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INVESTIGATIONS ON THE STUNNING AND STICKING OF CALVES:

SECTIONS A,B AND C

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MEAT RESEARCH RECORD A/88

INVESTIGATIONS ON THE STUNNING AND STICKING OF CALVES

Section A. Halal slaughter of calves: abattoir investigations
N.G. Gregory, R.W.D. Rowe and F.D. Shaw*

Section B. The effects of different methods of stunning and sticking on blood loss in calves
R.W.D. Rowe, N.G. Gregory, F.D. Shaw and W.R. Shorthose*

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F.D. Shaw, N.G. Gregory and R.W.D. Rowe*

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SECTION A

HALAL SLAUGHTER OF CALVES: ABATTOIR INVESTIGATIONS

N.G. Gregory, R.W.D. Rowe and F.D. Shaw

SUMMARY

The presence of head righting behaviour, eye reflex and normal, rhythmic, breathing movements was examined in 486 calves and sheep slaughtered by the 'Halal' method in three Australian abattoirs. In addition, the carotid arteries were examined for the presence of swelling with blood at their cut caudal ends in 160 calves and sheep. Only one of the calves showed symptoms of consciousness following stunning and this animal was found to have only one carotid artery cut. Calves, however, were more susceptible than lambs to developing large clots at the cut ends of the carotids and in some instances this may have led to sustained brain stem function.

INTRODUCTION

In recent years, there has been a growing overseas market for Halal slaughtered bobby calves and, in the main calving season, some abattoirs process in excess of 1,000 calves a day. The recognised method for Halal slaughter in Australia is to apply head only electrical stunning, followed within 10 sec by a "gash-stick" of all the soft tissues in the underside of the neck, such that both jugular veins and both carotid arteries are severed. However, there is concern that this method may not provide a humane kill. Firstly, there have been reports that calves undergo lateral head righting movements after the cut has been made, and these are regarded as being symptomatic of consciousness. Secondly, a proportion of cattle take some time to lose brain function following exsanguination (Newhook and Blackmore 1982; Daly *et al.* 1987), and this time could be longer than the duration of anaesthesia provided by the electrical stun (Blackmore and Newhook 1982).

If a proportion of calves regain consciousness following Halal slaughter then one would expect to see this in their spontaneous and reflex behaviour. In this study, head righting behaviour, the eye reflex and the presence of normal spontaneous breathing were examined as tests of brain function following Halal slaughter in calves and sheep. Reflex blinking, in response to manual tapping of the eyelid or cornea, was used as a test of brain stem function, which would be present in both the unanaesthetised and anaesthetised states. The presence of normal spontaneous breathing movements was taken to indicate that the epileptiform phase of the electroplectic fit had subsided, and that a part of medullary brain function had resumed. Besides these specific tests, any signs of overt behavioural consciousness such as head righting and escape behaviour were noted.

MATERIALS AND METHODS

The slaughter of calves and sheep was examined at three abattoirs. The animals were electrically stunned using head-only pin-type electrodes. Voltages were measured across the electrodes on open circuit and under load (115 ohm). A gash-cut of the neck was made within 10 sec of the stun. At two abattoirs the sticking was done by experienced Halal slaughtermen, whilst at the third, non-Halal slaughtermen performed the Halal cutting method (*imitated Halal*).

The animals examined for physical behaviour were selected at random after stunning and sticking and they represented about 25% of the attended kill. As an animal passed through the bleeding out area of the slaughterline, it was assessed for the presence of any head righting behaviour in which the head was turned laterally as if an attempt was

being made to regain an upright posture. In order to make a close examination of the reflexes, selected animals were pulled away from the others in the bleeding area and the tests were made while they were suspended from the overhead rail. Within 1 min of sticking (usual interval 20-40 sec), the eye reflex was tested by tapping the eyelid and/or the cornea and watching for a blink response. Care was taken to distinguish between convulsive blinking and reflex responsiveness to the stimulus. The animals' flanks were also observed for normal, rhythmic, breathing movements. Inspiratory gagging and slow rhythmic breathing were taken to be a form of anoxic gasping and were not considered to be normal breathing movements. When there was doubt about the pattern of breathing, two fingers were inserted into the caudal cut end of the trachea to feel for respiratory-exchange.

When an animal had either a positive eye reflex or normal rhythmic breathing, its carotid arteries were examined to determine whether they had been cut. A subjective appraisal of the rate of bleeding and the presence of swollen or clotted carotids was also made in some of the calves at this time. In addition, the size of the clots in carotid arteries was evaluated in 160 separate carcasses at 1 to 5 min post-sticking. The clots at the caudal cut end were assessed subjectively using a 0 to 6 point scale, where 0 represented no significant swelling and 6 was a large clot usually more than 1 cm in diameter and 2 cm in length. Samples of clots were removed and examined under a light microscope after fixing, routine wax processing, sectioning and staining for connective tissue (Mallory's trichrome method) and for fibrin (Lendrum's MSB method).

