final report

Project Code: B.LSM.0025

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Investigate ultrasound measurement techniques in lamb carcases for commercialisation of GR depth measures

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Investigate ultrasound measurement techniques in lamb carcases for commercialisation of GR depth measures

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MLA project code: **B.LSM.0025**

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Greenleaf Enterprises

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1 Background

Sheep CRC conducted a previous project to investigate the use of ultrasound in lamb carcases for the measurement of GR Depth. Other measures such as C-Site depth were also investigated. The objective was to develop a low cost solution for lamb processors to assess lamb carcase confirmation and ultimately lean meat yield (LMY).

A range of probes were used with varying success. A series of manual image analysis measures were taken that produced a LMY predictive equation with correlations of R^2 (adj) = 71.7 back to CT LMY. However, the automation of these measures, required for operation at commercial line speeds was not possible. Two main hurdles prevented the combination of ultrasound probes and existing image analysis technology from immediate commercial application. These included:

1. <u>Air bubbling in the fat layers</u> - This resulted in unclear images and complicated the automatic image analysis measurements; AND

2. <u>Fat and muscle compression</u> – Compression occurred at the measurement site between the probe and the muscle and produced additional measurement variation. This problem is also thought to be the major source of inaccuracy in the existing Hennessey measurements of GR depth.

A number of strategies were used to address the problems such as including wide face plates to disperse the compression away from the measurement site. Although each problem was overcome to varying degrees, no one combination of solutions addressed all issues.

2 Project Objectives

The purpose of this project was to test whether alternative ultrasound measurement methodologies included in the previous report recommendations could overcome barriers to prepare a commercially robust method for ultrasound scanning of lamb carcases for GR depth.

The primary objectives of this project were to:

1) Overcoming air bubbles in the fat preventing automatic measurement; AND

2) Develop a measurement and image analysis methodology that overcomes fat compression at the measurement site

3 Deliverable items

The key deliverables include:

- Report the accuracy and commercial relevance of new measurement methodologies
- Recommendation on development pathway for commercialisation of online GR Depth measure
- Identification of other potential measures using ultrasound that could be commercialised

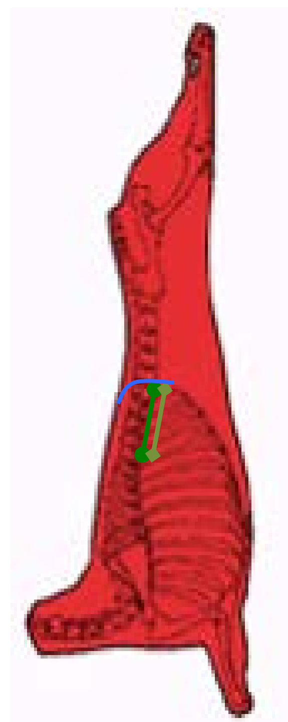
4 Data Collection Methods

4.1 Ultrasonic systems tested

Two ultrasonic detectors were compared – the Aloka 500 veterinary scanner, which has previously been used in a system for pork fat depth measurements in Australia and the USA, and a Sonoscope medical scanner. The Aloka probe was a 120mm probe, with a width of around 10mm. The Sonoscope used a 50mm probe, with a width of around 8mm. Both the Aloka and the Sonoscope allowed live image capture and measurements to be taken during changing conditions by capturing multiple images. A similar Aloka system had been used in past lamb scanning trials but had been unsuccessful.

Given the new measurement methodologies used in these trials it was decided to test the Aloka again in conjunction with the Sonoscope, which had never been tested. The Sonoscope system uses compounding capabilities in some of its probes and was selected specifically to address the air bubbling issues. Compounding allows sound from a wider range of angles to be captured and reported in a single image. Where single vertical sound planes would be obstructed by air bubbling, angled sound planes could be received from behind air bubbles, minimising their obstruction in auto-image analysis. A more detailed explanation of compounding is included in Section 11 on page **Error! Bookmark not defined.**.

4.2 Measurement Location



Both probes were used to take a series of images on a random selection of carcasses:

1. Longitudinal scans (Aloka and Sonoscope)
    a. Series of 25 longitudinal images taken over the GR site
    b. Varying degrees of pressure applied by the probe to the fat layer on the measurement site.
2. Transverse scans (Sonoscope only)
    a. Series of images taken over the C site
    b. Allows the measurement of C Site fat and eye muscle area

The diagram shows the anatomical placement of each ultrasound probe on the carcase.

