Forestry 1999, *Cattle spaying : National consultative committee on animal welfare (NCCAW) revised position statement,* October, accessed 4 January 2008, http://www.daff.gov.au/animal-plant-health/welfare/nccaw/guidelines/livestock/spaying

Geoff Neumann and Associates Pty Ltd 2005, *Review of the Australian model codes of practice for the welfare of animals,* Brighton, South Australia.

PISC (Primary Industries Standing Committee) 2002, *National guidelines for beef cattle feedlots in Australia (SCARM report 47)*, 2nd edition, CSIRO Publishing, Collingwood, Victoria, accessed 2 December 2007, http://www.publish.csiro.au/nid/22/sid/11.htm.

PISC (Primary Industries Standing Committee) 2004, *Model code of practice for the welfare of animals – cattle (PISC report 85)*, 2nd edition, CSIRO Publishing, Collingwood, Victoria, accessed 2 December 2007, http://www.publish.csiro.au/nid/22/sid/11.htm.

PISC (Primary Industries Standing Committee) 2006, *Model code of practice for the welfare of animals – the sheep (PISC report 89)*, 2nd edition, CSIRO Publishing, Collingwood, Victoria, accessed 2 December 2007, http://www.publish.csiro.au/nid/22/sid/11.htm.

SCAAHC (Standing Committee on Agriculture, Animal Health Committee) 1995, *Model code of practice for the welfare of animals – feral livestock animals – destruction or capture, handling and marketing (SCARM report 34)*, CSIRO Publishing, Collingwood, Victoria, accessed 2 December 2007, http://www.publish.csiro.au/nid/22/sid/11.htm.

8.2.2 Queensland

Veterinary Surgeons Act 1936 (Qld), accessed 1 December 2007, http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/V/VetSurgA36.pdf

Veterinary Surgeons Regulation 2002 (Qld), accessed 1 December 2007, http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/V/VetSurgR02.pdf

Animal Care and Protection Act 2001 (Qld), accessed 1 December 2007, http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/A/AnimalCaPrA01.pdf

Animal Care and Protection Regulation 2002 (Qld), accessed 1 December 2007, http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/A/AnimalCaPrR02.pdf

8.2.3 New South Wales

Veterinary Practice Act 2003 no 87 (NSW), accessed 1 December 2007, http://www.legislation.nsw.gov.au

Veterinary Practice Regulation 2006 (NSW), accessed 1 December 2007, http://www.legislation.nsw.gov.au

Prevention of Cruelty to Animals Act 1979 No 200 (NSW), accessed 1 December 2007, http://www.legislation.nsw.gov.au

Prevention of Cruelty to Animals (General) Regulation 2006 (NSW), accessed 1 December 2007, http://www.legislation.nsw.gov.au

Poisons and Therapeutic Goods Act 1984, accessed 15 May 2008, http://www.legislation.nsw.gov.au

Stock Medicines Act 1986, accessed 15 May 2008, http://www.legislation.nsw.gov.au

8.2.4 Australian Capital Territory

Animal Welfare Act 1992 (ACT), accessed 1 December 2007, http://www.legislation.act.gov.au/a/1992-45/default.asp

Animal Welfare Regulation 2001 (ACT), accessed 1 December 2007, http://www.legislation.act.gov.au/a/1992-45/default.asp

Code of Practice for the Welfare of Animals – Cattle (ACT) undated, accessed 2 December 2007, http://www.tams.act.gov.au/live/pets/animalwelfare/animalwelfarestandards-codesofpractice

Code of Practice for the Welfare of Animals – Sheep (ACT) undated, accessed 2 December 2007, http://www.tams.act.gov.au/live/pets/animalwelfare/animalwelfarestandards-codesofpractice

8.2.5 Victoria

Veterinary Practice Act 1997 (Vic), accessed 1 December 2007, http://www.dms.dpc.vic.gov.au/

Veterinary Practice Regulations 1998 (Vic), accessed 1 December 2007, http://www.dms.dpc.vic.gov.au/

Prevention of Cruelty to Animals Act 1986 (Vic), accessed 1 December 2007, http://www.dpi.vic.gov.au/DPI/nrenfa.nsf/LinkView/A82969C294308823CA2572B10006B94F51F52E6260BC77B8CA2572B10008EED4

Prevention of Cruelty to Animals Regulations 1997 (Vic), accessed 1 December 2007, http://www.dpi.vic.gov.au/DPI/nrenfa.nsf/LinkView/A82969C294308823CA2572B10006B94F51F52E6260BC77B8CA2572B10008EED4

Victorian Government Department of Primary Industries 2001, *Code of accepted farming practice for the welfare of cattle (Victoria)*, October, accessed 2 December 2007, http://www.dpi.vic.gov.au/dpi/nreninf.nsf/93a98744f6ec41bd4a256c8e00013aa9/3bd8abf5d04a5b49ca256f0f0009b4ec/$FILE/AG0009.pdf

Victorian Government Department of Primary Industries 2007, *Code of accepted farming practice for the welfare of sheep (Victoria), revision no. 2*, June, accessed 2 December 2007, http://www.dpi.vic.gov.au/DPI/nrenfa.nsf/LinkView/2ED9BA5326FC9D37CA25740C001A90182B72296A5108C4FFCA25734F0009F96F/$file/sheep_welfare_code_revision_2.pdf

8.2.6 Tasmania

Veterinary Surgeons Act 1987 (Tas), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/tas/consol_act/vsa1987258/

Veterinary Surgeons Regulations 2004 (Tas), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/tas/consol_reg/vsr2004367/

Animal Welfare Act 1993 (Tas), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/tas/consol_act/awa1993128/

Animal Welfare Regulations 1993 (Tas), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/tas/consol_act/awa1993128/

Department of Primary Industry and Fisheries undated (a), *Animal welfare standard – Tasmania – no 2, cattle*, accessed 2 December 2007, http://www.dpiw.tas.gov.au/inter.nsf/Attachments/EGIL-5432JM/$FILE/CattleStandard.pdf.

Department of Primary Industry and Fisheries undated (b), *Animal welfare standard – Tasmania – no 1, sheep*, accessed 2 December 2007, http://www.dpiw.tas.gov.au/inter.nsf/Attachments/EGIL-5485FU/$FILE/sheepstandard98.pdf.

Department of Primary Industries and Water & Animal Welfare Advisory Committee 2006, *Review of the* Animal Welfare Act 1993, Joint Report and Recommendations, July, accessed 2 December 2007, http://www.dpiw.tas.gov.au/inter.nsf/Attachments/SROS-6UN4RG/$FILE/Animal%20Welfare%20Act%20Review%20Report.pdf.

8.2.7 South Australia

Veterinary Practice Act 2003 (SA), accessed 1 December 2007, http://www.legislation.sa.gov.au/LZ/C/A/VETERINARY%20PRACTICE%20ACT%202003.aspx

Veterinary Practice Regulations 2005 (SA), accessed 1 December 2007, http://www.legislation.sa.gov.au/LZ/C/R/VETERINARY%20PRACTICE%20REGULATIONS%202005.aspx

Prevention of Cruelty to Animals Act 1985 (SA), accessed 1 December 2007, http://www.legislation.sa.gov.au/LZ/C/A/PREVENTION%20OF%20CRUELTY%20TO%20ANIMALS%20ACT%201985.aspx

Prevention of Cruelty to Animals Regulations 2000 (SA), accessed 1 December 2007, http://www.legislation.sa.gov.au/lz/c/r/prevention%20of%20cruelty%20to%20animals%20regulations%202000/current/2000.10.un.pdf

8.2.8 Western Australia

Veterinary Surgeons Act 1960 (WA), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/wa/consol_act/vsa1960258/

Veterinary Surgeons Regulations 1979 (WA), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/wa/consol_reg/vsr1979367/

Animal Welfare Act 2002 (WA), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/wa/consol_act/awa2002128/

Animal Welfare (General) Regulations 2003 (WA), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/wa/consol_reg/awr2003292/

Department of Local Government and Regional Development WA 2003, *Code of practice for sheep in Western Australia*, accessed 2 December 2007, http://www.dlgrd.wa.gov.au/Publications/Docs/CodeOfPractice_Sheep.pdf.

Department for Planning and Infrastructure, Government of Western Australia 2005, *The grazing of cattle in the northern pastoral areas of Western Australia,* accessed 2 December 2007, http://www.dpi.wa.gov.au/mediaFiles/pastoral_cattlenorth.pdf.

Department for Planning and Infrastructure, Government of Western Australia 2005, *The grazing of cattle in the southern pastoral areas of Western Australia,* accessed 2 December 2007, http://www.dpi.wa.gov.au/mediaFiles/pastoral_cattlesouth.pdf.

8.2.9 Northern Territory

Veterinarians Act (NT), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/nt/consol_act/va163/

Veterinarians Regulations (NT), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/nt/consol_reg/vr272/

Animal Welfare Act (NT), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/nt/consol_act/awa128/.

Animal Welfare Regulations (NT), accessed 1 December 2007, http://www.austlii.edu.au/au/legis/nt/consol_reg/awr237/.

8.2.10 International

Act on Animal Protection 1978 (Switzerland), accessed 10 December 2007, http://www.admin.ch/bvet.

Agriculture Canada 1991, *Recommended code of practice for the care and handling of farm animals – beef cattle,* Ottawa, 46 pp.