RESULTS

The calves at the two Halal slaughterhouses were stunned with 210 V applied for 1 sec and 304 V applied for 3 to 4 sec, respectively. The voltages measured under load were 202 and 291 V, respectively.

Forty three per cent of the Halal slaughtered calves had a positive eye reflex after sticking and 9% showed normal rhythmic breathing movements (Table A1). In the 18 calves that were breathing normally following Halal slaughter, only one did not have both its carotid arteries severed. Nine of the 18 calves were found to be either bleeding

TABLE A1: INCIDENCE OF CALVES AND SHEEP SHOWING A POSITIVE EYE REFLEX AND NORMAL RHYTHMIC BREATHING AFTER HALAL SLAUGHTER				
Slaughter method	Species	Number tested	Positive eye reflex (%)	Normal rhythmic breathing (%)
Imitated Halal	Calf	133	N.R.	9 (7)
Halal	Calf	199	86 (43)	18 (9)
Halal	Sheep	154	54 (35)	10 (6)
N.R. Not recorded				

slowly or to have clots in one, or both, of their carotid arteries. The overall incidence of one carotid artery being cut was lower in the Halal slaughtered calves than the Halal slaughtered sheep or calves slaughtered using the imitated Halal method (Table 2).

TABLE A2: INCIDENCE OF UNILATERAL CUTTING OF THE CAROTID ARTERIES IN ANIMALS WHICH HAD EITHER A POSITIVE EYE REFLEX OR NORMAL RHYTHMIC BREATHING AFTER SLAUGHTER

Slaughter method	Species	Number tested	Only one carotid completely cut (%)	One carotid completely cut, the other incompletely cut (%)
Imitated				
Halal	Calf	19	7 (37)	0 (0)
Halal	Calf	91	2 (2)	2 (2)
Halal	Sheep	55	7 (13)	1 (2)

None of the Halal slaughtered calves showed overt signs of consciousness such as head righting, escape behaviour and/or vocalisation. One of the calves slaughtered using the imitated Halal method was breathing and vocalised in such a manner that it was thought to be conscious. This animal was found to have only one of its carotid arteries cut.

A characteristic feature of the majority of the carotid arteries was the way in which ballooning of the cut end of the artery occurred. Examination of the cut end of the artery under a microscope showed that it was plugged with a white (platelet) clot and overlying this there was a variable sized red clot associated with the connective tissue sheath around the outer surface. Clot size was found to be smaller in the lambs than the calves. Wethers had clots intermediate in size between those in lambs and calves but the difference in size between wethers and calves was not statistically significant (Table 3). Clot size was smaller in calves slaughtered by professional Halal slaughtermen than in calves slaughtered by the imitated Halal method ($p < .05$).

TABLE A3: SUBJECTIVE SCORES FOR BLOOD CLOT SIZE IN THE CAROTID ARTERIES

Slaughter method	Species	Number of animals	Mean	$\pm$ SEM ^a
Imitated				
Halal	Lamb	30	1.13 ^a	0.19
Imitated				
Halal	Wether	17	2.65 ^{bc}	0.23
Imitated				
Halal	Calf	23	3.33 ^b	0.35
Halal	Lamb	26	0.58 ^d	0.14
Halal	Wether	33	1.88 ^e	0.24
Halal	Calf	31	2.31 ^{ce}	0.30

Means with different superscript letters were significantly different at least at $p < 0.05$.

^a SEM = Standard error of the mean.

DISCUSSION

The vertebral arteries of calves can continue to supply blood to the brain after the carotid arteries have been cut (Blackman *et al.* 1986). On the other hand, sheep do not have the same vascular anatomy as calves and the vertebral arteries are not thought to make any contribution to blood flow to the brain after the carotid arteries are severed. However sustained brain function in cattle following slaughter only occurs in a proportion of the animals (Daly *et al.* 1987), and it is likely that these animals have impaired bleeding from the carotids (Devine *et al.* 1987). Any factor which causes a slow bleed out in calves, such as spasm of the carotids, failure to cut both arteries or clotting of the arteries, could lead to resumption of consciousness.