The dark green line represents the stationary 100mm scan in a longitudinal direction at a set distance out from the backbone. In the case of the GR tissue depth measure the probe would be equipped with a spacer device in a commercial system to locate the probe 110mm out from the backbone. The C-site is located 40-45mm out from the backbone with the blue line representing the transverse probe placement.

4.3 Measurement location in plant

The last round of trials using the compounding probe and reported in this document were conducted at Cobram lamb processing plant in December 2011. All measures were taken on line after the electrical stimulator but prior to entry into the chiller.

An optional measurement location prior to pelting the carcase had been proposed if time and line layout allowed. The slaughter floor location was not conducive to taking pelt-on measurements. Also the time required to setup ultrasound systems on the slaughter floor, then disassemble and setup pre-chiller would not have allowed the same carcases to be measured for comparison between pelt-on and pelt-off. Given the compounding probe seemed to overcome the air bubbling, pelt-on measures were not important to the success of the trials.

4.4 Determining accuracy of ultrasound results

Ultrasound measurements of the GR site (a combined muscle and fat depth measurement, 11 cm from the centreline, over the last rib) were compared against accurate measurements conducted by trial staff using the cut and measure method.

4.5 Measurements

Images from the Aloka and Sonoscope are shown in Figure 1 and Figure 2. These show the ribs as bright spots above long shadows. The shadows result from the bone absorbing or scattering the sound, therefore little is reflected back into the probe. As the GR site is over the last rib, this shows that the key features for a GR depth measurement are observed in the ultrasound image. The calculated measurement is therefore simply the distance to the top of the rib in the image.

The measurement method followed the following steps:

1. Locate the measurement (GR) site manually and place the probe in position
2. Locate the measurement site on the ultrasound image
3. Press the probe into the carcase at the measurement site to smooth out any bubbles
4. Release the pressure over about a one second period until the probe no longer touches the surface
5. Images are captured along the entire measurement process, which can then be filtered to extract the information required

The “high pressure” images were taken with the probe pressed against the carcase in the same manner as is done in most ultrasonic systems used for tissue measurement. The “low pressure” image was taken as the probe was drawn away from the carcase, on the final image that retained a reasonable quality image. “High pressure” images were expected to compress to a value lower than the true GR depth, but were expected to form a consistent reading with repeated measurements due to compressibility limits on the fat and muscle. The “low pressure” images were expected to be more accurate when compared with the cut and measure method, which is done at zero pressure, but their repeatability may be less consistent due to variations in both directionality and image quality when releasing the probe.