Animal Protection Act 1997 (Poland), accessed 15 May 2008, http://www.animallaw.info/nonus/statutes/stpoapa1997.htm#Chapter_12.

Animal Protection Ordinance 2001 (Switzerland), accessed 10 December 2007, http://www.admin.ch/bvet.

Animal Remedies (Develveting) Regulations 1994 (New Zealand)

Animal Welfare Act 1999 (New Zealand), accessed 1 December 2007, http://www.biosecurity.govt.nz/animal-welfare/.

Animal Welfare Act 2006 (UK), accessed 15 May 2008, http://www.opsi.gov.uk/ACTS/acts2006/pdf/ukpga_20060045_en.pdf.

Canadian Agri-Food Research Council 1995, *Recommended code of practice for the care and handling of sheep,* Ottawa, 37 pp.

EC (Commission of the European Communities) 2002, *Communication from the commission to the Council and the European Parliament on animal welfare legislation on farmed animals in third countries and the implications for the EU,* 18 November, accessed 15 May 2008, http://ec.europa.eu/food/animal/welfare/international/2002_0626_en.pdf.

European convention for the protection of animals kept for farming purposes 1976, accessed 15 May 2008, http://www.coe.int/T/E/Legal_affairs/Legal_co-operation/Biological_safety,_use_of_animals/Farming/.

European Council Directive 91/629/EEC laying down minimum standards for the protection of calves, 1991, 19 November, accessed 15 May 2008, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0629:EN:HTML.

European Council Directive 98/58/EC on the protection of animals kept for farming purposes 1998, 20 July, accessed 15 May 2008, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31998L0058:EN:HTML.

Clayton LA 2003, *Overview of Brazil's legal structure for animal issues,* Michigan Sate University – Detroit College of Law, accessed 14 December 2007, http://www.animallaw.info/nonus/articles/ovbrazil.htm.

DEFRA (Department for Environment Food and Rural Affairs [UK]) 2003a, *Code of recommendations for the welfare of livestock: cattle,* London, accessed 15 May 2008, http://www.defra.gov.uk/animalh/welfare/farmed/cattle/booklets/cattcode.pdf.

DEFRA (Department for Environment Food and Rural Affairs [UK]) 2003b, *Code of recommendations for the welfare of livestock: sheep,* London, accessed 15 May 2008, http://www.defra.gov.uk/animalh/welfare/farmed/sheep/booklets/sheep.pdf.

Environmental Crimes Law 1999 (Brazil), accessed 15 May 2008, http://www.animallaw.info/nonus/statutes/stbrecl1999.htm.

FAWC (Farm Animal Welfare Council [UK]) 1997, *Report on the welfare of dairy cattle,* accessed 8 January 2008, http://www.fawc.org.uk/reports/dairycow/dcowrtoc.htm.

FAWC (Farm Animal Welfare Council [UK]) 2008, *FAWC report on the implications of castration and tail docking for the welfare of lambs,* accessed 8 July 2008, http://www.fawc.org.uk/pdf/report-080630.pdf.

Mutilations (Permitted Procedures) (England) Regulations 2007 (UK), accessed 15 May 2008, http://www.opsi.gov.uk/si/si2007/uksi_20071100_en_1.

NAWAC (National Animal Welfare Advisory Committee [New Zealand]) 1992, *Code of Recommendations and Minimum Standards for the Welfare of Deer during the Removal of Antlers 1992*, Ministry of Agriculture and Fisheries, Wellington, New Zealand accessed 15 May 2008, http://www.biosecurity.govt.nz/animal-welfare/codes/antlers/index.htm.

NAWAC (National Animal Welfare Advisory Committee [New Zealand]) 2005a, *Animal welfare (painful husbandry procedures) code of welfare 2005*, 23 December, Ministry of Agriculture and Fisheries, Wellington, New Zealand, accessed 30 November 2007, http://www.biosecurity.govt.nz/animal-welfare/codes/painful-husbandry/index.htm.

NAWAC (National Animal Welfare Advisory Committee [New Zealand]) 2005b, *Animal welfare (painful husbandry procedures) code of welfare report*, 31 October, accessed 30 November 2007, http://www.biosecurity.govt.nz/animal-welfare/codes/painful-husbandry/index.htm.

NCBA (National Cattlemen's Beef Association [USA]) undated, *The cattle industry's guidelines for care and handling of beef cattle,* Centennial, Co, accessed 15 May 2008, http://www.bqa.org/uDocs/Guidelines%20for%20the%20Care%20and%20Handling%20of%20Cattle.pdf.

NYSCHAP (New York State Cattle Health Assurance Program) 2007, *NYSCHAP cattle welfare*, accessed 14 January 2008, http://nyschap.vet.cornell.edu/about.asp.

Recommendations adopted by the Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes: recommendation concerning cattle 1988, accessed 15 May 2008, http://www.coe.int/t/e/legal_affairs/legal_co-operation/biological_safety%2C_use_of_animals/farming/Rec%20cattle%20E.asp#TopOfPage.

Recommendations adopted by the Standing Committee of the European Convention for the Protection of Animals Kept for Farming Purposes: recommendation concerning sheep 1992, accessed 7 July 2008, http://www.coe.int/t/e/legal_affairs/legal_co-operation/biological_safety%2C_use_of_animals/farming/Rec%20sheep%20E.asp#TopOfPage.

SCAHAW (European Commission's Scientific Committee on Animal Health and Animal Welfare) 2001, *The welfare of cattle kept for beef production,* 25 April, accessed 15 May 2008, http://ec.europa.eu/food/fs/sc/scah/out54_en.pdf.

Tomaselli M 2003, *International comparative animal cruelty laws,* Michigan Sate University – Detroit College of Law, accessed 14 December 2007, http://www.animallaw.info/articles/ddusicacl.htm.

Turk DS 2007, *Detailed discussion of cattle laws,* Michigan Sate University – Detroit College of Law, accessed 14 December 2007, http://www.animallaw.info/articles/ddusbovine.htm.

Welfare of Farmed Animals (England) Regulations 2007 (UK), accessed 15 May 2008, http://www.opsi.gov.uk/si/si2007/uksi_20072078_en_1.

Wepruk J 2004, 'A report on animal welfare law in Canada', Alberta Farm Animal Care, June, accessed 5 December 2007, *http://www.afac.ab.ca/lawsregs/awlcanada.pdf,* 11 pp.

8.2.11 Non-government

AVA (Australian Veterinary Association) 2008, *Policies – Part 5 – Identification of animals* and *Part 8 – Cattle health and welfare*, accessed 15 May 2008, http://www.iimage.com.au/ava.com.au/policies.php?c=0&catid=72&catname=Policy%20Compendium%20-%20For%20Public%20Access.

AVMA (American Veterinary Medical Association) 2008, *Policy statements*, accessed 15 May 2008, http://www.avma.org/issues/policy/default.asp.

Animal Welfare Institute 2006, *Animal welfare approved standards for beef cattle and calves,* Washington DC, accessed 15 May 2008, http://www.awionline.org/farm/standards/beef_onprint.htm.

Animal Welfare Institute undated, *Animal welfare approved standards for sheep,* Washington DC, accessed 7 July 2008, http://www.animalwelfareapproved.org/uploads/docs/Animal%20Welfare%20Approved%20Sheep%20Standards%20Version%201.01%2005.30.08.pdf.

CVMA (Canadian Veterinary Medical Association) 2008, *Position statements on animal welfare issues – castration, tail docking, dehorning of farm animals*, accessed 15 May 2008, http://canadianveterinarians.net/ShowText.aspx?ResourceID=48.

FASS (Federation of Animals Science Societies [US]) 1999, 'Chapter 5: Guidelines for beef cattle husbandry' and 'Chapter 9: Guidelines for sheep and goat husbandry', in *Guide for the care and use of agricultural animals in agricultural research and teaching*, first revised edition (January 1999), accessed 15 May 2008, http://www.fass.org/docs/agguide/Chapter05.pdf.

Grandin Livestock Handling Systems 2008, *Outline of cattle welfare critical control points on feedlots, ranches and stocker operations,* accessed 15 May 2008, http://www.grandin.com/cattle.welfare.ccp.html.

KRAV 2001, *KRAV 2001 standards*, Uppsala, Sweden, accessed 15 May 2008, http://www.organic-europe.net/country_reports/sweden/downloads/krav_2001_03.pdf.

HSI (Humane Society International [Australia]) 2006a, *'Humane Choice' standards – cattle*, Avalon, accessed 15 May 2008, http://www.hsi.org.au/news_library_events/Humane%20Choice/Standards%20Updated%20May%2008/Humane_Choice_Standards_Feb06_specifics_Cattle.pdf.

HSI (Humane Society International [Australia]) 2006b, *'Humane Choice' standards – sheep*, Avalon, accessed 15 May 2008, http://www.hsi.org.au/news_library_events/Humane%20Choice/Standards%20Updated%20May%2008/Humane_Choice_Standards_Feb_06_specifics_Sheep.pdf.

Nielsen B & Thamsborg SM 2001, 'Organic beef production with emphasis on feeding and health of dairy bred bull calves', in M Hovi & T Baars (eds),*Proceedings of the 4th Network for Animal Health and Welfare in Organic Agriculture workshop,* March, pp. 155-168.