This study has shown that when routine Halal slaughter was performed under inspection, none of the calves showed signs of lateral head righting. Basic brain stem functions were retained in a proportion of calves, but their incidence was similar to those observed in sheep and they were not associated with recognisable consciousness. The conclusion therefore from this study of Halal slaughter in abattoirs was that, in the animals that were inspected, it provided a humane kill. Nevertheless, this finding is based on a limited number of calves. If future experience shows that there is a problem with resumption of consciousness in routine Halal slaughter, then several factors need to be examined *in situ*. It needs to be established whether the animals are being stunned properly and that both carotid arteries are being cut. If this is so and the incidence of overt recovery is high, then preemptive procedures, such as captive bolt stunning or thoracic sticking after the Halal cut, could be considered. In addition, the cut caudal ends of the carotid arteries should be examined for "ballooning" with blood. Platelet clots covering the cut end of the artery were found to be associated with the swelling of the sheath of the artery. Platelets are known to release vasoactive amines which could promote a vasospasm (Graham and Keatinge 1975). Alternatively vasospasm could also be induced mechanically at the time the cut was made. The end result could be a slower blood flow. In this respect it is interesting to note that sheep carotid arteries behave as if they contain multi-unit smooth muscle systems, whereas the carotid arteries of cattle behave as if they are comprised of single-unit muscle systems (Graham and Keatinge 1975; Speden 1970). The implication is that muscle cell to muscle cell contraction is more likely to occur in the calf carotids when they are cut and this could lead to a more pronounced vasospasm. On these theoretical grounds, there could be justification in recommending that Halal slaughter should be made as a single cut with a sharp knife, as this should minimise any mechanically induced vasospasm.

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SECTION B

THE EFFECTS OF DIFFERENT METHODS OF STUNNING AND STICKING ON BLOOD LOSS IN CALVES

R.W.D. Rowe, N.G. Gregory, F.D. Shaw and W.R. Shorthose

SUMMARY

Three experiments were conducted to determine the rate and amount of blood loss occurring with different stunning and sticking methods in calves. In experiments 1 and 2, captive bolt stunning was used; in experiment 3, either captive bolt or electrical stunning was used. In experiment 1 there were 2 methods of sticking; (i) thoracic stick and (ii) bilateral incision of carotid and jugular vessels at the head end of the neck ('Halal' high). In experiment 2 there were an additional 2 sticking methods; (iii) bilateral incision of carotid and jugular vessels at the brisket end of the neck ('Halal' low) and (iv) unilateral incision of the carotid and jugular vessels. In experiment 3 all animals were stuck using the 'Halal' high method.

In experiments 1 and 2, the average rate of blood loss following the thoracic stick was greater than that following the bilateral stick. There was no evidence that the location of the bilateral stick on the neck had any effect on rate of blood loss. There was considerable variation between animals in rate of blood loss following the bilateral stick. While many individual animals had a rate of blood loss similar to that recorded from the thoracic stick animals, there were some individuals that bled slowly.

In experiment 3 it was found that calves stunned electrically bled faster than those stunned with the captive bolt. Electrically stunned calves stuck by the 'Halal' method bled as fast as, or faster than those slaughtered by any of the other methods.

INTRODUCTION

It is generally accepted that slaughtering sheep with a head only electrical stun followed by immediate cutting of the neck vessels is a humane procedure. However, doubts have been expressed as to whether this combination is humane for calves (Blackmore and Newhook 1982).

Studies with the electroencephalogram (EEG) have indicated that unstunned sheep are likely to become unconscious within a few seconds of bilateral incision of the neck vessels. Furthermore, a flat EEG, which indicates brain death, is likely to be present within 45 seconds of the incision. However with unstunned calves, there is one report of the EEG not indicating loss of consciousness until almost 80 seconds after the incision (Devine *et al.* 1986), while the time to flat EEG can exceed 120 seconds (Newhook and Blackmore 1982). It must be emphasised that, in many cases, calves lose consciousness as rapidly as sheep, and it is only a small percentage of calves that apparently maintain a near normal brain function for a prolonged period after the incision. It has been suggested that faulty experimental technique is the reason for this variation (Devine *et al.* 1987). In particular it has been stated that if the incision is not made in the correct location on the neck then inadequate bleeding may occur and this will lead to prolonged brain function. Bleeding efficiency may also depend on the stunning method that is used.

The humaneness of a slaughter method based on a head-only electric stun followed promptly by a neck cut depends largely on the amount of blood released, and the rate of blood flow, following the cut. As part of investigations into the humaneness of Halal and other slaughter methods for calves, it was decided to conduct experiments which involved the measurement of blood loss after various stunning and sticking procedures. For the purpose of comparing different sticking methods (experiments 1 and 2) calves were stunned with a captive bolt pistol, shackled, hoisted and then stuck using one of the four methods listed below. Comparisons were also made between the captive bolt and electrical stunning methods (experiment 3).

