Training manual

on

'APPLICATION OF DIAGNOSTIC IMAGING IN ANIMAL REPRODUCTION MANAGEMENT'

Compiled and prepared by

Department of Veterinary Gynaecology and Obstetrics

Veterinary College and Research Institute,

Orathanadu – 614 625, Thanjavur

Sponsored by

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Pudukottai

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'APPLICATION OF DIAGNOSTIC IMAGING IN ANIMAL REPRODUCTION MANAGEMENT'

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2022

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IMPORTANCE AND NEED OF IMAGING DIAGNOSTICS IN ANIMAL REPRODUCTION MANAGEMENT

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Fertility of dairy cattle is the gateway of production and backbone of rural economy. Our country stands first in the milk production globally, but the bovine population behind this production scenario is also huge. Ever rising infertility problems and inadequate management systems seem to be the major hurdles in the production status of the animals. If these obstacles could be resolved, we can attain a mammoth stature in milk production, a real "White Revolution". Inspite of tireless efforts, achieving an optimal fertility of dairy cattle still remains a dream process.

Cattle in rural areas generally suffer from two major reproductive conditions - Anoestrus condition or failure of coming to oestrus and repeat breeding or repeated failure to conceive. Repeat breeding is the most frequently encountered but poorly understood condition affecting the reproductive efficiency and economy of milk production in cattle and buffaloes. Reproductive inefficiency of cattle due to repeat breeding syndrome is an expensive hitch in profitable dairy production as the age at first calving in heifers is delayed and the inter-calving interval is extended, thus leading to lowering of calf crop (Thakur *et al*., 2006). This syndrome can be one of the more frustrating problems affecting reproductive management of a dairy herd. Increase in inter calving interval due to repeat breeding means increase in dry / open period. It was reported that the farmers would incur a loss of around Rs.300 – 400 per day due to one day increase in open period due to missing a fertile oestrus and delay in pregnancy diagnosis (Abdullah *et al*., 2014).

One of a national study, documented an incidence rate of 77.43 per cent among cattle, of which, 38.33 per cent animals were repeat breeders, 39.10 per cent were anoestrus followed by varied incidences of endometritis, cervical pathologies, fallopian tube defects, prolonged oestrus and silent oestrus (Kumar and Singh, 2018). In a recent survey conducted in Tamil Nadu, it was found that only 35 per cent of cows and buffaloes were pregnant as against a desirable level of 70 per cent; around one third of cows and buffaloes were infertile because of anoestrus or repeat breeding. This means that out of 50 lakh breedable cows and buffaloes available in Tamil Nadu, around 15 lakh are infertile.

Precise diagnosis is the first major step in deciding the appropriate remedial measure for infertile conditions. Imaging diagnostics including ultrasound and X-ray have boosted the reproductive management efficiently in large and small animals respectively.

Ultrasound techniques are becoming increasingly important in animal reproduction, offering both a mean of diagnosis and a useful therapeutic tool. Accordingly, understanding the use of ultrasound technology is critical in contemporary animal sciences, since ultrasound examinations are now a routine component of diagnostic workups in reproduction. Apart from pregnancy diagnosis, ultrasound technology offers the assessment of pregnancy status and foetal viability in order to identify animals that fail to conceive. Early identification of reproductive disorders is one of the key managemental strategy in improving the reproductive efficiency animals. The new information that has been generated through imaging technologies has thrown light on therapeutic uses, thereby opening up new areas for field level applications.

Challenges in bovine breeding systems warranted introduction of new user-friendly technologies. Ultrasonograhy is a potent alternate technology in the field conditions. Adapting new methods, especially ultrasound machines which are now become cheap and affordable may prevent loss for the marginal farmers in our country. Strengthening the diagnostic facilities (like ultrasound machines) and basic infrastructure in veterinary clinics is the important development measure to be taken for improving the diagnostic skills. Making the best use of ultrasonography in the field will provide a breakthrough in Veterinary diagnostics and Profession as well.

References:

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Thakur, S., Singh, M. and Vasishta, N.K. (2006). Study on etiology of repeat breeding in Himanchal Pradesh. Punjab Vet J 4: 27-29.

BASIC PRINCIPLES AND OPERATIONAL PROCEDURES OF ULTRASONOGRAPHY

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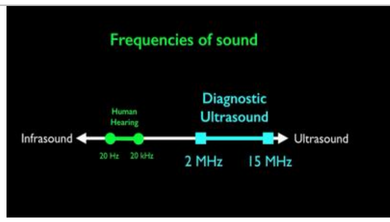
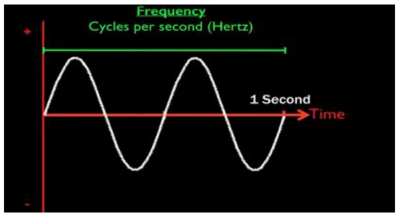
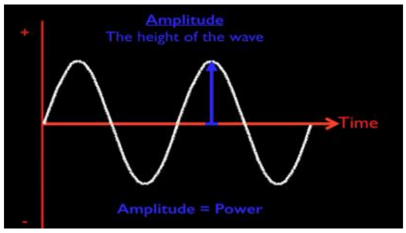
Diagnostic ultrasound, also called sonography or diagnostic medical sonography, is an imaging method that uses high-frequency sound waves to produce images of structures within your body.