RSPCA (Australia) 2006, *Policies & position papers. Part B: farm animals*, accessed 15 May 2008, http://www.rspca.org.au/policy/B.pdf.

RSPCA (UK) 2006, *RSPCA welfare standards for sheep,* June, accessed 7 July 2008, http://www.rspca.org.uk/servlet/Satellite?blobcol=urlblob&blobheader=application%2Fpdf&blobkey=id&blobtable=RSPCABlob&blobwhere=1147695610417&ssbinary=true.

RSPCA (UK) 2007, *RSPCA welfare standards for beef cattle,* November, accessed 15 May 2008, http://www.rspca.org.uk/servlet/Satellite?pagename=RSPCA/RSPCARedirect&pg=welfarestandards&marker=1&articleId=1125906255595.

9 Appendixes

9.1 Veterinary and medical experts consulted

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9.2 Papers on the productivity or welfare effects of cattle castration

Reference	Country	Breed(s)	Age at castration	Production system	Method (pain relief)	Parameters of interest
Fenton et al 1958	UK	NS	7 wks	Feedlot	Bu or R or S (NS)	Weight gain and clinical observations to 6 wks
Carroll et al 1963	UK	Sh, F	1 or 7 mths	Feedlot	S (NS)	Weight gain, feed efficiency, body dimensions, carcass characteristics to 18 mths
Mullen 1964	UK	F	3-5 mths	Hand-reared and feedlot	Bu or R or S (NS)	Weight gain and clinical observations to 24 wks
Champagne et al 1969	US	H	Birth, 2 , 7, or 9 mths	Feedlot	S (NS)	Weight gain, feed efficiency, body dimensions, carcass characteristics to 15 mths
Johnston & Buckland 1976	Can	Ho	4 mths	Feedlot	NS (+dehorning)	Cortisol for 48 hrs
Clarke-Lewis 1977	UK	-	-	-	Bu	General clinical observations
Hinton 1977	UK	-	-	-	Bu	General clinical observations
Cox 1977	UK	-	-	-	Bu	General clinical observations
Zweiacher et al 1979	US	Xbred beef	180 kg	Feedlot	S[1] (NS)	Weight gain, general clinical observations
Hill et al 1985	US	A, H, SG pure and Xbred	15 dd	Sucking and grazing +/- implants	S (NS) or C	Scrotal oedema, weight gain to 196 dd
Fell et al 1986	Aus	F, mixed beef	4-11 wks	Grazing	R or S (nil)	Cortisol (salivary), behaviour, weight gain and condition for 4 wks
Macaulay et al 1986	US	H	3 wks	Feedlot	S (NS) or C or Bu	Behaviour, total blood cell counts and differentials
Baker & Gonyou 1986	US	A	8 mths	Feedlot +/- implants	S (nil)	Weight gain, testosterone, behaviour
Hinch & Lynch 1987	Aus	H	4 mths	Grazing	NS	Ease of handling
Worrell et al 1987	US	AxHx(Si)xG	70, 230, 320 or 410 kg	Feedlot + implants	S (NS)	Weight gain, carcass characteristics to slaughter
Bagley et al 1989	US	Xbred (A, H, B)	Birth or 4 mths	Sucking +/- implants	R	Weight gain, body dimensions to weaning

Reference	Country	Breed(s)	Age at castration	Production system	Method (pain relief)	Parameters of interest
Coventry et al 1989	Aus	Sh	3-6 mths	Grazing	C	Clinical observations
Fordyce et al 1989	Aus	B Xbred	Mixed (50-128 kg)	Grazing	C	Clinical observations, weight gain for 199 dd
Cohen et al 1990	Can	H	8 mths	Feedlot	S (NS) or C	Cortisol, PCV, glucose, proteins, NEFA, creatinine, urea nitrogen, rectal temp for 6 dd
King et al 1991	Can	Mixed xbred A, H, C, Si, MA	78 or 167 dd (3 or 5 mths)	Sucking	S (NS) or Bu	Cortisol, weight gain to weaning
Mellor et al 1991	UK	F	1-7 dd	Hand-reared	R	Behaviour, cortisol for 4 hrs
Faulkner et al 1992	US	Xbred	6-9 mths	Feedlot	S (+/-BX)	Cortisol, haptoglobin, clinical observations, chute activity, feed intake and weight gain for 27 dd
ZoBell et al 1993	Can	Xbred composite beef breeds, (Si)xH	8-9 mths	Feedlot + implants	Ba (NS) or S (NS)	Weight gain, carcass characteristics for 112 dd
Robertson et al 1994	UK	Ay	6, 21 or 42 dd	Hand-reared	S (nil), Bu (nil) or R (nil)	Cortisol, behaviour for 3 hrs
Chase et al 1995	US	A, H, B	20-21 mths	Feedlot	S (L) or Ba (nil)	Cortisol, WBC, feed intake and weight gain for 35 dd
Molony et al 1995	UK	Ay	1 wk	Hand-reared and feedlot	S, R, Bu or R+Bu	Cortisol, behaviour for 48 days
Jago et al 1996	NZ	Mixed	11 or 17 mths	Grazing	S (L) or I	Weight gain, carcass composition and meat quality for 135 dd
Restle et al 1996	Braz	Xbred	8 mths	Grazing	S (NS) or Bu	Weight gain, carcass characteristics for 25 mths
Fisher et al 1996	Ire	F	5 mths	Feedlot	S (+/-L), Bu (+/-L)	Cortisol, feed intake and weight gain for 35 dd
Fisher at al 1997a	Ire	F	5 mths	Feedlot	S (nil)	Cortisol, haptoglobin, fibrinogen, IFN-γ, feed intake and weight gain for 28 dd
Fisher at al 1997b	Ire	F	5 mths	Feedlot	S (nil)	Cortisol, haptoglobin, fibrinogen, IFN-γ, WBC, N:L, feed intake and weight gain for 28 dd
Browning et al 1997	US	Xbred[2]	Birth or weaning	Sucking and feedlot	NS	Weight gain, carcase traits to 12 mths

Reference	Country	Breed(s)	Age at castration	Production system	Method (pain relief)	Parameters of interest
Carragher et al 1997	NZ	F	17 or 5 mths	Grazing and feedlot	S (L)	Cortisol, haptoglobin, NEFA, BOH, urea, feed intake and weight gain for 28 dd
Murata 1997	Jap	H	3-4 mths	Feedlot	Bu (NS)	Cortisol, WBC and differentials
Lyons-Johnson 1998	US	A, Si, Xbred	Birth, 33 or 36 wks (weaning)	NS	S (NS) or Ba	Haptoglobin
Keane 1999	Ire	F, FxC	5-6 or 11-12 mths	Grazing and feedlot	S (L)	Weight gain for 12 mths
Knight et al 1999	NZ	A, FxH, FxSi	8 or 17 mths	Grazing	S (NS)	Weight gain and carcass characteristics at slaughter
Knight et al 2000	NZ	A, AxF, Si, D cross	14 or 8-9 mths	Grazing	S (L) or Ba (+/-L)	Clinical observations, weight gain for 85 dd or 4 mths
Stookey et al c2001	Can	NS	NS (sexually mature)	NS	S (+/-E) or Ba (+/-E)	Behaviour, clinical observations, weight gain to slaughter
Fisher et al 2001	NZ	A, AxF, Si, A Xbred	14 or 9 mths		S (L) or Ba (L)	Cortisol, haptoglobin, behaviour and weight gain for 57 dd
Lents et al 2001	US	AxRP	2-3 or 7-8 mths	Sucking and grazing + implants	S (NS) or Ba	Weight gain to weaning (7 - 8mths) and 50 dd after weaning
Earley & Crowe 2002	Ire	F	5 mths	Feedlot	S (+/- L,+/-K)	Cortisol, haptoglobin, fibrinogen, IFN-γ, WBC, routine haematology, feed intake and weight gain for 35 dd
Stafford et al 2002	NZ	F cross	2-4 mths		Sx2[3], Bu, Ba, R (all +/-L,+L+K)	Cortisol, clinical observations, weight gains for 13 wks
Ting et al 2003	Ire	H/F	11 mths	Feedlot	S (+/-K)	Cortisol, haptoglobin, fibrinogen, IFN-γ, WBC, routine haematology, behaviour, feed intake and weight gain for 35 dd
Ting et al 2003	Ire	H/F	13 mths	Feedlot	Bu (+/-L,+K,+LXE)	Cortisol, haptoglobin, fibrinogen, IFN-γ, WBC, routine haematology, behaviour, feed intake and weight gain for 35 dd
Zulauf et al 2003	Switz	NS	110-160kg	NS	Bu (+/-(N+Se+L))	Cortisol, fibrinogen, WBC, clinical observations, feed intake and weight gain
Ting et al 2005	Ire	H/F	1.5-5.5 mths	Hand-reared and feedlot	Bu	Cortisol, haptoglobin, fibrinogen, IFN-γ, WBC, scrotal temp and weight gain for 35 dd

Reference	Country	Breed(s)	Age at castration	Production system	Method (pain relief)	Parameters of interest
Pang et al 2006	Ire	H/F	5 mths	Feedlot	Ba (+/-Ca) or Bu (+/-Ca)	Cortisol, haptoglobin, fibrinogen, IFN-γ, WBC, routine haematology, feed intake and weight gain for 35 dd
Thüer et al 2007	Switz	Si, (Si)xRH	21-28 dd	Hand-reared	Bu (+/-L) or R (+/-L)	Cortisol, behaviour, clinical observations to 3 mths
Coetzee et al 2007	US	A cross	4-6 mths	Feedlot	S (+/-A, SS)	Cortisol