METHODS

Experiments

Three experiments were conducted. In experiment 1 a total of 12 calves were allocated equally to 2 treatment groups (see later), while in experiment 2 a total of 24 calves were allocated equally to 4 treatment groups. Twenty four calves were used in experiment 3, 15 in one treatment group and 9 in another. In experiments 1 and 3 blood loss was assessed by blood collection only, while in experiment 2 blood loss was also assessed by continuous measurement of animal weight during the bleeding process.

Calves

Calves were purchased from a local saleyard and immediately delivered to the Laboratory. The majority of animals were slaughtered on the day of arrival, although in some cases they were not slaughtered until 2, 3 or 4 days after arrival. Animals held at the laboratory were fed twice daily with a milk replacer. On any one day at least two animals were slaughtered. Calf liveweight varied between 27.0 and 50.0 kg; both males and females of various breeds and cross breeds were represented.

Methods of stunning

After their liveweight was recorded, the animals were stunned. In experiments 1 and 2 all animals were stunned with a captive bolt pistol (Cash X, purple cartridges) placed in the frontal position. In experiment 3 animals were restrained in a net hammock before being stunned. In this experiment stunning was by either a captive bolt pistol placed in the frontal position or by a head only electrical stun (313 V, as measured across a 115 ohm load, for 4 sec). After stunning, the animals were hoisted until their heads were approximately one metre above the ground; the appropriate sticking method was then applied.

Methods of sticking

The two treatments used in both experiments 1 and 2 were;

(i) *Thoracic stick* - A long (16 cm) knife was used to penetrate the skin over the midline at the base of the neck. The knife was then moved upwards (the animal was suspended by the hind legs) to enter the thoracic cavity and cut the major blood vessel (brachio-cephalic trunk) near the base of the heart;

(ii) *'Halal' stick (high)* - A transverse incision, which severed the carotid and jugular vessels on both sides of the neck, was made on the neck adjacent to the head. This form of incision has been described as being "ear-to-ear". It was the only method used in experiment 3.

The two additional stick treatments used in experiment 2 were;

(iii) *'Halal' stick (low)* - As for (ii) above except that the cut was made at the brisket end of the neck rather than at the head end.

(iv) *Unilateral stick* - The point of the knife was inserted through the skin over the midline in the position of the 'Halal' (high) incision. The knife blade was then moved laterally to sever the carotid and jugular vessels on one side of the neck only. In experiments 1 and 2 all sticking was performed by one slaughterman only. In experiment 3, two slaughtermen were involved, but, since there was no significant difference in the amounts of blood collected from the calves they slaughtered, their results were pooled.

Blood collection and measurement

In all three experiments large, pre-weighed buckets of 80 litres capacity and a diameter of 460 mm at the top were used to collect blood. One bucket was used to

collect the blood during the period 0-60 seconds post-stick while a separate bucket was used to collect blood during the period 60-90 seconds post-stick.

In experiment 2, the weight of the calf before, at various stages during, and after bleeding was recorded on Toledo scales (Model 8136) using a transducer (Precision ST250).

Statistical analyses

Statistical analyses were performed by analysis of variance.

RESULTS

Stun-stick intervals

In experiment 1 the mean stun-stick interval for the 'Halal' group was 16 seconds, for the thoracic stick group it was 19 seconds.

In experiment 2 the mean stun-stick intervals for the thoracic, 'Halal' (high), 'Halal' (low) and unilateral groups were 45, 33, 36 and 38 seconds respectively. One of the calves in the thoracic stick group had a stun-stick interval of 98 seconds; with the exception of this one animal all stun-stick intervals were less than 51 seconds.

In experiment 3 the mean stun-stick intervals for the electrical and captive bolt stunning methods were 25 and 19 sec (from commencement of stun) respectively. It must be emphasised that shorter stun-stick intervals are recommended for electrical stunning of calves in practice.

The results can be expressed in many ways. It is considered by the authors that the expression 'blood released in the first 60 seconds (as a percentage of liveweight)' provides a useful indication of the relative, if not absolute, merits of the different sticking methods. Values for this expression, BL60 (%LW), for the various treatments for all experiments are listed in Table B1.