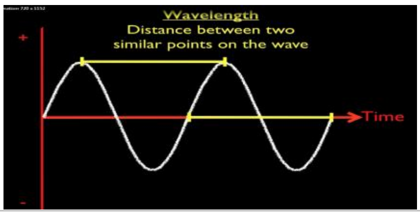
Physical principles

Images are created according to the propagation of ultrasound (sound waves with frequencies beyond what can be perceived by the human ear) within the tissues. Frequency of a sound wave is defined as the number of repetitions of this wave (cycle) per second. One cycle per second =1 Hz. A high-frequency sound, therefore, has a shorter wavelength and more cycles per second (cycles/s or Hz) than a low-frequency sound. The human ear can perceive sounds in the range of 20–20,000 cycles/s, or up to 20 kHz. Beyond this range, it is called "ultrasound." Ultrasound frequencies used in medical imaging generally vary between 3 and 12MHz, or 3–12 million cycles/s, which is well beyond what the human ear can perceive. The wave length is the distance covered by one sound wave during one cycle and determines the penetration power of this sound wave in the tissue.







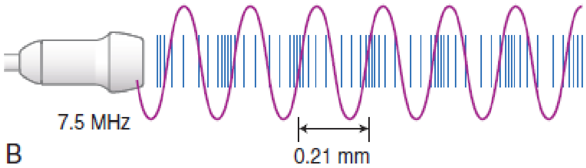


Frequencies in the millions of cycles per second have short wavelengths (submillimetre) that are essential for high resolution imaging. The shorter the wavelength (or higher the frequency), the better the resolution. Frequency and wavelength are inversely related if the sound velocity within the medium remains constant.

Velocity m/sec = Frequency (cycles/ sec) x wavelength (m)

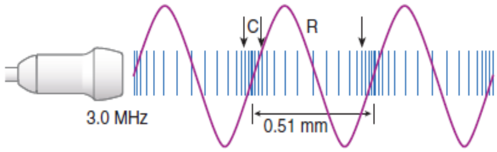
Higher frequency

- More no. of cycles per second
- Better resolution
- Less penetration
- Application: Superficial structure



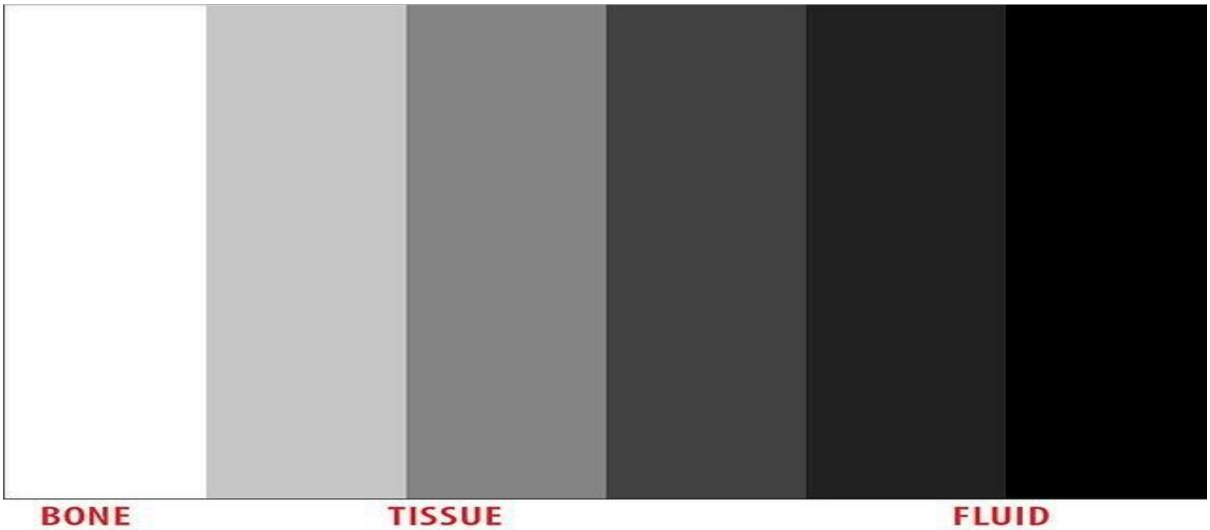
Low frequency

- Less no. of cycles per second
- Less resolution
- More penetration
- Application: Deeper structure



The speed of sound (propagation velocity) is affected by the physical properties of tissue, primarily the tissue's resistance to compression, which depends on tissue density and elasticity (stiffness). Propagation velocity is increased in stiff tissues, decreased in tissues of high density. The average velocity of diagnostic ultrasound in the soft tissues of the body is 1540 m/sec.