1 2 surgical methods: 'elastrator' bands with ligation below, or emasculator, used on exposed spermatic cords
2 Holstein dam, sire breed not specified
3 2 surgical methods: spermatic cords broken by traction or cut with emasculator

Abbreviations					
Breed		**Method / Pain relief**		**Parameters**	
A	Angus	A	aspirin p.o.	BOH	β-hydroxybutyrate
Ay	Ayshire	Ba	latex band	IFN-γ	stimulated lymphocyte production of interferon-γ
B	Brahman	Bu	Burdizzo	N :L	neutrophil to lymphocyte ratio
C	Charolais	BX	butorphanol plus xylazine i.v.	NEFA	non-esterified fatty acids (= free fatty acids)
D	Devon	C	chemical (α-hydroxypropionic or lactic acid)	PCV	packed (red) cell volume
F	Friesian	Ca	carprofen	WBC	white blood cell count
G	Gelbvieh	E	epidural		
H	Hereford	I	immunocastration		
Ho	Holstein	K	ketoprofen		
MA	Maine Anjou	L	local anaesthetic		
RH	Red Holstein	LXE	lignocaine plus xylazine epidural		
RP	Red Poll	N	NSAID not specified		
NS	not specified	R	rubber ring		
SG	Santa Gertrudis	NS	not specified (usually means no pain relief)		
Sh	Shorthorn	S	surgical		
Si	Simmental	Se	sedative not specified		
		SS	sodium salicylate i.v.		

9.3 Published analgesia protocols for castration in cattle

Source	Method	Obs	Breed	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Pang et al 2006	Band Callicrate	CO	Friesian	22	191	10		Carprofen IV 1.4mpk, 20min pre castration		2	12h C and 35d APP, haematology and ADG C increase from 0-2h & 2-6h same as castrated controls C no different to uncastrated controls 6-12h C AUC not different to castrated control
Stafford et al 2002	Band Callicrate	CO	Friesian cross	8-16	68-132	9			L 2%; 3ml intratesticle + 2ml SC in ventral scrotum, 20min pre castration	3	8h C and 8w wound healing observations period C increase following castration prevented
Stafford et al 2002	Band Callicrate	CO	Friesian cross	8-16	68-132	9		K IV 3mpk, 20min pre castration	L 2%; 3ml intratesticle + 2ml SC in ventral scrotum, 20min pre castration	3	8h C and 8w wound healing observations period C increase following castration prevented No benefit of K in addition to that provided by L
Pang et al 2006	Burdizzo 2 crushes of 10s, 1cm apart	CO	Friesian	22	191	10		Carprofen IV 1.4mpk, 20min pre castration		0	12h C and 35d APP, haematology and ADG C increase from 0-2h & 2-6h, 6-12h same as castrated controls C AUC no different than castrated control
Thüer et al 2007a,b	Burdizzo 2 crushes of 1min, 0.5-1cm apart (proximal then distal)	CBP	Simmental & cross with Friesian	3-4	61	15			L 2%; 10ml into spermatic cord & SC scrotal neck, 5min pre castration	1	72h C and 84d B observation period L significantly reduced immediate pain which was strong in control calves C rose within 20min but significantly less than untreated control and to resting level by 90min where it remained to final observation at 72h B response minor with no effect of L P painful until day 15, not different to control

Source	Method	Obs	Breed	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Fisher et al 1996	Burdizzo 2 crushes of 10s, 1cm apart	CO	Friesian	22	173	8			L 2%; 8ml intratesticle + 3ml SC at site of crush, 15min pre castration	1	72h observation period for C, 35d for other parameters Reduced C compared with control for 1.5h Scrotal swelling greater than control calves for 35d
Stafford et al 2002	Burdizzo 2 crushes of 10s, 1cm apart	CO	Friesian cross	8-16	68-132	10			L 2%; 3ml intratesticle + 2ml SC in ventral scrotum, 20min pre castration	1	8h C and 8w wound healing observations period Transient increase in C returned to control level by 1h and remained there throughout sampling period
Ting et al 2003b	Burdizzo 2 crushes of 10s, 1cm apart	CBO	Friesian	56	307	10			L 2%; 8ml intratesticle + 3ml SC at site of crush, 20min pre castration	1	72h C, 6h B and 35d APP and haematology C rise attenuated between 0.25 & 1.5h C significantly higher than castrated control from 2-6h and not different from 6.5-12h C AUC not different from castrated control
Ting et al 2003b	Burdizzo 2 crushes of 10s, 1cm apart	CBO	Friesian	56	307	10	Xylazine epidural C1-C2, 0.05mpk + L 2% 0.4mpk, 10 min pre castration			1	72h C, 6h B and 35d APP and haematology C rise attenuated between 0.25 & 1.5h C significantly higher than castrated control from 2-6h and not different from 6.5-12h C AUC not different from castrated control

Source	Method	Obs	Breed	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Zulauf et al 2003	Burdizzo 2 crushes of 30s	CO	Simmental x Limousin	ND	110-160	14	Xylazine IM 0.1mpk 15min pre castration Tolazoline IM 0.5mpk 5min post castration	Ramifenazone (isopyin) IV 12mpk + phenylbutazone IV 6mpk15min pre castration	L 2%, 5ml neck of scrotum	1	3h C and 7d fibrinogen and white blood cells Only four samples of blood for C determination, 15min precastration at (time of xylazine and NSAID administration), 5min precastration at time of local anaesthetic, post castration at 5min and 3h. No C differences between treated and controls (castrated and uncastrated) except at 3h when castrated control had higher C than treated calves. Onset and duration of effect not established Treated calves had reduced scrotal swelling and marginally higher feed intake over 3d than controls
Stafford et al 2002	Burdizzo 2 crushes proximal then distal	CO	Friesian cross	8-16	68-132	9		K IV 3mpk, 20min pre castration	L 2%; 3ml intratesticle + 2ml SC in ventral scrotum, 20min pre castration	3	8h C and 8w wound healing observations period C increase following castration prevented
Ting et al 2003b	Burdizzo 2 crushes of 10s, 1cm apart	CBO	Friesian	56	307	10		K IV 3mpk 20min pre castration		3	72h C, 6h B and 35d APP and haematology C rise attenuated between 0.25 & 1.5h C lower than castrated control 2-12h C AUC not different to uncastrated control Abnormal standing B reduced but not eliminated
Thüer et al 2007a,b	Rubber ring	CBP	Simmental & cross with Friesian	3-4	61	15			L 2%; 10ml into spermatic cord & SC scrotal neck, 5min pre castration	1	72h C and 84d B observation period No or minor pain in immediate response to RR application No differences in C or B responses compared with uncastrated control calves to 72h or 7d P painful for 7w, not different to control

Source	Method	Obs	Breed	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Stafford et al 2002	Rubber ring	CO	Friesian cross	8-16	68-132	10			L 2%; 3ml intratesticle + 2ml SC in ventral scrotum, 20min pre castration	3	8h C and 8w wound healing observations period C increase following castration prevented
Stafford et al 2002	Rubber ring	CO	Friesian cross	8-16	68-132	10		K IV 3mpk, 20min pre castration	L 2%; 3ml intratesticle + 2ml SC in ventral scrotum, 20min pre castration	3	8h C and 8w wound healing observations period C increase following castration prevented No benefit of K in addition to that provided by L
Coetzee et al 2007	Surgical Drill torsion to spermatic cord and extirpation of testes	C	Angus cross	16-26	215-275	5		Aspirin 50mpk PO 1min pre castration		0	12h observation period Concurrent measurement of C and salicylate Large inter-individual variation in C reducing ability of study to demonstrate differences C values in uncastrated controls the same as castrates for 4h, associated with handling and restraint C clearly is not specific measure of pain Oral treatment with aspirin led to increased C for 1.5h, suggesting administration itself is stressful
Faulkner et al 1992	Surgical	CO	Cross bred beef	26-39	214	67	Xylazine IV 0.02mpk + Butorphanol IV 0.07mpk 90s before castration			0	7d observation period for C and haptoglobin Only 3 blood samples: pretreatment and at 3 and 7d after castration No effect of xylazine or butorphanol on any parameter Inadequate dose or time before castration possible

Source	Method	Obs	Breed	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Coetzee et al 2007	Surgical Drill torsion to spermatic cord and extirpation of testes	C	Angus cross	16-26	215-275	5		Sodium salicylate IV 50mpk 0min pre castration		1	12h observation period Concurrent measurement of C and salicylate Large inter-individual variation in C reducing ability of study to demonstrate differences C values in uncastrated controls the same as castrates for 4h, associated with handling and restraint C clearly is not specific measure of pain C ceiling effect apparent Attenuation of C response to castration for 1.5h, associated with plasma salicylate >25μg/ml
Ponvijay 2007	Surgical Pinhole ligation of spermatic cord (1 chromic catgut)	BP	Friesian-Jersey cross	7-8	36, 47	2			L 2%; 2.5ml SC spermatic cord	3	30d observation period No behavioural differences between ligated and unligated control calves. Low sensitivity of observations which were made only once daily. Between 15 and 20d atrophy of testes noted. Asepsis likely critical to successful procedure
Chase et al 1995	Surgical Emasculator Scrotal incision and spermatic cord emasculator	C	Angus, Brahman, Hereford	80-90	395-465	14			L 2%; 25ml into spermatic cord, 3min pre castration	NA	35d C observation period C samples taken pre castration, 2min after castration, then at 2 days and every 2-3d until 35d No description of behaviour at time of castration. No untreated but castrated control group Infrequent C samples (including day of surgery) make assessment of effects of L invalid)
Stafford et al 2002	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CO	Friesian cross	8-16	68-132	9			L 2%; 3ml intratesticle + 2ml SC at site of incision, 20min pre castration	0	8h C and 8w wound healing observations period C increase following castration greater than castration control