TABLE B1: VALUES FOR BL60 (%LW)

Expt Number	Number of calves	Stunning method	Sticking procedure	Mean	Range
1	6	Captive bolt	Thoracic	4.67	3.98 - 5.55
	6	Captive bolt	'Halal'(high)	3.58	2.46 - 4.52
2	6	Captive bolt	Thoracic	4.26	3.39 - 5.09
	6	Captive bolt	'Halal'(high)	3.76	2.47 - 4.94
	6	Captive bolt	'Halal'(low)	3.95	2.30 - 5.22
	6	Captive bolt	Unilateral	3.21	2.56 - 4.04
3	15	Electric	'Halal'(high)	4.43	1.94 - 5.33
	9	Captive bolt	'Halal'(high)	3.53	2.19 - 4.05

There were no significant differences between treatments within either experiment 1 or experiment 2. However, when the results for the two treatment groups common to both experiments were combined, BL60 (%LW) values for the thoracic stick group were significantly ($P < 0.05$) greater than those of the 'Halal' (high) group.

For experiment 3 the differences were statistically significant ($P < 0.05$).

The results for experiment 2 are illustrated in Figure B1. Because of the large animal-to-animal variation, particularly with the 'Halal' and unilateral groups, it was

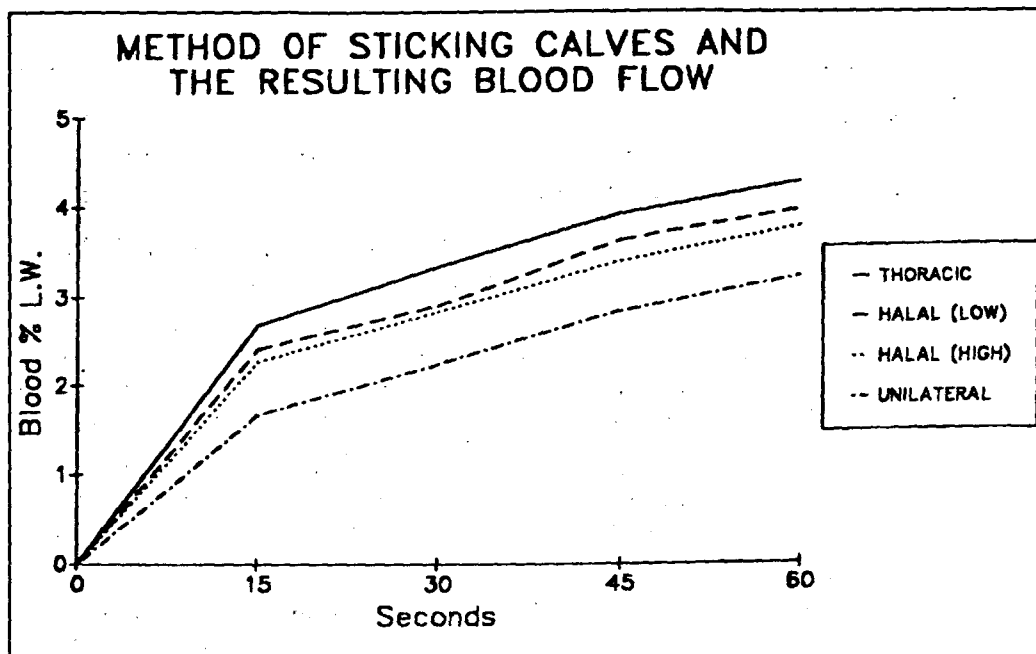


Figure B1. Graph showing the results of experiment 2.

not possible to demonstrate statistical significance at any of the post-stick times.

There was no evidence that the number of days the animals were held (and fed) at the Laboratory had any effect on the rate of blood loss.

DISCUSSION

These studies were conducted as part of an investigation into Halal slaughter (electric stun followed by bilateral stick) of calves. An underlying assumption in this work, was that a slow bleed out following Halal slaughter could be prejudicial to the calf's welfare; and so various factors which might influence bleeding rate were examined. Captive bolt stunning was used instead of electrical stunning when comparing different sticking methods, for both humane and practical reasons. The unilateral stick treatment could not be used in conjunction with electrical stunning as it was likely that some calves would recover consciousness. In addition, it was considered that the use of captive bolt stunning would increase the accuracy of measuring blood flow and blood volume. Following an electric stun there can be intense clonic convulsions during the period 10-50 seconds post-stun and it would be difficult to obtain accurate body weight readings via the transducer during these convulsions. Convulsions do occur following captive bolt stunning but in general they are less intense and of shorter duration than those following electric stunning. In experiment 2 it was often difficult to immediately obtain the initial pre-stick weight following the

hoisting of the stunned calf. This led to prolonged stun-stick times. If electric stunning had been used the animals may have been entering the recovery phase at the time of the stick and thus the slaughter process may have been inhumane.