Echogenicity of Body tissues and substances based on the tissue or organ density.

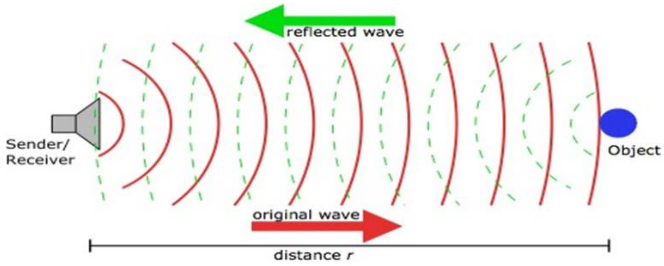


Bone	Gas, organ boundaries	Fat, Vessel walls	Liver, Storage fat, Spleen, Prostate	Muscle, Renal cortex, Renal medulla	Bile, Urine

Basic component of ultrasound machine

❖ **Pulser**

Ultrasound imaging is based on the pulse-echo principle. This means that sound is produced by the transducer in pulses rather than continuously. The pulser (or transmitter) applies precisely timed high-voltage pulses to the piezoelectric crystals within the transducer, which then emits short bursts of ultrasound into the body. The image is formed from the echoes returning to the transducer from the tissues after each pulse. Therefore, adequate time must be allowed for all echoes to return before the transducer is pulsed again. Typically, sound is transmitted less than 1% of the time; the transducer is waiting for all echoes to return more than 99% of the time.



When the crystal is pulsed, approximately two or three wavelengths are emitted in each pulse before a backing block in the transducer dampens the vibration. Thus, the spatial pulse length is commonly two or three wavelengths. A higher frequency transducer emits shorter wavelengths, and therefore correspondingly shorter pulses, than a lower frequency transducer. There are two points of clinical importance with regard to the pulser. i.e., Power control and Pulse repetition frequency (PRF).

Modes of Image Display

A-Mode

The least frequently used mode of image display is A-mode (amplitude mode), but it has special use for ophthalmic examinations and other applications requiring precise length or depth measurements, including back fat determination in production animals.

B-Mode

B-mode (brightness mode) displays the returning echoes as dots whose brightness or gray scale is proportional to the amplitude of the returned echo and whose position corresponds to the depth at which the echo originated along a single line (representing the beam's axis) from the transducer. B-mode is usually displayed with the transducer positioned at the top of the screen and depth increasing to the bottom of the screen.

M-Mode

M-mode (motion mode) is used for echocardiography along with B-mode to evaluate the heart. M-mode tracings usually record depth on the vertical axis and time on the horizontal axis. The image is oriented with the transducer at the top. The single line of B-mode dots described before, with brightness (gray scale) proportional to echo amplitude, is swept across a video monitor or recorded on a strip chart recorder. The motion of the dots (change in distance of reflecting interfaces from the transducer) is recorded with respect to time. The echo tracings produced with M-mode are useful for precise cardiac chamber and wall measurements and quantitative evaluation of valve or wall motion with time.

Real-Time B-Mode

Real-time B-mode scanners display a moving gray-scale image of cross-sectional anatomy. This is accomplished by sweeping a thin, focused ultrasound beam across a triangular, linear, or curvilinear field of view in the patient many times per second. The field is made up of many single B-mode lines, as described before. Sound pulses are sent out and echoes received back sequentially along each B-mode line of the field until a complete sector image is formed. Each line persists on the display monitor until it is renewed by a subsequent sweep of the beam. A malfunctioning transducer can dramatically illustrate how the image is composed of a series of separate lines. A narrow beam diameter enables the formation of a tomographic cross-sectional image, which is only a few millimetres thick. The beam may be steered mechanically or electronically through the field, with the frame rate (image renewal time) dependent on the depth displayed. The frame rate must be slower for displaying deeper depths because more time is needed for the echoes to return to the transducer. Sagittal, transverse, dorsal, and oblique planes through the body may be obtained by changing the transducer's orientation on the skin. The two basic types of real-time B-mode scanners are mechanical sector scanners and arrays of various configurations. The most versatile real-time sector scanners are also capable of A-mode and M-mode image production.

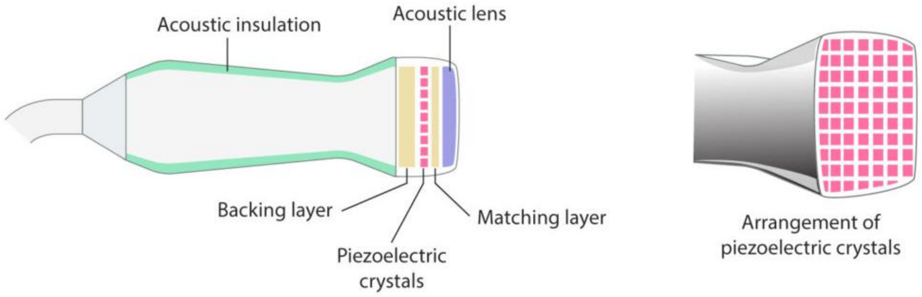
Doppler mode

Special ultrasound technique that evaluates blood flow through a blood vessel, including the body's major arteries and veins in the abdomen, etc.