Source	Method	Obs	Breed	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Fisher et al 1996	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CO	Friesian	22	173	8			L 2%; 8ml intratesticle + 3ml SC at site of incision, 15min pre castration	1	72h observation period for C, 35d for other parameters Reduced C compared with control for 1.5h C response greater than Burdizzo group
Earley & Crowe 2002	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CO	Friesian	22	215	8			L 2%; 6ml intratesticle + 3ml SC at site of incision, 20min pre castration	1	35d observation period Peak C response at 2.63h but significantly less than control C response only reduced for 75m C AUC not significantly less than control
Caulkett et al 1993	Surgical Emasculator Scrotal incision and spermatic cord emasculator for 90s	O	Cross bred beef	52-78*	300-600	77	Xylazine epidural C1-C2, 0.07mpk in 7.5ml, 30 min pre castration			2	2h* observation period (peri-surgical only) Degree of sedation, analgesia and ataxia assessed No untreated castrated control group Sedation adequate in 97.4% (75/77) animals Surgical analgesia good (no response to incision and little response to traction) in 80.5 and adequate (little response to incision, some response to traction) in 19.5%. Ataxia absent or slight in 83.1%, moderate in 14.3% and severe in 2.6% (2 animals) Good pain control over short observation period. However, need at least 20-30min for analgesia

Source	Method	Obs	Breed	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Ting et al 2003a	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CBO	Friesian	48	300	10		K IV 3mpk 20min pre castration		2	72h C, 6h B and 35d APP and haematology K did not prevent immediate rise in C post castration K reduced C between 2 and 6h compared with castration control but elevated and the same as castration control from 6.5 to 12h C AUC significantly reduced by K K reduced abnormal standing and increased rumination during 6h B monitoring K prevented leukocytosis present in castration control calves
Ting et al 2003a	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CBO	Friesian	48	300	10		K IV 3mpk split and given 20 and 0min pre castration		2	72h C, 6h B and 35d APP and haematology K did not prevent immediate rise in C post castration K reduced C between 2 and 6h compared with castration control but elevated and the same as castration control from 6.5 to 12h C AUC significantly reduced by K No advantage of split dose K over single dose
Ting et al 2003a	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CBO	Friesian	48	300	10		K IV 3mpk split and given 20 and 0min pre castration + 3mpk at 24h post castration		2	72h C, 6h B and 35d APP and haematology K did not prevent immediate rise in C post castration K reduced C between 2 and 6h compared with castration control but elevated and the same as castration control from 6.5 to 12h C AUC significantly reduced by K No advantage of K at 24h
Stafford et al 2002	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CO	Friesian cross	8-16	68-132	8		K IV 3mpk, 20min pre castration	L 2%; 3ml intratesticle + 2ml SC at site of incision, 20min pre castration	3	8h C and 8w wound healing observations period C increase following castration prevented

Source	Method	Obs	Breed	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Earley & Crowe 2002	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CO	Friesian	22	215	8		K IV 3mpk, 20min pre castration		3	35d observation period Peak C response at 0.29h but significantly less than control C AUC significantly less than control Reduced acute phase protein response for 7d Increased average daily gain over 35d B response at time of surgery not described but expected to be significant
Earley & Crowe 2002	Surgical Emasculator Scrotal incision and spermatic cord emasculator	CO	Friesian	22	215	8		K IV 3mpk, 20min pre castration	L 2%; 6ml intratesticle + 3ml SC at site of incision, 20min pre castration	3	35d observation period Peak C response at 4.61h but significantly less than control C AUC significantly less than control Reduced acute phase protein response for 7d Increased average daily gain over 35d No added benefit of L over K alone. However, B response at time of surgery not described but expected to be significant and alleviated by L
Stafford et al 2002	Surgical Pull Scrotal incision and testes & spermatic cord removed by traction	CO	Friesian cross	8-16	68-132	10			L 2%; 3ml intratesticle + 2ml SC at site of incision, 20min pre castration	0	8h C and 8w wound healing observations period C increase following castration no different to greater than castration control
Stafford et al 2002	Surgical Pull Scrotal incision and testes & spermatic cord removed by traction	CO	Friesian cross	8-16	68-132	10		K IV 3mpk, 20min pre castration	L 2%; 3ml intratesticle + 2ml SC at site of incision, 20min pre castration	3	8h C and 8w wound healing observations period C increase following castration prevented

* estimate only

Abbreviations			
A	adrenaline (in combination with lignocaine)	LA	local anaesthesia
ADG	average daily gain	NA	not assessable (eg no untreated control group for comparison)
APP	acute phase proteins	ND	not described
L	lignocaine	P	palpation
Observations		**Effect score** (based on reported C and B observations)	
C Cortisol		0	No or minor difference compared with castrated control
B Behaviour		1	Significant but short lived effect, < 2h
O Other (for example, sedation, analgesia, ataxia, average daily gain, feed intake, scrotal circumference, acute phase proteins [fibrinogen, haptoglobin], interferon, general haematology, wound healing)		2	Significant effect for 2-6h
		3	Significant effect for at least 6h
		4	Complete or near complete elimination of evidence of pain and distress

9.4 Papers on the productivity or welfare effects of dehorning cattle

Reference	Country	Breed(s)[1]	Age at horn removal	Production system	Method (pain relief)[2]	Parameters of interest[3]
Johnston & Buckland 1976	Can	Ho	4 mths	Feedlot	NS (+dehorning)	Cortisol for 48 hrs
Winks et al 1977	Aus	B cross	3-3.5 yrs	Grazing	GD (dehorning or tipping) (nil)	Weight gains to 154 dd
Loxton et al 1982	Aus	B cross	4, 7, 19 or 30 mths	Grazing	KD (nil) or CD (nil)	Weight gains, clinical observations
Carter et al 1983	Aus	J	18-22 mths	NS	GD (nil, L or EI)	Cortisol, haemorrhage
Laden et al 1985	US	Ho	8 wks	Feedlot	EC (nil)	Cortisol, albumen, glucose, PCV, Hb, weight gain for 4 wks
Wiersma 1985	Can	Ho	1-21 dd	NS	Ch	General clinical observations
Boandl et al 1989	US	Ho	7-10 and 14-16 wks	Feedlot	EC (+/-L)	Cortisol
Kihurani et al 1989	Ken	NS	1-5 yrs	NS	DW (L)	Wound healing
Goonewardene & Hand 1991	Can	Xbred beef	319 kg	Feedlot	KD	Weight gain to 106 dd
Wohlt et al 1994	US	Ho	3-4 wks	Feedlot	EC (nil)	Cortisol
Cooper et al 1995	Can					
Morisse et al 1995	Fra	M	4 or 8 wks	Hand-reared then feedlot	CS (+/-L) or EC (+/-L)	Cortisol, behaviour to 24 hrs
Petrie et al 1996	NZ	F	6-8 wks	Hand-reared	SD (+/-L) or GC (+/-L)	Cortisol
Bengtsson et al 1996	Swe	SR, SW	7-29 dd	NS	NOP (+/-LX), LN (+/-LX)	Behaviour, clinical observations, horn growth at 170 dd
McMeekan et al 1997	NZ	F	14-16 wks	Feedlot	SD	Cortisol to 9 hrs
McMeekan et al 1998a	NZ	F	3-4 mths	Feedlot	SD (+/-B)	Cortisol to 9 hrs
McMeekan et al 1998b	NZ	F	3-4 mths	Feedlot	SD (B, K, or B+K)	Cortisol to 9 hrs
Sylvester et al 1998a	NZ	F	5-6 mths	Grazing	SD (nil or L) or SD+GC (nil or L)	Cortisol
Sylvester et al 1998b	NZ	F	5-6 mths	Grazing	SD or saw or GD or DW (all nil)	Cortisol

