Ultrasound in Cattle Practice: Linear vs Sector scanning

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Introduction
Transrectal real time ultrasound has become the most common method of performing pregnancy diagnosis and reproductive examinations in cattle practice in Australia. Ultrasound has provided a fast, minimally invasive and accurate way to determine pregnancy status, identify ovarian structures, identify uterine pathology and determine pre-partum sex of the foetus.

Types of scanners
The main types of ultrasound that are used in Australia are classed as linear array, curvilinear array or mechanical sector scanners.

Linear and curvilinear array scanners utilise a transducer which is composed of a large number of crystals. The crystals fire in rapid succession to produce a very clear image. Linear scanners utilise crystals in a line which are used to produce a rectangular image. Curvilinear scanners are linear arrays shaped into convex curves which produce a wider field of view in a wedge fan shape (Figure 1).

Mechanical sector ultrasound scanners are characterised by the use of an electric motor to move multiple crystals over an area to generate a real time image. The image displayed can be described as either pie or wedge shaped (Figure 1).

Figure 1 Schematic of different transducers. Figure from Small animal Diagnostic Ultrasound, 2nd edition.
One of the most significant differences between a linear and a sector scanner is the frequency of the transducer. In general, sector scanners tend to have lower MHz transducers when compared to the linear array scanners. Depth of tissue penetration of sound waves and image resolution is dependent upon and inversely related to the frequency of the transducer. Thus, a 5.0 MHz transducer results in greater tissue penetration and lesser image detail, whereas a 7.5 MHz transducer results in lesser tissue penetration and greater image detail. An ultrasound scanner equipped with a 5.0 MHz transducer is most useful for bovine practitioners conducting routine reproductive examinations; however, small ovarian structures such as developing follicles are best imaged with a 7.5 MHz transducer.

Due to the harsh environments that many dairy and beef cattle practitioners are encountered when performing pregnancy diagnosis there are several key components of an appropriate ultrasound. The ultrasound must be:

- Lightweight
- Mobile
- Robust (able to cope with a mild to moderate traumatic incident)
- Relatively waterproof
- Able to be cleaned and disinfected
- Have good battery life

The ultrasound requirements for the majority of Australian dairy and beef veterinary practitioners who work with seasonal or split calving producers are different to the requirements of dairy practitioners overseas who work in predominantly year round calving systems. In seasonal systems, the main use of the ultrasound is for pregnancy/empty diagnosis as opposed to year round systems where there is also a requirement to perform a significant amount of ovarian ultrasonography. The difference between the two systems led to many Australian practitioners becoming early adopters of “arms free” rectal ultrasonography, relying on either a metallic or plastic introducer to carry the ultrasound transducer into the rectum. The use of the introducer allows for very large numbers of animals to be tested at significant speed with much lower fatigue for the operator. An additional benefit to using the introducer is that there is less trauma for the cow compared with the introduction of an arm into the cow. Units that have the ability to be used manually and on an introducer are advantageous for practitioners who work with a mix of seasonal and year round operations.

There are several different units available in Australia; Table 1 is a summary of the most commonly used ultrasound units with important information regarding each unit.
**Table 1 Comparison of commonly used ultrasounds in bovine practice.** Data obtained from company websites. Not all of the available ultrasounds are shown in the table please refer to individual company websites for full range.