❖ **Transducer**

The transducer (commonly referred to as a scan head or probe) plays the dual role of transmitter and receiver of ultrasound through use of piezoelectric crystals. Piezoelectric crystals vibrate and emit sound when voltage is applied to them by the pulser. The range of frequencies emitted by a particular transducer depends on the characteristics and thickness of the crystals contained within the scan head.

The ultrasound transducer from the side and front.



Modern transducers are capable of multifrequency operation, termed broad bandwidth. A range of frequencies are produced, composed of a preferential (central) frequency in addition to higher and lower frequencies. Advances in transducer technology allow simultaneous imaging of the near and far fields with sound waves of different frequencies. This allows the maximal resolution possible for a given depth without having to switch transducers.

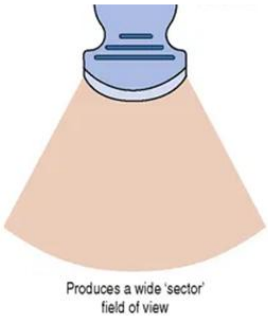
- **Types of probes**

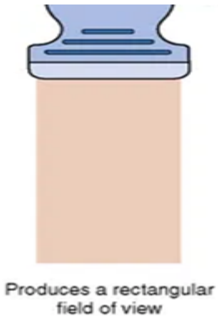
A-Phased array, B-Microconvex, C-Large convex array, D-Linear array, E- Linear array – Rectal

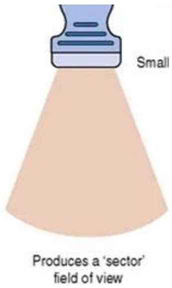
Shape of the ultrasound image based on the probe

A	Phased array probe	:	Smaller foot print, fits between the ribs, Low frequency and Echocardiography
B	Micro convex probe	:	Smaller foot print low and high frequency, preferably abdominal
C	Large convex array probe	:	Large foot print, low Frequency, Increased Depth, Abdominal US
D	Linear array probe	:	Flat foot print, High frequency, Maximum depth 10-13 cm and Musculoskeletal, intestine or vessel
E	Linear array -Rectal probe	:	Flat foot print, High frequency, Maximum depth 10-13 cm and large animal reproductive ultrasound

Convex array	Linear array	Phased array





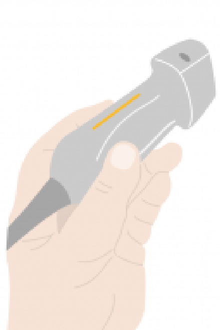


Probe indicator

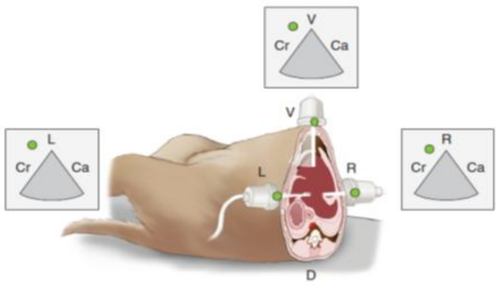
Every ultrasound probe has an orientation notch that is a small marker or grooved line on one side of the probe. Begin by holding the probe with the thumb side of your hand near the orientation notch or groove.

Transducer orientation

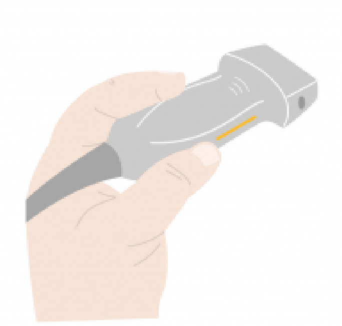
When using the longitudinal orientation, hold the probe so that the orientation notch is pointing towards the patient's head. When using the transverse orientation, the notch should be towards the patient's right side. This will orient your screen to the corresponding plane.



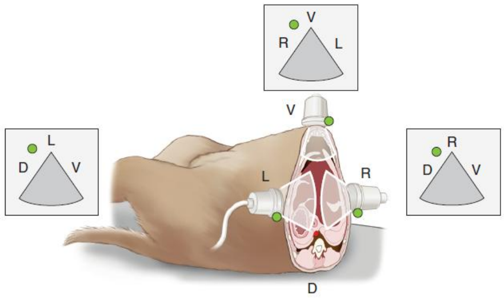
Sagittal or longitudinal orientation



Example: Dog – Dorsal recumbency – abdominal examination - Sagittal or longitudinal orientation of probe



Transverse orientation



Example: Dog – Dorsal recumbency – abdominal examination - Transverse orientation of probe

❖ **Overall Gain (Amplification) Control**

The overall gain control affects the amplification of returning echoes, directly responsible for overall image brightness. All ultrasound machines have a gain control that causes uniform amplification of all returning echoes regardless of their depth of origin.