The results for the different sticking methods indicated that there was a faster loss of blood following a thoracic stick than following a 'Halal' stick. There was no evidence that the location of the 'Halal' stick in the neck affected rate of blood loss. There was considerable variation between animals within each treatment and so, in some animals, the rate of blood loss following a 'Halal stick' was similar to that obtained following a thoracic stick. However, with other animals the rate of blood loss following the Halal stick was low and so, on average, the thoracic stick gave a quicker bleed out than the Halal stick. A similar variability in bobby calf bleeding rates has been reported by other workers (Blackmore 1984) and it also occurred when one carotid artery was cut.

The results obtained from experiments 1 and 2 did not differ significantly for the two treatment groups common to both experiments (thoracic stick and 'Halal' (high) stick). The main difference between the two experiments was that in experiment 2 the stun-stick times were prolonged. It would therefore appear that delaying the stick has little effect on rate of blood loss. However, if electric stunning is used it is important for humanitarian reasons that stun-stick times be kept to a minimum. The stun-stick times used here would be much greater than those possible when animals are stunned in a 'V' restrainer and stuck immediately they exit. If calves are stunned, shackled, and hoisted, stun-stick times will be prolonged and of the order of those used here.

Electrical stunning resulted in a more rapid blood loss in comparison with the captive bolt. A similar result has been recorded in sheep (Blackmore and Newhook 1976). There are at least two factors which may contribute to this; (i) differences in the amount of blood available for release, (ii) differences in blood pressure. During the tonic phase of the electric stun the muscles are contracted. This results in blood being squeezed out of the capillaries and smaller veins within the muscles and into the larger veins between the muscles. This blood will flow towards the heart and will presumably be released following the Halal stick. Both stunning methods cause a rise in blood pressure, although the time course and duration of the increased pressure may differ (Shorthose 1968; Kirton *et al.* 1978). There was considerable variation in bleeding rate obtained with electrical stunning. The reason for this variation is not clear, but in all likelihood it would lead to similar variation in the time to loss of brain function following Halal slaughter.

The method of sticking used in these experiments was similar to, but not identical with, that which is used in the majority of commercial abattoirs. In commercial abattoirs, the calf is horizontal or at a 45° angle, with its neck stretched, at the moment the incision is made. Within a few seconds the calf is in a vertical position. In our experiments the calves were held vertically with their necks relaxed at the moment of incision and remained in the vertical position during the bleeding period.

It has been suggested that rate of blood loss may depend on the technique used by an individual slaughterman. The slaughterman who performed the sticking process on the majority of calves in these experiments was an experienced, competent, slaughterman. However, he did not have specific experience with Halal slaughter techniques. It is possible that subtle changes in technique may have a marked effect on rate of blood loss, but further studies would be required to clarify this point.

CONCLUSION

Following a captive bolt stun, a thoracic stick yields more blood in the first 60 seconds post-stick than does a 'Halal' stick. The position of the 'Halal' stick on the neck has no significant effect on blood loss. The combination of electrical stunning and 'Halal' stick results in a greater blood yield in the first 60 seconds than the combination of captive bolt stunning and 'Halal' stick.

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SECTION C

BLOOD LOSS AND ELECTROENCEPHALOGRAM ACTIVITY FOLLOWING UNILATERAL AND BILATERAL STICKING OF ANAESTHETISED CALVES

F.D. Shaw, N.G. Gregory and R.W.D. Rowe

SUMMARY

The effect of cutting one carotid artery was compared with cutting both carotid arteries in terms of the time to isoelectric EEG in pentobarbitone anaesthetised calves. The spontaneous activity of the EEG continued at least three times as long when one artery was cut, as compared to when both arteries were cut. In one case, when only one carotid artery was cut, EEG activity continued for over 5 minutes. There is a strong possibility that sensibility could recur when electrically stunned calves receive a unilateral cut.

INTRODUCTION

The importance of severing both carotid arteries when slaughtering sheep is well documented (Newhook and Blackmore 1982; Gregory and Wotton 1984a). Devine *et al.* (1987) reported that an electrically stunned calf, which inadvertently had only one artery cut, appeared to be recovering 90 sec after the stun. With both sheep and calves, if only one carotid is cut, blood will continue to flow through the intact carotid until pressure has fallen sufficiently to allow collapse of that artery. In the case of calves, there is an additional effect which could allow brain function to continue for longer when only one carotid artery is cut. They have an anastomosis between their vertebral and occipital arteries, and, so long as blood pressure remains elevated, blood may also flow through this anastomosis and sustain brain function.

In practice, some calves may have only one carotid cut. The possible effect of this on the humaneness of the slaughter process was investigated by comparing the effects of unilateral or bilateral cutting of the carotids on electroencephalogram (EEG) activity. For ethical reasons, the experiment was conducted using anaesthetised calves.