Reference	Country	Breed(s)[1]	Age at horn removal	Production system	Method (pain relief)[2]	Parameters of interest[3]
McMeekan et al 1999	NZ	F	3-4 mths	Feedlot	SD (L, K, or L+K)	Behaviour to 48 hrs
Goonewardene et al 1999	Can	BS, DS	<1 wk	Feedlot	CP	Behaviour from 6-9 mths
Graf & Senn 1999	Swit	BSw, HF, J, xbreds	4-6 wks	Hand-reared	EC (+/-L)	Cortisol, ACTH, vasopressin, behaviour for 4 hrs
Grøndahl-Nielsen et al 1999	Den	F	4-6 wks	Hand-reared	EC (nil, L, XB or L+XB)	Cortisol, heart rate, behaviour, feed intake and weight gain for 7 dd
Faulkner & Weary 2000	Can	Ho	4-8 wks	Hand-reared	EC (L+X+/-K)	Weight gain, behaviour for 48 hrs
Stafford et al 2000	NZ	F	6 wks	Feedlot	SD (+/- L)	Behaviour
Mellor et al 2002	NZ	NS	10 wks	Feedlot	SD (+/-L)	Catecholamines, cortisol
Sutherland et al 2002	NZ	F	3-4 mths	Feedlot	SD (nil, L, L+P or L+K)	Cortisol
Sutherland et al 2002	NZ	F	3-4 mths	Feedlot	SD (nil or L+B) or SD+GC (L+B)	Cortisol
Stafford et al 2003	NZ	F	3 mths	Feedlot	SD (nil, L+K, X, L+X or L+X+T)	Cortisol
Milligan et al 2004	Can	Ho	<2 wks	Feedlot	GC (L+/-K)	Cortisol, behaviour, feed intake and weight gain for 24 hrs
Sylvester et al 2004	NZ	F	5-6 mths	Grazing	SD (+/-L)	Behaviour
Stilwell et al 2004	Port	NS	NS	NS	C, SD, CP (all +/- L, +L+F)	Cortisol
Millman et al 2005	Can	Dairy (NS)	<1 mth	NS	NS (nil, L or K)	Heart rate, respiratory rate, behaviour
Vickers et al 2005	Can	Ho	10-35 dd	Hand-reared	CP (X or X+L); CP (X) or EC (X+L)	Behaviour
Steinhardt 2006	Ger?	GRP, GBW	22-59 dd	Sucking	NS (X)	Wide range of physiological parameters
Doherty et al 2007	US	HF	10-12 wks	Feedlot	EC (nil, 2%L or 5%L)	Cortisol, plasma proteins, routine haematology, behaviour
Gibson et al 2007	NZ	F	6-9 mths	Feedlot	SD (KPH+/-L)	EEG, ECG
Stilwell et al 2008	Port	HF	10-40 dd	Feedlot	CP (nil, F -5 min or -60 min)	Cortisol, behaviour

Abbreviations					
Breed		**Method / Pain relief**		**Parameters**	
B	Brahman	B	bupivacaine local anaesthetic (cornual block)	ACTH	adrenocorticotrophic hormone
BS	Beef Synthetic	C	cautery (not specified)	ECG	electrocardiogram
BSw	Brown Swiss	CD	calf dehorners	EEG	electroencephalogram
DS	Dairy Synthetic (Can)	Ch	disbudding by chemical injection (Chem-Cast®)	Hb	haemoglobin
F	Friesian	CP	caustic paste	PCV	packed (red) cell volume
GBW	German Black & White	CS	caustic stick		
GRP	German Red Pied	DW	dehorning wire		
HF	Holstein Friesian	EC	electrical cautery		
Ho	Holstein	EI	electroimmobilisation		
J	Jersey	F	flunixin i.v.		
M	Montbeliard	GD	guillotine dehorner		
NS	not specified	GC	gas cautery		
SR	Swedish Red	K	ketoprofen		
SW	Swedish White	KD	keystone dehorner		
		KPH	ketamine + propofol i.v. then gaseous halothane gen. anaes.		
		L	lignocaine local anaesthetic (cornual block)		
		LN	liquid nitrogen cryosurgery		
		NOP	nitrous oxide probe cryosurgery		
		P	phenylbutazone		
		SD	scoop dehorner		
		T	tolazoline i.v. (reversing agent for xylazine)		
		X	xylazine i.v. or i.m.		
		XB	xylazine + butorphanol i.m.		

9.5 Published analgesia protocols for dehorning cattle

Source	Method	Obs	Breed/Gender	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Vickers et al 2005	Caustic paste	B	Friesian female	1-5	ND	10	xylazine IM 0.2mpk 20min pre DH			NA	12h observation period No caustic DH group without sedation/ analgesia Caustic paste DH painful but less so than hot iron Increases in 3 selected Bs 1-4h after DH
Vickers et al 2005	Caustic paste	B	Friesian female	1-5	ND	10	xylazine IM 0.2mpk 20min pre DH		L 2%; 1.5ml CN + 3ml RB 10min pre DH	NA	12h observation period Caustic paste DH painful but less so than hot iron No caustic DH group without sedation/ analgesia Lignocaine offered no additional benefits over xylazine alone. There was no L only group
Vickers et al 2005	Caustic paste	B	Friesian female	1-5	ND	8	xylazine IM 0.2mpk 20min pre DH			NA	12h observation period No caustic DH group without sedation/ analgesia Caustic paste DH painful but less so than hot iron Increases in 3 selected Bs 1-4h after DH
Stilwell et al 2008	Caustic paste	CB	Friesian female	1-6	ND	5		Flunixin IV 2.2mpk, 1h pre DH		0	24h observation period C rise in flunixin group no different to untreated DH control Disturbed B present at 15min, 1h and 3h
Stilwell et al 2008	Caustic paste	CB	Friesian female	1-6	ND	5		Flunixin IV 2,2mpk, 5 min pre DH		0	24h observation period C rise in flunixin group no different to untreated DH control Disturbed B present at 15min, 1h and 3h
Morisse et al 1995	Caustic stick 2min	CB	Montbeliard male	4	ND	19			L 2%; 4ml CN 15min pre DH	1	24h observation period LA not confirmed, 40% incomplete C responses low, but higher with hot iron method Effects of DH apparent only for 4h L reduced response to DH

Source	Method	Obs	Breed/Gender	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Lepkova et al 2007	Embryotomy wire	CB	Red pied female (late pregnancy)	104+	ND	6	xylazine IV 0.1mpk ketamine IV 2mpk			NA	8h observation period Cows were studied under general anaesthesia No dehorned control Pronounced rise in C to peak at 0.5h and return to baseline at 2.5h where it remained
Lepkova et al 2007	Embryotomy wire	CB	Red pied female (late pregnancy)	104+	ND	6	xylazine IM 0.2mpk		L 2%; 20ml CN (time before dehorning ND)	NA	8h observation period LA confirmed by needle prick CN only. Possible innervation from other nerves not assessed. No dehorned control Pronounced rise in C returning to baseline at 2h Apparent LA breakthrough and C rise at 4-6.5h
Lepkova et al 2007	Embryotomy wire	CB	Red pied female (late pregnancy)	104+	ND	6			L 2%; 20ml CN (time before dehorning ND)	NA	8h observation period LA confirmed by needle prick CN only. Possible innervation from other nerves not assessed. No dehorned control Pronounced rise in C to peak at 0.25h and return to baseline at 4h. Marked avoidance and defence reactions throughout observation period
Vickers et al 2005	Hot iron electric 15s	B	Friesian female	1-5	ND	8	xylazine IM 0.2mpk 20min pre DH		L 2%; 1.5ml CN + 3ml RB 10min pre DH	NA	12h observation period No hot iron DH group without sedation/ analgesia Increased frequency of selected B during 4h post DH
Doherty et al 2007	Hot iron electric DND	CBO	Friesian female	10-12	ND	8			L 2%; 5ml, 3 sites; 30 min pre DH	0	72h observation period LA not confirmed Spike in C post DH to pre DH at 1.5h. No breakthrough in C as LA expected to dissipate at 2-3h
Boandl et al 1989	Hot iron electric 2-3 mins	C	Friesian female	7-16	82-149	12			L 2% + A; 5ml CN; 5 min before	0	30 min observation period only. LA not confirmed C increase in response to DH the same as DH control

Source	Method	Obs	Breed/Gender	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Petrie et al 1995	Hot iron gas 3-5s	C	Friesian male	6-8	35-68	8			L 2%; 3ml CN 20 min pre DH	0	8h observation period LA confirmed by needle prick Small short lived increase in C post DH, but no difference between cautery control and L groups throughout period of observation
Doherty et al 2007	Hot iron electric DND	CBO	Friesian female	10-12	ND	8			L 5%; 5ml, 3 sites; 30 min pre DH	1	72h observation period LA not confirmed Lower frequency of kicking at time of dehorning Apparent breakthrough rise in C at 4h
Grøndahl-Nielsen et al 1999	Hot iron electric 15s	CO	Friesian male female	4-6	49-60	8	xylazine IM 0.2mpk butorphanol IM 0.1mpk			1	4h observation period Calves deeply sedated throughout observation period and B measures not possible.
Grøndahl-Nielsen et al 1999	Hot iron electric 15s	CO	Friesian male female	4-6	49-60	8	xylazine IM 0.2mpk butorphanol IM 0.1mpk		L 2%; volume ND CN; 15min pre DH	1	4h observation period LA not confirmed Calves deeply sedated throughout observation period and B measures not possible. Reduced adverse B response during DH
Morisse et al 1995	Hot iron electric 1min	CB	Montbeliard male	8	ND	23			L 2%; 4ml CN 15min pre DH	1	24h observation period LA not confirmed, 40% incomplete C responses low, but lower with caustic stick Effects of DH apparent only for 4h L reduced response to DH
Milligan et al 2004	Hot iron gas DND	CB	Friesian male female	0.3-2	50	20			L 2% + A; 5ml CN 10min pre DH	2	8h observation period LA not confirmed No untreated control group Baseline C highest in youngest calves
Milligan et al 2004	Hot iron gas DND	CB	Friesian male female	0.3-2	50	20		K IM 3 mpk 10min pre DH	L 2% + A ; 5ml CN 10min pre DH	2	8h observation period LA not confirmed No untreated control group Baseline C highest in youngest calves K offered little benefit over L in study of young calves