❖ **Time Gain Compensation (TGC):**

It selectively amplifies the weak returning (attenuated) signals from deeper structures. The time-gain compensation (TGC) controls are used to produce an image that is balanced in brightness, from near field to far field. Echoes returning from deeper structures are weaker than those arising from superficial structures because of increased sound attenuation. The echo return time is directly related to the depth of the reflecting surface, as described previously. To selectively compensate for the weaker echoes arriving at the transducer from deeper structures, the gain is increased as the length of echo return time also increases. This compensation process is graphically represented by a TGC curve displayed on many ultrasound monitors. The TGC curve represents the gain setting in effect at any particular depth.

❖ **Image resolution - focal zones**

The focal zone is the narrowest portion of the ultrasonic beam in the tissue, and the point of the emitted beam with the best spatial resolution.

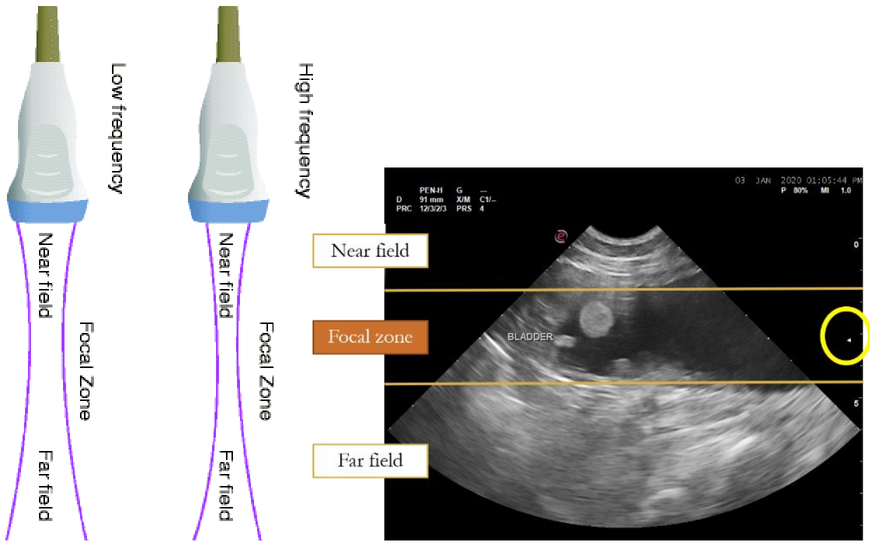
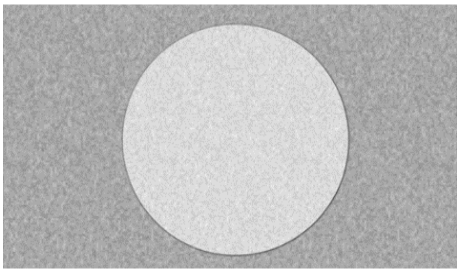


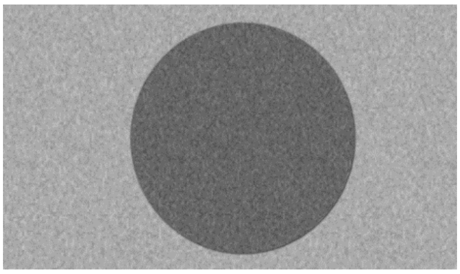
Image interpretation

Image echogenicity

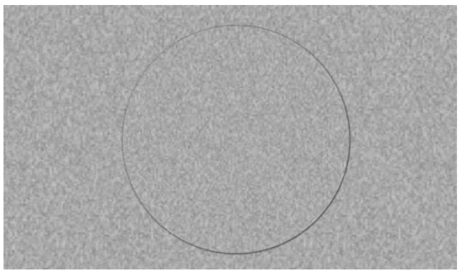
Hyperechoic:
Areas of high echo intensity, also referred to as echogenic, or echo rich. Bright (light gray to white) image intensity.



Hypoechoic:
Areas of low echo intensity, also termed echo poor. Darker gray image intensity



Isoechoic:
Organs or tissues with equal echogenicity when compared at identical depth and machine settings, or echoes that are essentially equal to normal parenchyma



Anechoic:
Areas with no echoes, or echo free. Appears black and generally represents a fluid-filled structure; transmits sound easily, without attenuation.

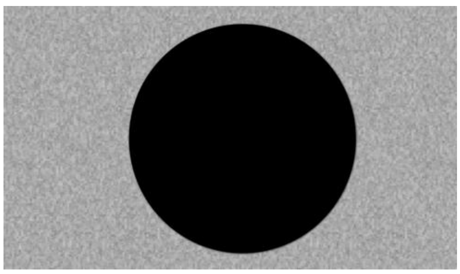


Image texture

It based on the size, spacing, and regularity of dots in the ultrasound image. The dots may be small, medium, or large, and they may be closely or widely spaced. In addition, size and spacing may be uniform (regular, homogeneous) or nonuniform (irregular, heterogeneous).