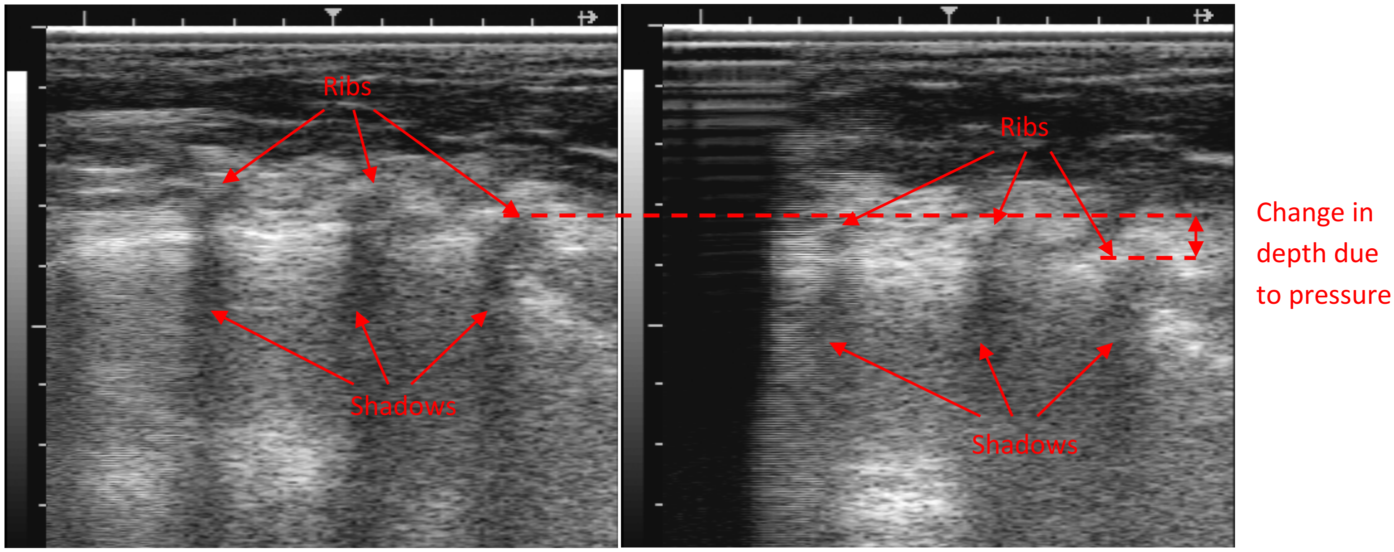


Figure 1: Ribs on ALOKA ultrasound image for a) high pressure b) low pressure

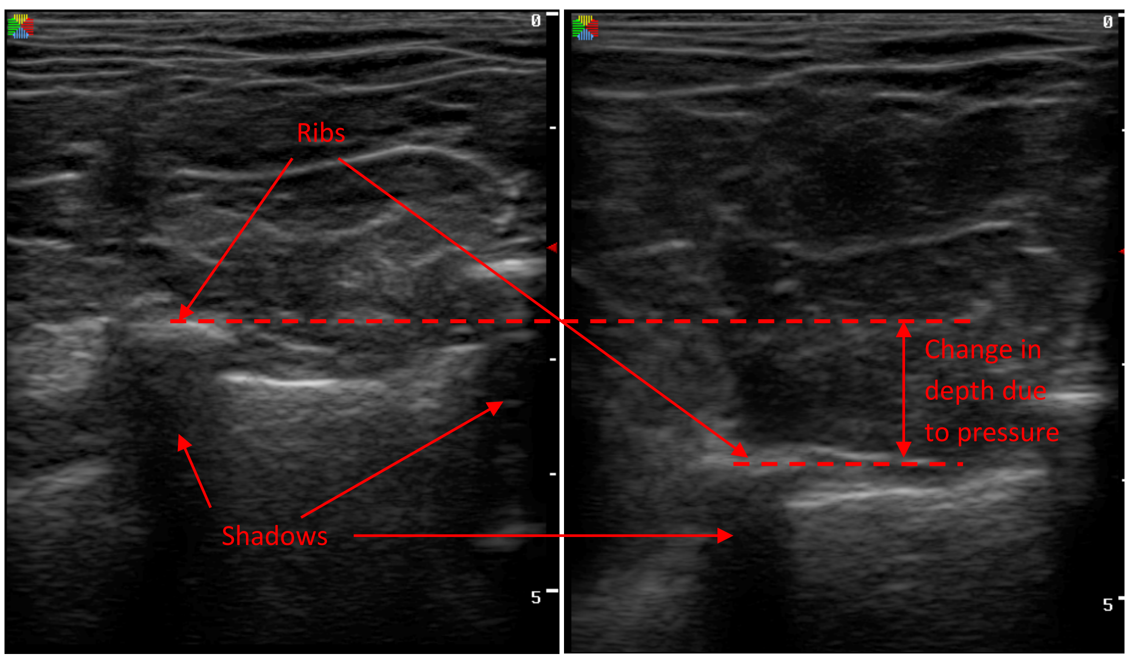


Figure 2: Ribs on Sonoscope ultrasound image for a) high pressure b) low pressure

4.6 Calibration

The resolution of the Aloka was measured at 0.2mm, while that of the Sonoscope was 0.1mm. This sets the minimum error for the fat and muscle depth measurements. However, the measurement error was estimated at 0.8mm and 0.4mm, respectively, due to the shape variations in the rib.

5 Results

The effect of the pressure can be seen in Figure 1 and Figure 2. Where less pressure is applied, the measurement can be significantly deeper. This is also seen in Figure 3 and Figure 4 where the “high pressure” measurements were typically below the “One to One” line. The low pressure measurements were closer to the “One to One” line.