Source	Method	Obs	Breed/Gender	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Graf & Senn 1999	Hot iron electric 10-20s	B	Various dairy breeds male female	4-6	ND	10			L 2%; 13ml CN + 2 site RB; 20min pre DH	2	4h observation period LA not confirmed All post DH behaviours markedly attenuated for 2h.
Graf & Senn 1999	Hot iron electric 10-20s	CO	Various dairy breeds male female	4-6	ND	8			L 2%; 13ml CN + 2 site RB; 20min pre DH	2	4h observation period LA not confirmed Plasma hormone concentrations increases almost prevented for 2h
Grøndahl-Nielsen et al 1999	Hot iron electric 15s	CBO	Friesian male female	4-6	49-60	8			L 2%; volume ND CN; 15min pre DH	2	4h observation period LA not confirmed Reduced adverse B response during DH
Faulkner & Weary 2000	Hot iron electric 35s	B	Friesian male female	4-8	58-95	10	xylazine IM 0.2mpk, 20 min pre DH	K PO 3mpk in milk, 2h pre DH, 2 & 7h post DH	L 2%; 4.5ml CN RB; 10 min pre DH	3	24h observation period Xylazine induced recumbency in all calves Ketoprofen absorption not confirmed (in humans oral bioavailability reduced by milk and food) No significant head shaking and ear flicking post DH. Some head rubbing at 6-12h post DH.
Stafford et al 2003	Scoop	C	Friesian female	12	58-171	10	xylazine IM 0.1mpk 20min pre DH tolazoline IV 2mpk 5min post DH		L 2%; 5ml CN 15min pre DH	0	8h observation period LA confirmed Calves sedated and recumbent Integrated C response was higher even than the untreated DH group
Stilwell 2008	Scoop	CB	Friesian female	13-21	ND	5			L 2%, 5ml CN 5min pre DH	0	24h observation period C increaser 1-6h post DH similar to DH control Less abnormal B than DH control at 15min but similar at to DH control at 1, 3 and 6h
Sutherland et al 2002a	Scoop	C	Friesian gender ND	12-16	56-169	9	ACTH IV 0.28 μg/kg 6h pre DH			0	24h observation period Integrated C response the same as that of DH alone
McMeekan et al 1999	Scoop	B	Friesian female	12-16	100	8			L 2%; 6ml CN; 20min pre DH	1	48h observation period LA not confirmed Reduced adverse B response during DH
McMeekan et al 1999	Scoop	B	Friesian female	12-16	100	8		K IV 3mpk 20min pre DH		1	48h observation period Little overall reduction in pain associated B

Source	Method	Obs	Breed/Gender	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Petrie et al 1995	Scoop	C	Friesian male	6-8	35-68	8			L 2%; 3ml CN 20 min pre DH	1	8h observation period LA confirmed Small short lived increase in C post DH, thence pronounced increase in C between 2 & 7.5h Scoop DH induced greater C response than hot iron.
Stafford et al 2003	Scoop	C	Friesian female	12	58-171	10	xylazine IM 0.1mpk 20min pre DH			1	8h observation period LA confirmed Calves sedated and recumbent Transient post DH rise in C , at control levels from 1-3h, and sustained rise in C from 3h post DH
Sylvester et al 1998	Scoop + hot iron gas 6s	C	Friesian male	20-24	99-159	10				1	36h observation period (at least hourly to 9h + 36h) C response to scoop + hot iron parallel but numerically less than scoop alone
Sylvester et al 2004	Scoop	B	Friesian male	20-26	130	20			L 2%; 6ml CN; 15 min pre DH	2	29h observation period LA confirmed No difference to no DH control to 2h Dehorning caused significant pain that lasted at least 6h
Mellor et al 2002	Scoop	CO	ND	10	57-87	10			L 2%; 5ml CN; 20 min pre DH	2	8h observation period. LA not confirmed Cortisol low for 2h Unexplained protracted NA release
Gibson et al 2007	Scoop	EEG ECG	Friesian female	26-39	125-178	10	light GA: ketamine propofol halothane		L 2%; 20ml RB left horn only; 25 min pre DH	2	10min observation period. No differences in EEG variables compared with pre dehorning values.
Stafford et al 2003	Scoop	C	Friesian female	12	58-171	10	xylazine IM 0.1mpk 20min pre DH		L 2%; 5ml CN 15min pre DH	2	8h observation period LA confirmed Calves sedated and recumbent Pre DH rise in C, at control levels to 3h, thence rose and higher then DH levels until final 8h observations

Source	Method	Obs	Breed/Gender	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Sutherland et al 2002a	Scoop	C	Friesian gender ND	12-16	56-169	8			L 2% 6ml CN 15min pre DH B 0.25% 6ml CN 2h post DH	2	24h observation period LA confirmed, 5h LA provided by double injection C levels exceeded pre DH levels between 5.5 & 10h C levels same as untreated to 5h and beyond 10h 24h integrated C not different to DH calves
Sutherland et al 2002a	Scoop	C	Friesian gender ND	12-16	56-169	10		PBZ IV 4-5 mpk 15min pre DH	L 2% 6ml CN 15min pre DH B 0.25% 6ml CN 2h post DH	2	24h observation period LA confirmed, 5h LA provided by double injection PBZ plus L equivalent to L alone (ie no PBZ effect) PBZ did not reduce delayed C response post LA
Sutherland et al 2002a	Scoop	C	Friesian gender ND	12-16	56-169	9	ACTH IV 0.28 µg/kg at DH		L 2% 6ml CN 15min pre DH B 0.25% 6ml CN 2h post DH	2	24h observation period LA confirmed, 5h LA provided by double injection
Sutherland et al 2002b	Scoop	C	Friesian gender ND	12-16	56-169	7			L 2% 6ml CN 15min pre DH B 0.25% 6ml CN 2h post DH	2	24h observation period C rose only after 5h and returned to pre DH levels at 9.5h
Sylvester et al 1998	Scoop	C	Friesian male	20-24	99-159	7			L 2%; 6ml CN 30min pre DH	2	36h observation period (at least hourly to 9h + 36h) LA confirmed C response to DH almost abolished for 3h post DH
McMeekan et al 1998a	Scoop	C	Friesian	12-16	63-110	10			B 0.25%; 6ml CN 20min pre DH	2	9h observation period No rise in C for 4h post DH At 4h, significant and protracted rise in C until 8h
McMeekan et al 1998a	Scoop	C	Friesian	12-16	63-110	10		K IV 3mpk 20min pre DH		2	9h observation period C levels rose post DH to same level as untreated DH calves, then to pre DH level between 2-9h
McMeekan et al 1998b	Scoop	C	Friesian female	12-16	62-110	10			B 0.25%; 6ml CN 20min pre DH	2	9h observation period Control levels of C for 4h. Significant and protracted C increase from 4.3-9h Overall integrated C not different from DH control Short term control only

Source	Method	Obs	Breed/Gender	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
McMeekan et al 1998b	Scoop	C	Friesian female	12-16	62-110	10			B 0.25%; 6ml CN immediately pre DH	2	9h observation period Control levels of C for 4h. Significant and protracted C increase from 4.3-9h Little difference between LA immediately before or 20min before DH Overall integrated C not different from DH control Short term control only
Stilwell 2008	Scoop	CB	Friesian female	13-21	ND	5		Flunixin IV 6ml, 5min pre DH	L 2%, 5ml CN 5min pre DH	3	24h observation period C levels remained no different to pre DH levels Abnormal B less than DH control at 15min, 1h & 6h, but not different at 3h and 24 h
McMeekan et al 1999	Scoop	B	Friesian female	12-16	100	8		K IV 3mpk 20min pre DH	L 2%; 6ml CN; 20min pre DH	3	48h observation period LA not confirmed Marked reduction in pain associated B
Stafford et al 2003	Scoop	C	Friesian female	12	58-171	10		K IV 3mpk 15min pre DH	L 2%; 5ml CN 15min pre DH	3	8h observation period LA confirmed C remained at pre DH level throughout study
Sutherland et al 2002a	Scoop	C	Friesian gender ND	12-16	56-169	8		K IV 3-4mpk 15min pre DH	L 2% 6ml CN 15min pre DH B 0.25% 6ml CN 2h post DH	3	24h observation period LA confirmed, 5h LA provided by double injection C exceeded pre DH levels only between 6.5 & 12h K reduced delayed C response as LA dissipated
McMeekan et al 1998a	Scoop	C	Friesian	12-16	63-110	10		K IV 3mpk 20min pre DH	B 0.25%; 6ml CN 20min pre DH	3	9h observation period Transient C increase post DH, thence control levels until 9h
McMeekan et al 1998a	Scoop	C	Friesian	12-16	63-110	10		K IV 3mpk 20min pre DH	L 2%; 6ml CN 20min pre DH	3	9h observation period Transient C rise post DH, thence control levels to end
McMeekan et al 1998b	Scoop	C	Friesian female	12-16	62-110	10			B 0.25%; 6ml CN 20min pre DH B 0.25%; 6ml CN 4h post DH	3	9h observation period Control levels of C (except at 4h) for 8 h, then progressive rise still increasing at final observation Control for 8h but C increase from 8h