Fine or coarse parenchymal texture refers to small or large dot size, respectively. A uniform texture suggests similar size and spacing of dots throughout the parenchyma. A heterogeneous texture suggests that the dot size, spacing, or both may vary throughout the parenchyma.

Dot size	Small (fine), Medium, Large (coarse)	Uniform (regular, homogeneous) Nonuniform (irregular, heterogeneous)
Dot spacing	Close, Wide	Uniform (regular, homogeneous) Nonuniform (irregular, heterogeneous)

Uniform and nonuniform (homogeneous and heterogeneous) can refer to either echogenicity or texture. For example, one should specify heterogeneous parenchymal echogenicity or heterogeneous parenchymal texture, or both. Merely stating that there is a heterogeneous parenchymal appearance is confusing because echogenicity, texture, or both may be nonuniform.

Further reading

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HANDLING ULTRASONOGRAPHIC EQUIPMENT AND ACCESSORIES AND INTERPRETATION OF ULTRASONOGRAPHIC IMAGES

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Transrectal ultrasonic imaging is an effective tool for characterizing ovarian structures viz., follicle and corpus luteum, because it is non-invasive and permits repeated examinations of the ovarian follicles including follicles that are below the ovarian surface.

Linear-array transducers of 5.0 and 7.5 MHz frequency ranges are most commonly used in cattle, and most veterinary ultrasound scanners are compatible with probes of different frequencies. However, specialized applications including ovum pickup and follicle ablation involve a transvaginal approach using a sector transducer. 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.

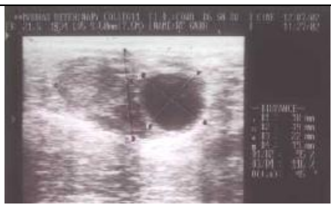
Setting up the Ultrasound scanner

- Fix the rectal probe and turn on the power to the equipment.
- Set the Ultrasound scanner to B mode.
- Colour, Gain and Contrast indices are set and maintained constantly throughout the study.
- Remove the dung and clear the rectal passage so as to enable clear imaging of ovarian structures and to avoid misleading interpretations.
- Apply scanning gel to entire transducer area.
- Hold the probe in the palm and introduce it per rectum with the face of transducer focused towards the rectal wall.
- Care should be taken to maintain the transducer position throughout the study.
- Each ovary should be scanned and imaged in more than one plane to ensure that all measurable follicles and corpus luteum were detected.

Imaging of Follicle:

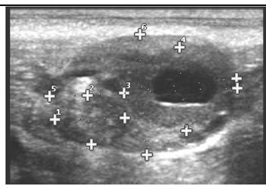
The most distinguishable ovarian structures are antral follicles. Antral follicles are fluid-filled structures surrounded by an inner layer of granulosa cells and an outer layer of thecal cells.

- Because follicles are fluid-filled structures they absorb ultrasound waves and are displayed as black circular structures on the screen (*i.e*., anechoic or non-echogenic) surrounded by echogenic ovarian tissue (Fig.1).

	
Large dominant follicle	**Small subordinate follicles**

Imaging of Corpus luteum:

Corpora lutea (CL) appear as distinctly echogenic areas within the ovarian stroma. The ovarian stroma and CL all contain varying degrees of dense cells and result in a gray image on the screen. Many CL appear as a solid tissue masses but may also contain fluid-filled cavities (cystic corpora lutea) and the cavities range from <2 to >10 mm in diameter. Ovarian cysts containing luteinized tissue should not be confused with a normal CL containing a fluid-filled cavity (Fig.2).

	
Corpus luteum	**Cystic corpora lutea**

Biometry of the structures

- The internal ultrasound caliper was utilized to measure the length and width of these structures and the diameter was determined by taking the mean of their length and width of the structures

REPRODUCTIVE ULTRASONOGRAPHY IN CATTLE

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Success of dairy industry lies on the sustainability of milk production, which in turn depends on sustained reproductive capacity of the animals. In general, success of every life depends on the sustainability. Eventhough many organs are functioning for the sustenance of life, there are two vital 'organ beats' that determines the value of life. For the physical life to sustain, we need the continuous 'heart beat'. For the reproductive life to sustain we need the uninterrupted 'Gonadal (testicular/ovarian) beat'. In males, the spermatogenic cycle occurs throughout the reproductive life. Likewise in females of any species, we could record the occurrence of follicular development in ovaries continuously till the reproductive senescence.

The incidence of repeat breeding is influenced by many factors such as nutrition, lactational status, breeding practices etc. However, recent epidemiological studies indicate that, in addition to these factors, follicular developmental pattern might probably contribute to the reproductive efficiency in dairy herds. Ovarian follicles are the vital units which provide proper environment and nourishment for the female gametes, the oocytes. The follicular developmental pattern during the oestrous cycle directly or indirectly indicates the fertility of the animal. So investigations are carried out to assess the utero-ovarian characteristics in cattle and to manipulate it positively for enhancing the fertility.