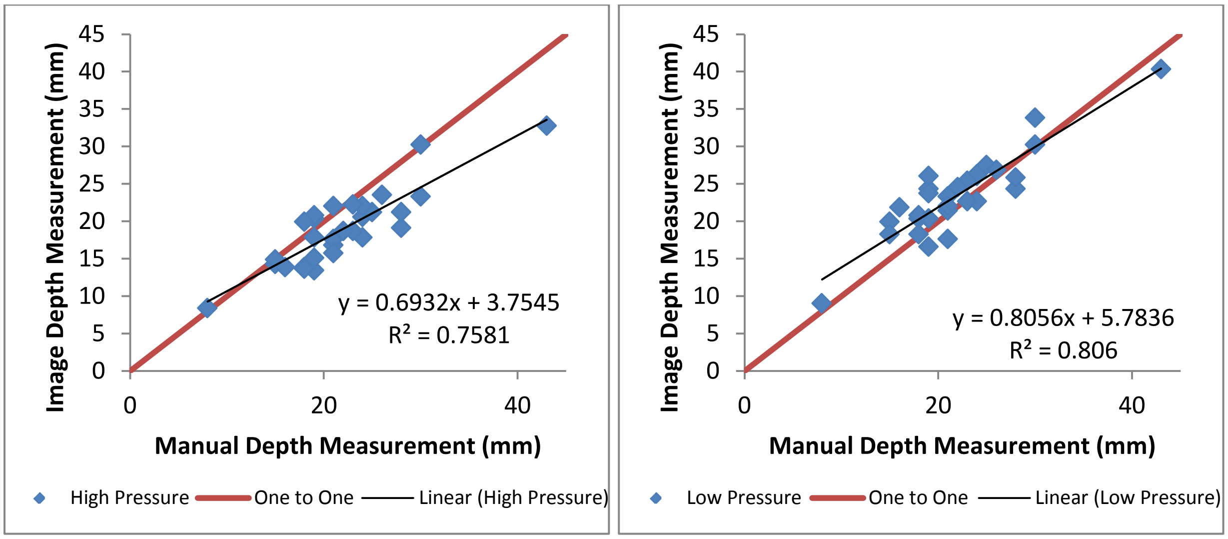


Figure 3 Comparison of image analysis depth measurements to cut and measure depth measurements for the Aloka (a) High pressure and (b) Low pressure. The One to One line shows the expected value of the image depth measurement given the manual depth measurement.

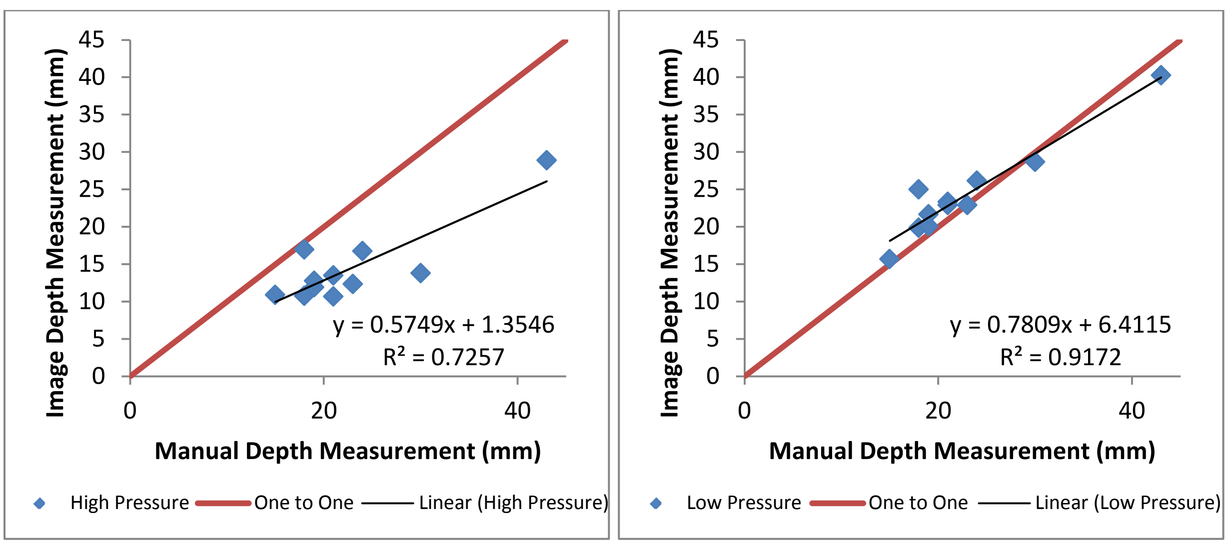


Figure 4 Comparison of image analysis depth measurements to cut and measure depth measurements for the Sonoscope (a) High pressure and (b) Low pressure. The One to One line shows the expected value of the image depth measurement given the manual depth measurement.

The R^2 values indicate how well the ultrasound measurement methods compare with manual GR depth. Table 1 indicates that the low pressure method using the Sonoscope produced the best match to the cut and measure method.