<table>
<thead>
<tr>
<th>Company</th>
<th>Easi scan 2</th>
<th>Easi-curve</th>
<th>Duo-Scan 3</th>
<th>iScan</th>
<th>Animal profi 2</th>
<th>Ibex lite</th>
<th>Bovi-scan Curve</th>
<th>Bovi-scan Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCF technology</td>
<td>BCF technology</td>
<td>BCF technology</td>
<td>Draminski</td>
<td>xDraminski</td>
<td>EI medical engineering</td>
<td>ReproScan</td>
<td>Reproscan</td>
<td></td>
</tr>
<tr>
<td>Scanner type</td>
<td>Linear</td>
<td>Curvi-linear</td>
<td>Sector</td>
<td>Linear</td>
<td>Sector</td>
<td>Linear/curvi-linear</td>
<td>Curvi-linear</td>
<td>Linear</td>
</tr>
<tr>
<td>Weight</td>
<td>2kg with battery</td>
<td>2kg with battery</td>
<td>3kg with battery</td>
<td>2kg with battery</td>
<td>1.5kg with battery</td>
<td>2kg with battery</td>
<td>2kg with battery</td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>4.5 - 8.5MHz</td>
<td>3 - 7MHz</td>
<td>2.5 - 7.5MHz</td>
<td>4 - 9MHz</td>
<td>3.5 – 7MHz</td>
<td>2.5 – 8MHz Depends on probe</td>
<td>2 – 5MHz</td>
<td>5 – 9MHz</td>
</tr>
<tr>
<td>Depth</td>
<td>4-12cm</td>
<td>8cm -24cm</td>
<td>Up to 32cm</td>
<td>Up to 12cm</td>
<td>7- 12cm</td>
<td>Depends on probe</td>
<td>6cm - 22cm</td>
<td>4cm – 16cm</td>
</tr>
<tr>
<td>Dust-proof</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Splash-proof</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Battery life</td>
<td>4 hours</td>
<td>7 hours</td>
<td>5 hours</td>
<td>5 hours</td>
<td>4hrs 30min</td>
<td>6 hours</td>
<td>8 hours</td>
<td>8 hours</td>
</tr>
<tr>
<td>Arm free scanning</td>
<td>Yes with introducer</td>
<td>Yes with introducer</td>
<td>Yes (no other way)</td>
<td>No</td>
<td>No</td>
<td>Yes with introducer</td>
<td>Yes with introducer</td>
<td>Yes with introducer</td>
</tr>
<tr>
<td>Probes</td>
<td>128 element linear, 60mm footprint</td>
<td>128 element convex, 60mm footprint</td>
<td>Radial 170 degrees</td>
<td>Radial 180 degrees</td>
<td>Probe dependant</td>
<td>60mm convex</td>
<td>80 element linear 60mm footprint</td>
<td></td>
</tr>
<tr>
<td>Inter-changeable Probe</td>
<td>No</td>
<td>No</td>
<td>Yes (sheep probe)</td>
<td>No</td>
<td>Yes</td>
<td>Multiple probes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Other uses</td>
<td>Yes (Thoracic, soft tissue)</td>
<td>Yes (Thoracic, abdominal)</td>
<td>Sheep (with a separate probe)</td>
<td>Yes (Thoracic, soft tissue)</td>
<td>Yes (Thoracic, soft tissue, abdominal)</td>
<td>Yes (dependant on probe selected)</td>
<td>Yes (Thoracic, abdominal)</td>
<td>Yes (Thoracic, soft tissue)</td>
</tr>
</tbody>
</table>
Comparison of scanners for reproductive applications

Early pregnancy diagnosis (28 - 32 day)
In order to perform early pregnancy diagnosis, there is a requirement for both high image quality and the ability to have a large enough image. Linear scanners taken in by hand have been used for this purpose for many years due to the high sensitivity when using this method. The improvement in image quality in linear and curvilinear scanners in recent years has led to the ability to perform early diagnosis with the transducer on an introducer. In saying this, the use of the introducer does increase the chance of a misdiagnosing the early pregnant animal as empty, therefore in almost all cases, the authors recommend that the empty diagnosis should be confirmed by performing manual rectal ultrasonography. The sector scanner on an introducer can be used for early pregnancy diagnosis but in the authors’ experience, the sensitivity of the procedure is much lower than the linear scanner. The sector scanner is often used as a screening tool with potential empties confirmed by manual introduction of a linear scanner.

Routine pregnancy diagnosis (6 weeks to 16 weeks)
Pregnancy diagnosis between 6 and 16 weeks is the most common use of ultrasonography in well managed dairy and southern beef properties. The use of both the sector and linear/curvilinear scanners on an introducer are perfect for this purpose. Both types of units are very accurate in determining gestational age in the hands of an experienced operator.

Late pregnancy diagnosis (16 weeks plus)
Consistently determining pregnancy status in cattle greater than 16 weeks of gestation can be variable between the different units. Whilst a linear scanner on an introducer can frequently be used for this purpose, due to the decreased depth obtained by most scanners, it can be difficult to determine pregnancy in very obese animals which are at an advanced stage of gestation. The increased depth obtained by both the curvilinear and sector scanners makes them more suitable for this performance.