Source	Method	Obs	Breed/Gender	Age (w)	Weight (kg)	N	Sedation anaesthesia	NSAID	Local anaesthesia	Effect score	Comments
Sylvester et al 1998	Scoop + hot iron gas 6s	C	Friesian male	20-24	99-159	8			L 2%; 6ml CN 30min pre DH	3	36h observation period (at least hourly to 9h + 36h) LA confirmed LA + hot iron cautery after scoop DH almost abolished C response for 9h (still absent at 36h)
Sutherland et al 2002b	Scoop + hot iron gas 6s	C	Friesian gender ND	12-16	56-169	7			L 2% 6ml CN 15min pre DH B 0.25% 6ml CN 2h post DH	4	24h observation period Hot iron treatment caused significant avoidance behaviour Hot iron cautery virtually abolished the delayed C response to LA breakthrough at 5h

Abbreviations			
A	adrenaline (in combination with lignocaine)	GA	general anaesthesia
ACTH	adrenocorticotropic hormone	L	lignocaine
B	Bupivacaine	LA	local anaesthesia
CN	cornual nerve block	NA	not assessable (no untreated dehorning control for comparison)
DH	dehorning	ND	not described
DND	duration of hot iron contact not described	PBZ	phenylbutazone
ECG	electrocardiogram	RB	ring block
EEG	electroencephalogram		

Observations	**Effect score**
C Cortisol	0 No or minor difference compared with dehorned control
B Behaviour (for example, tail flicking, head shaking, ear flicking, ruminating)	1 Significant but short lived effect, < 2h
O Other (for example, catecholamines, ACTH, vasopressin, total plasma protein, RBC, total and differential WBC, Hb, fibrinogen, neutrophil:lymphocyte ratio, α_1- acid glycoprotein, heart rate)	2 Significant effect for 2-6h 3 Significant effect for at least 6h 4 Complete or near complete elimination of evidence of pain and distress

9.6 Drugs registered for sedation or analgesia of cattle in Australia

Regn #	Product name	Product description
Acepromazine maleate		
37415	ACEMAV INJECTION 10MG/ML TRANQUILISER ANAESTHETIC PREMEDICANT	20, 50, 100ml Mavlab 10mg/ml acepromazine maleate
40625	DOPHARMA SEDAJECT ACEPROMAZINE INJECTION	100ml Bomac 15mg/ml acepromazine maleate
50521	ILIUM ACEPRIL-10 INJECTION TRANQUILLISER, PRE-ANAESTHETIC MEDICATION	20ml Troy Laboratories 10mg/ml acepromazine maleate
38769	ORALJECT SEDAZINE - A.C.P. ORAL TRANQUILLISER FOR HORSES AND CATTLE	30ml Vetsearch 12mg/ml acepromazine maleate
40076	A.C.P. 10 ANAESTHETIC PREMEDICATION, TRANQUILLISER AND TRAVEL SICKNESS STERILE INJECTION	20ml Delvet 13.5mg/ml acepromazine maleate
Dexamethasone		
36251	VR TRIDEXIN 0.5 STERILE GLUCOCORTICOID INJECTION	50ml VR dexamethasone trimethylacetate (4.1mg/mL)
47779	DEXAPHOS 5 INJECTION	50ml Jurox 5mg/ml dexamethasone phosphate
35941	VOREN DEPOT LONG ACTING CORTICOSTEROID	50ml BI 1mg/ml dexamethasone 21-isonicotinate
35959	VOREN DEXAMETHASONE ESTER FOR INJECTION	50ml BI 3mg/ml dexamethasone 21-isonicotinate
36988	COLVASONE INJECTION DEXAMETHASONE SODIUM PHOSPHATE 2 MG/ML	50ml Norbrook 2mg/ml dexamethasone sodium phosphate
40617	DOPHARMA DEXAJECT DEXAMETHASONE INJECTION	100ml Dopharma 2mg/ml dexamethasone sodium phosphate
51945	NORASONE INJECTION	50ml Norbrook 1.52mg/ml dexamethasone sodium phosphate
52298	DEXADRESON INJECTION	50ml

		Intervet 2mg/ml dexamethasone sodium phosphate
52859	DEXASON ANTI-INFLAMMATORY AND GLUCOGENIC STEROID INJECTION	50ml Ilium 2mg/ml dexamethasone sodium phosphate
37231	DEXAFORT AQUEOUS SUSPENSION OF DEXAMETHASONE AS MIXED ESTER	50ml Intervet 2mg/ml dexamethasone phenpropionate + 1mg/ml dexamethasone sodium phosphate
40769	DEXOL 5 CORTICOSTEROID INJECTION	100ml Bomac 5mg/ml dexamethasone sodium phosphate
50583	ILIUM DEXAPENT ANTI-INFLAMMATORY & GLUCOGENIC STEROID INJECTION	50ml Ilium 5mg/ml dexamethasone sodium phosphate
51976	COLVASONE INJECTION	50ml Norbrook 2mg/ml dexamethasone sodium phosphate (= 1.52mg/ml dex)
59150	DEXAVET AP LONG ACTING CORTICOSTEROID INJECTION	50ml Bomac 5mg/ml dexamethasone triethylacetate
51447	ILIUM TRIMEDEXIL ANTI-INFLAMMATORY STEROID INJECTION	50ml Ilium 5mg/ml dexamethasone trimethyl acetate
Flunixin meglumine		
40439	ILIUM FLUNIXIL INJECTION	100ml Ilium 50mg/ml flunixin meglumine
47802	FLUNIX ANTIINFLAMMATORY INJECTION	50ml Parnell 50mg/ml flunixin meglumine
48183	FLUMAV FLUNIXIN INJECTION	50ml Mavlab 50mg/ml flunixin meglumine
50626	FLUNIXON INJECTION	50 and 100ml Norbrook 50mg/ml flunixin meglumine
50810	FLUROX INJECTION	50ml Juroz 50mg/ml flunixin meglumine
51812	FLUXIMINE INJECTION	50 and 100ml Bomac 50mg/ml flunixin meglumine

37013	FINADYNE SOLUTION	50ml SPAH 50mg/ml flunixin meglumine
Ketoprofen		
40634	KETOFEN 100 INJECTABLE	50ml Merial 100mg/ml ketoprofen
53423	ILIUM KETOPROFEN INJECTION	50ml Ilium 100mg/ml ketoprofen
56418	KEY INJECTION	50ml Parnell 100mg/ml ketoprofen
Lignocaine hydrochloride		
37429	LIGNOMAV 20MG/ML LOCAL & REGIONAL ANAESTHETIC	100ml Mavlab 20mg/ml lignocaine hydrochloride (=17.2mg/ml lignocaine))
37332	LIGNO PLAIN 2% STERILE INJECTION	100ml Jurox 20mg/ml lignocaine hydrochloride
40800	BOMACAINE LOCAL ANAESTHETIC	100ml Bomac 20mg/ml lignocaine hydrochloride
50269	LIGNOCAINE 20 LOCAL ANAESTHETIC INJECTION	100ml Ilium 20mg/ml lignocaine hydrochloride
37328	LIGNADREN 2% STERILE INJECTION	100ml Jurox lignocaine hydrochloride (20mg/mL) + adrenaline(0.01mg/mL)
51301	LIGNOCAINE 20 WITH ADRENALINE - 1-100,000 LOCAL ANAESTHETIC INJECTION	100ml Ilium lignocaine hydrochloride (20mg/mL) + adrenaline tartrate (0.0182mg/mL)
Meloxicam		
50674	METACAM 5 SOLUTION FOR INJECTION	100ml BI 5mg/ml meloxicam
54061	METACAM 20MG/ML SOLUTION FOR INJECTION	50ml BI 20mg/ml meloxicam
Pethidine hydrochloride		

37717	PETHIDINE INJECTION	50ml Parnell 50mg/ml pethidine hydrochloride
50550	JUROX PETHIDINE INJECTION	50ml Jurox 50mg/ml pethidine hydrochloride
Prilocaine hydrochloride		
36684	PRILOCAINE 2% TISSUE NON-IRRITATING LOCAL ANAESTHETIC	100ml Delvet 20mg/ml prilocaine hydrochloride
37700	PARNELL PRILOCAINE LOCAL ANAESTHETIC INJECTION	20, 100ml Parnell Laboratories 20mg/ml prilocaine hydrochloride
Tolfenamic acid		
61712	ILIUM TOLFEJEC ANTI-INFLAMMATORY INJECTION FOR CATTLE AND PIGS	100ml Ilium 40mg/ml tolfenamic acid
Xylazine hydrochloride		
37038	ANASED INJECTION	50ml Lloyd 100mg/ml
38653	ILIUM XYLAZIL-20 ANALGESIC, SEDATIVE AND MUSCLE RELAXANT INJECTION	20ml and 50ml Ilium 20mg/ml xylazine hydrochloride
46046	BOMAZINE 20 SEDATIVE INJECTION FOR CATTLE, DOGS AND CATS	50ml Bomac 20mg/ml xylazine hydrochloride
47524	VR ROMAZINE 20 SEDATIVE, ANALGESIC AND MUSCLE RELAXANT FOR CATTLE, HORSES, DEER, DOGS AND CATS	20ml VR 20mg/ml xylazine hydrochloride
Yohimbine hydrochloride		
37699	REVERZINE INJECTION	20ml Parnell 10mg/ml xylazine hydrochloride