Table 1: Correlation of manual and ultrasound GR depth measurement for (a) high pressure method and (b) low pressure method

Instrument	High Pressure		Low Pressure	
	R^2 Values	RMSE	R^2 Values	RMSE
Aloka	0.76	5.56	0.81	2.44
Sonoscope	0.73	10.21	0.92	1.73
Aloka (same carcases as Sonoscope)	0.80	3.54	0.87	2.46

The low pressure method for the Sonoscope was used on a smaller dataset. A similar sample set for the Aloka was selected from the data, covering the same carcases as the Sonoscope. The R^2 was significantly improved for this dataset, suggesting that the high R^2 may be due to the group of carcases utilised. Although the study demonstrates the technology and measurement methodology addresses previous issues well, further data capture is necessary to determine the typical comparison between the two methods.

The images from the Aloka show a large amount of noise below the ribs. In contrast, the noise below the Sonoscope images was reduced. This suggests that the Sonoscope would be better for automated image analysis methods, which would rely on the shadow to indicate the location of the rib. Conversely, the size of the larger Aloka probe reduced the variation and displacement due to pressure delivering a higher correlation with lower error in the high pressure tests. However, neither system perfomed well enough in the high pressure tests for it to be considered a viable measurement method.

5.1 Additional measures

The Sonoscope does produce a clearer image than any other ultraousnd system tested on lamb to date. It is possible to view a cross-section of the muscles by sliding the detector along the transverse direction. This is shown in Figure 5. This opens the possibility for measuring a range of different locations and reference points automatically including C-site depth and eye muscle area. Observations during these trials indicate the compression of muscle in the loin in the ultrasound scans was significant. For this reason eye muscle area measures would be more viable than depth and width measures in the future.

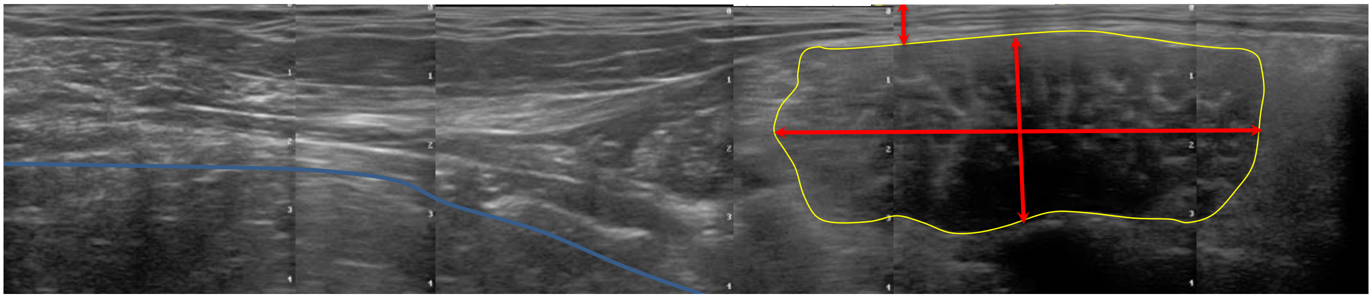


Figure 5: Transverse scan quality likely to enable loin eye depth and width measures in second stage development

6 Summary

6.1 Air bubbling overcome

The Sonoscope "compounding" probe overcomes air bubbling issues from previous trials that hindered development of auto-image analysis techniques.

- The system was only trialled at one plant so alternative de-pelting techniques may produce more air bubbling; however
- The basic capabilities of the compounding were sufficient to overcome air bubbling at this plant. Further adjustments may be required on other sites which the Sonoscope system appears to be capable of.

6.2 Fat and muscle compression overcome

Low pressure measurement methodologies overcome fat and muscle compression issues experienced in the past.

Although a range of complex image analysis capabilities would need to be developed, other aspects of the methodology make it very simple to manage in a commercial application including:

- No moving parts (in manual application)
    - Opportunity to automate probe placement in future
    - Simplicity of measure would facilitate automated placement
- No pressure sensors or other process critical measurement inputs
- No operator variables such as pressure applied to carcase surface
    - Still requires operator to locate the GR site as in manual
- Auto measurement (computer generated) and auto entry of result
    - Plants using manual palpation would not require any additional staff to operate.

6.3 Commercial measurement potential

Although the data sets collected with the final measurement configurations are small the previous hurdles have been overcome. The newest measurement methodologies appear robust enough to commercialisation while dealing with previous hurdles.