Determining gestational accurately becomes difficult in cattle above 16 weeks of gestation. Due to the limited depth of the linear scanner, it is extremely difficult to accurately age greater than about 17 weeks of gestation. Experienced operators who perform a large number of pregnancy diagnoses above 17 weeks can achieve good accuracy with both the sector and curvilinear scanner to a higher gestational age.

High throughput pregnancy diagnosis
The increase of rotary dairies in Australia has led to the challenge for dairy veterinarians to attempt to perform pregnancy diagnosis at a sufficient speed to minimise disruption to normal milking. It is not unusual for a single ultrasound operator to perform pregnancy diagnosis on a herd of 1000 cows averaging 240 to 300 cows per hour.

In this case, there is an advantage to have increased depth as well as field of view. The sector scanner on an introducer was specifically developed for this purpose and was traditionally the machine of choice by dairy veterinarians. Whilst the linear scanner was able to be used for this purpose, the decreased depth and field of view made the task more difficult and often slightly slower than the sector scanner. The recent development of the curvilinear scanner has changed the situation. Whilst the field of view is still less than the sector scanner, in the hands of an experienced operator there is now no difference in speed between the units.

In the beef situations the use of sector scanners in over the race scanning has made the processing of large numbers of animals in a relatively short time possible and saves the crushing of individual animals. The adaption of setups has made this relatively safe.
Identification of twins
Reliable and consistent identification of twins is aided by using an ultrasound with greater depth and field of view, especially when the foeti are in separate horns. Whilst one can use the linear scanner to identify twins, the sector scanner does have a significant advantage due to the lower frequency and wider field. The development of the curvilinear scanner has significantly improved the detection rate for twin pregnancy in the author’s experience.

Identification of the empty uterus
Whilst all units are capable of identifying the empty uterus, a greater confidence can be achieved with the linear and curvilinear scanners due to the superior image quality. The greatest sensitivity is achieved when using a linear/curvilinear scanner manually.

Profound changes in uterine characteristics occur during the oestrus cycle. The higher definition and image quality of linear and curvilinear scanners can be used to accurately determine the stage of the oestrus cycle by changes in wall thickness and the presence of oedema within the wall of the uterus.

Ovarian structures
Ovarian tissue can easily be easily visualised with good quality ultrasound equipment. Ultrasonography can be used to discern follicular and luteal structures such as corpora luteum, follicular and luteal cysts as well as follicles of all stages. As the ovary often needs to be imaged in 3 dimensions to try and determine which structures are present, ovarian ultrasonography is best performed used a linear/curvilinear ultrasound taken in manually. Ultrasounds on an introducer can be used for identification of ovarian structures but this often takes longer and is not possible in all cases.

Foetal sexing
Foetal sexing is generally performed between 8 and 16 weeks of gestation. Identification of the genital tubercle requires high image quality, especially earlier in gestation, thus the ultrasounds which have a higher frequency are most suitable for this purpose. The linear and curvilinear scanners are mostly used for this purpose. One of the additional requirements for foetal sexing is that the foetus often needs to be manipulated into a particular orientation which can only be achieved with an ultrasound that can be taken in manually.

Abnormal foetal development
Some of the more common foetal abnormalities that are detected by using ultrasound include foetal death, maceration or mummification of the foetus, Schistosoma Reflexus, foetal hydrops and foetal anasarca. All ultrasound units are capable of identifying these foetal abnormalities but are easier to diagnose with ultrasounds which have a higher image quality.

Uterine Pathology
The main uterine pathologies that are commonly identified with ultrasound include pyometra, mucometra and endometritis. All scanners are capable of detecting both pyometra and mucometra with relative ease if there is adequate fluid present. Linear and curvilinear scanners may have increased sensitivity of detecting mild endometritis when there are only small amounts of accumulated fluid and the main pathologic change is an increased uterine thickness.

Other uses
Whilst the major use of an ultrasound unit in cattle practice is for reproductive examinations, there is also the opportunity to use the units for assessing other body systems such as the respiratory, mammary, gastrointestinal and integumentary system. The linear and curvilinear scanners can be used for this purpose because of their higher
image quality with the curvilinear scanner preferred due to increased depth achieved.

The other benefits of the linear and curvilinear scanners are that they can be used for other species such as equine and small animals.

**Conclusion**

As ultrasound units are a significant capital item, it is important that veterinarians are fully informed when making a purchase. The major consideration for what type of ultrasound is purchased should be based on how the ultrasound is going to be used.