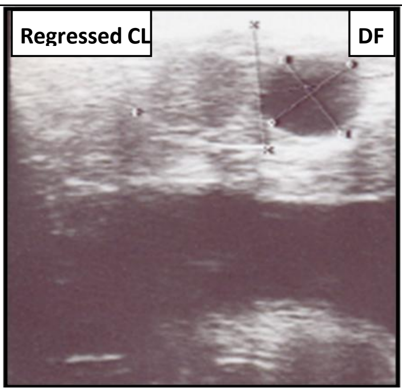
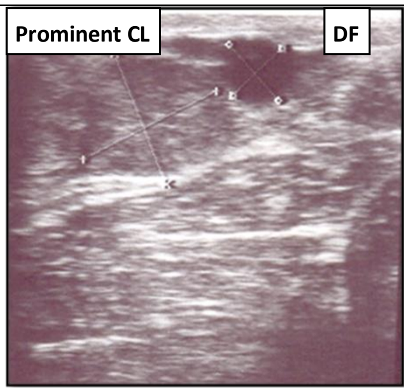
Ultrasonographic imaging of ovarian structures

Transrectal ultrasonic imaging is an effective tool for characterizing ovarian structures viz., follicle and corpus luteum, because it is non-invasive and permits repeated examinations of the ovarian follicles including follicles that are below the ovarian surface. Linear-array transducers of 5.0 and 7.5 MHz frequency ranges are most commonly used in cattle. 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.

It is important to recognise both normal and abnormal structures on transrectal ultrasound examination. It is also essential to realise that there may be significant variation between cows. Therefore, ultrasound examination findings should always be interpreted in combination with anamnesis, available records and visual observations.

Diagnosing aberrations of oestrum

Efficient and accurate detection of estrus is the key management factor determining the successful application of artificial insemination to achieve an improved reproductive performance in dairy cows. Normally crossbred cows exhibit estrus in an interval of 21 days (18-24 days). However, some animals are found to exhibit estrus-like signs during the mid luteal phase of the oestrous cycle. This behavioral estrus signs during the period of mid cycle is referred to as mid-cycle oestrus (MCO). Incidence of mid-cycle oestrus (MCO) is also equally limiting the reproductive efficiency in crossbred cattle leading to economic losses. It's interesting to notice that the animals with MCE also exhibit signs similar to that of true oestrum like restlessness, clear vaginal discharge, mounting etc. Per-rectal gyneco-clinical examination also revealed moderate to good tonicity of uterine horns simulating the oestrum. Insemination of cows during such aberrant estrus would be one situation leading to pseudo-repeat breeding condition thereby increasing the inter-calving period. Ultrasonographic investigation revealed that there was no significant difference in the diameter of dominant follicle between normal oestrum and MCO but the diameter of CL was significantly larger in MCO (>15mm) than in oestrm (< 15mm)

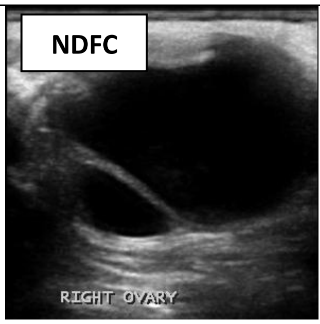
	
Normal oestrus	**Mid-cycle oestrus**

Ovarian follicular cyst and its deviations

Ovarian follicular cyst (OFC) is an important ovarian dysfunction and a major cause of reproductive failure in dairy cattle which has an economic impact on dairy industry. OFC is a consequence of a mature follicle that fails to ovulate at the appointed time during the oestrous cycle. OFCs undergo one of three fates:

i. cysts may remain dominant for a prolonged period without other follicular growth,
ii. cysts may lose dominance and be replaced by a cyst from a new follicular wave (cyst turnover), or
iii. cysts may lose dominance and a new dominant follicle (DF) may develop and ovulate (Non-dominant follicular cysts - NDFC).

In the recent years, we could observe an increase in the incidence of these third category cysts among the crossbred cows. It could be due to interventions of imaging diagnostics. The NDFCs are thin walled fluid filled structures uniquely characterized by their uncontrollable acute or chronic increase in diameter and extremely non-responsive to regular hormonal therapies. No nymphomaniac or anoestrus symptoms could be observed in the affected animals, instead the cows are cyclic with normal follicular turnover but remains infertile (cyclic non-breeders or repeat breeders).

	
Follicular cyst	NDFC along with DF

Endometritis

Endometritis is a common condition affecting dairy cattle which negatively affects reproductive performance. Clinical endometritis is defined as purulent or mucopurulent uterine discharge present approximately 21 to 26 days postpartum. Subclinical cases of endometritis may not have uterine discharge, however fertility is negatively affected. Transrectal ultrasonography may be used to evaluate cows for signs of endometritis. Indicators of endometritis on ultrasound exam include accumulation of intrauterine fluid containing echogenic particles (‘snowy’ appearance) and thickening of the endometrium due to endometrial oedema and inflammation. However, ultrasonography alone does not always provide a definitive diagnosis of endometritis.