MATERIALS AND METHODS

Six calves of 37 kg liveweight (range 33 to 41 kg) were anaesthetised with 18 mg pentobarbitone sodium per kg, administered intravenously. They were then suspended from a spreader and subcutaneous bipolar EEG needle electrodes positioned transhemispherically. After recording a stable EEG for approximately one minute, either one or both carotid arteries and their accompanying vein or veins were cut in the neck using the spear or gash sticking methods respectively. The EEG was recorded until it became isoelectric. Blood was collected for the first minute following sticking to provide an estimate of bleeding rate.

RESULTS

The results for each animal are shown in Table C1. The average 60 sec blood yield was 3.7% in the calves with both carotid arteries cut and 3.9% in those with only one cut. The average peak to peak EEG amplitude immediately before the calves were stuck was 40 μ V (range 29 to 62 μ V). The average time to isoelectric EEG activity was 33 and 189 sec for the bilaterally and unilaterally cut calves respectively. These

TABLE C1 : EFFECT OF CUTTING ONE OR BOTH CAROTID ARTERIES ON BLEEDING EFFICIENCY AND THE EEG IN CALVES

Calf number	Number of carotids severed	Blood weight at 60 sec as % of liveweight	Time to isoelectric EEG
1	1	4.41	115
2	1	4.27	109
3	1	2.92	343
4	2	4.07	30
5	2	3.94	33
6	2	3.10	35

estimates are based on the time to the first 5 sec period of isoelectric (or near isoelectric) activity and the peak to peak amplitude of the EEG at this time was $8 \mu\text{V}$ (range 5 to $10 \mu\text{V}$). The corresponding values for the time to the first one sec period of isoelectric activity were 30 and 160 sec.

Figure C1 shows the EEG trace of an anaesthetised calf (calf 4) before and after a bilateral stick, while Figure C2 shows the trace before and after a unilateral stick (calf 1).

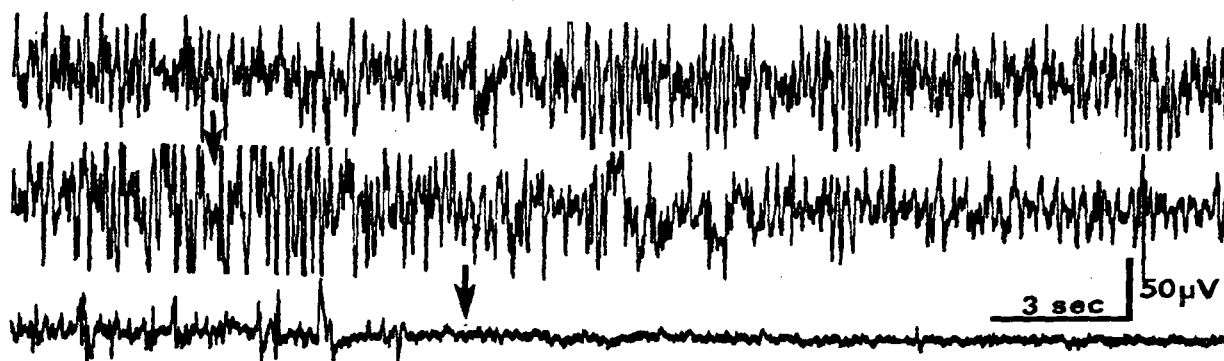


Figure C1: Electroencephalogram of Calf 4 showing high amplitude low frequency signal of the anaesthetised state (line 1). Bilateral severance of carotid arteries indicated by arrow (line 2). Onset of isoelectric trace (approximately 30 sec post-stick) indicated by arrow (line 3).

DISCUSSION

The results clearly indicate that brain function in anaesthetised calves is present for a prolonged period when only one carotid artery is cut. Gregory and Wotton (1984a) have reported a similar finding in sheep; bilateral cutting of carotids resulted in mean time to loss of brain responsiveness (as measured by visual evoked responses) of 14 sec; with unilateral severance, the mean time was 70 sec. Thus, brain responsiveness lasted approximately 5 times longer when only one carotid was cut. In the present