7 Recommendations

1) Collect a larger data set from additional plants
    a) Now that a measurement methodology has been tested a wider data set should be collected to ensure there are no unexpected impediments to development of a commercially robust online measurement system
    b) Greenleaf are conducting trials to collect additional data outside the scope of this project which can be used to address these unknowns

2) Develop a commercialisation document for measurement of GR depth that outlines the following aspects:
    a) Proposed application
        i) What the system would look like, how it would integrate with the operator, types of outputs available to processors, producers and researchers
        ii) Operational, management and maintenance requirements of the system
        iii) Estimated commercial installation cost
    b) Target performance accuracy
        i) Expected correlation to GR depth and to other measures
        ii) Expected correlation to actual carcase value
        iii) Methodologies used during development to validate output accuracy
    c) Development components
        i) Measurement technology development – primarily software
        ii) User and Management systems interface – primarily software
        iii) Making the system commercially robust – primarily hardware with some data communication
    d) Procedures for validation and approval by Standards bodies like AUS-Meat
    e) Commercialisation options
    f) Timeframe and estimated budget

8 Figures and Tables

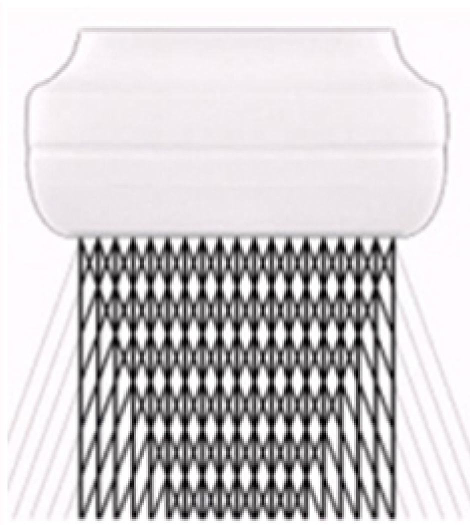
9 Appendix: The Impact of COMPOUND IMAGING on Image Quality

COMPOUND IMAGING is a broad bandwidth technology that combines multiple coplanar images captured from different beam angles and from multiple ultrasound frequency spectra to form a single image in real time. Spatial compounding reduces speckle artifacts and improves contrast resolution.

The following images demonstrate the way in which sound can travel "behind" air bubbles in the subcutaneous fat layer of the lamb carcase.

No Compound Imaging

Compound Imaging



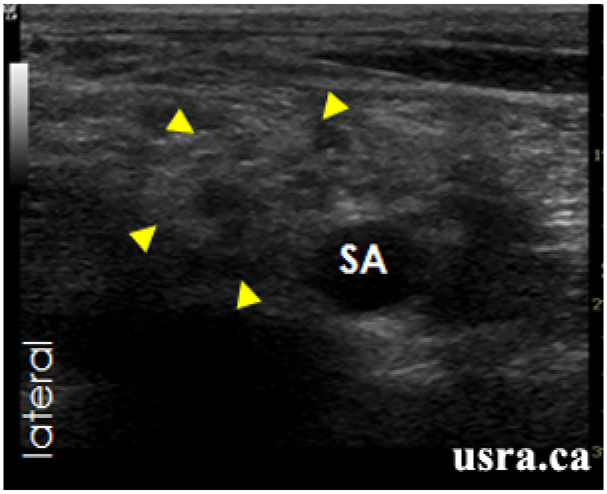
The following ultrasound images demonstrate the improvement in image clarity resulting from compounding. Minor differences in clarity have a large impact on auto recognition capabilities.

Median Nerve in the Forearm (12 MHz Transducer, 3 cm Depth)

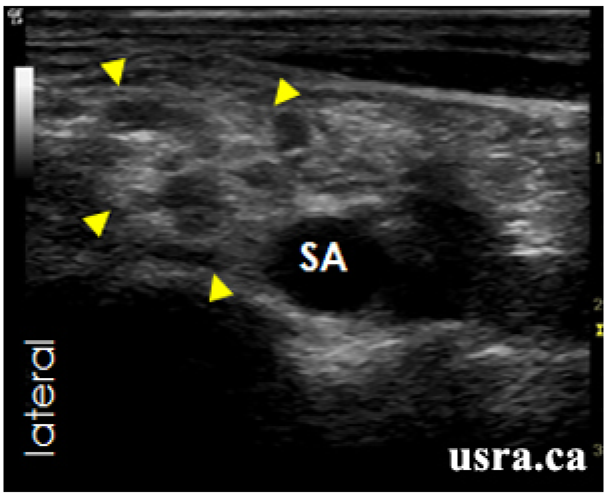
No Compound Imaging

Compound Imaging

Supraclavicular Region (10 MHz Transducer, 3 cm Depth)



No Cross Beam (No Compound Imaging)



Cross Beam (Compound Imaging)