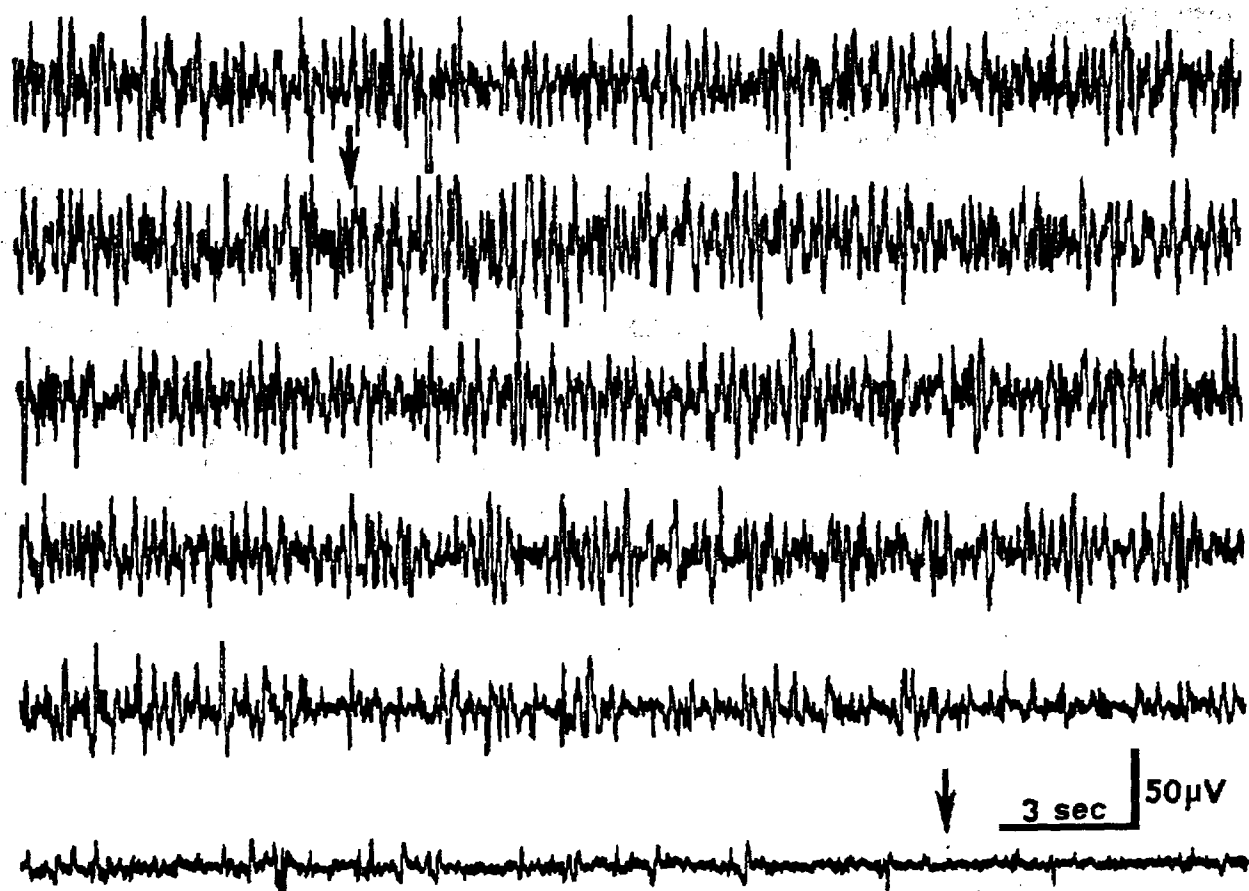


Figure C2: Electroencephalogram of Calf 1 showing high amplitude low frequency signal of the anaesthetised state (line 1). Unilateral severance of carotids indicated by arrow (line 2). Onset of isoelectric trace (approximately 115 seconds post-stick) indicated by arrow (line 6).

experiment, a comparison of the mean values for time to isoelectric EEG indicated brain activity lasted approximately 6 times longer when only one carotid was cut.

In a similar experiment with anaesthetised calves, but with bilateral incision only, the mean time to isoelectric electrocorticogram was 23 sec (S.D. = 11, $n = 8$) (Gregory and Wotton 1984b), which is not markedly different from the mean value of 33 sec recorded in the present experiment. The 60 sec blood weight data indicates that unilateral severance can result in a satisfactory rate of blood loss. A similar finding has been reported in sheep (Blackmore and Newhook 1976). Thus, the sustained brain function with unilateral sticking did not seem to be due to a protracted bleeding out period. It is concluded that the sustained brain function must have been largely due to perfusion through the remaining carotid artery, with perhaps some contribution from the vertebral arteries.

In one calf (calf 3), which had only one carotid artery cut, EEG activity continued for over 5 minutes. It is more than likely that the potential for consciousness would also be increased in this situation. Bearing in mind that the effect of electrical stunning lasts for only a finite period, it is felt that there is a strong possibility that sensibility could recur when electrically stunned calves receive a unilateral cut.

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