Pyometra

Pyometra is generally defined as an accumulation of pus within the uterus. Compared to manual palpation, the differences between uterine enlargement due to pregnancy and pyometra are easily recognisable on ultrasound examination. While foetal fluids in the uterus appear anechoic, pyometra appears as distension of the uterine lumen with contents of mixed echogenicity. Additionally, there will be no evidence of a foetus, foetal membranes or placentomes on ultrasound examination of a cow with pyometra.

In addition to manual per rectal examination, ultrasonography should be included in the infertility investigation to examine and evaluate the cow's reproductive status. This enables to assess the architecture of the ovaries, uterus, reproductive vasculature and surrounding structures for accurate diagnosis of the aberrations. Early diagnosis with appropriate therapeutic intervention will aid in improving the bovine fertility and production thereof.

REPRODUCTIVE ULTRASONOGRAPHY IN SHEEP AND GOATS

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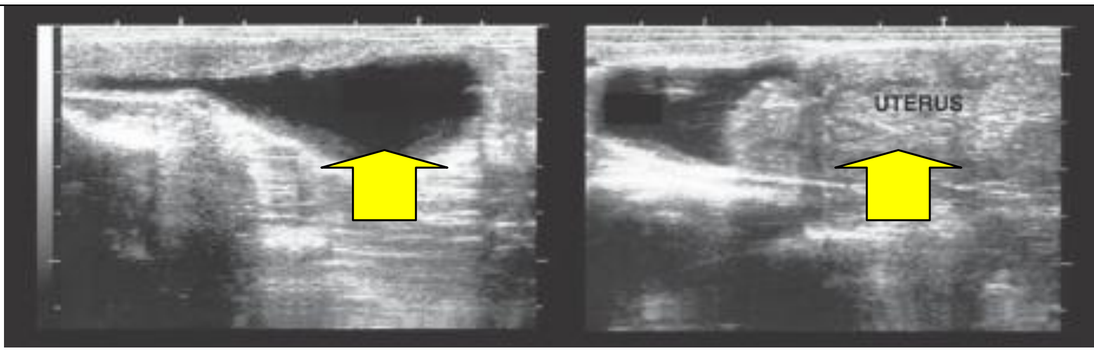
First use of ultrasonography in small ruminants was described in 1983, for pregnancy diagnosis both in sheep and goats. Ultrasonographic evaluation of the male genital system in small ruminants was first reported in 1988; however, unlike in the bovine, application of ultrasounds in small ruminants is scare. Currently, around 25 years later, ultrasonography is no longer an elite technique for few selected breeders but a widely recognized and used key tool in reproductive management and research. Many veterinarians in cattle practice routinely employ ultrasonographic examination using 5MHz linear array scanners transrectally for examination of the ovaries and uterus, as well as for the early detection, and possibly sexing, of bovine embryos. This equipment can also be employed to provide diagnostic quality ultrasound images for the ovine or caprine uterus, ovaries and associated reproductive structures for immediate results.

Methodologies for diagnostic ultrasonography in small ruminant reproduction

Bladder, uterus, vagina and ventral abdomen

The absence of fleece/hair in the ventral midline and inguinal area expedites preparation when examining the ventral and caudal abdomen in sheep and goats. Ultrasonographic examination of the bladder and caudal abdomen are undertaken in the standing animal, by using either 5.0MHz linear array or sector scanners (10cm versus 20 field depth, respectively). The caudal abdomen is examined for the bladder and gravid uterus.



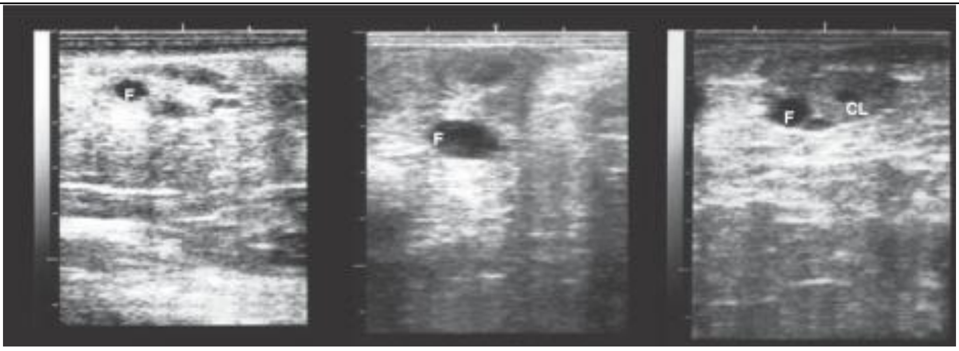
Bladder	Uterus

Ultrasonographic images of the urinary bladder (left image) and of the uterus cranially to the bladder (right image)

The right inguinal region is chosen, because the left side of the abdomen is largely occupied by the rumen. Ultrasound gel is liberally applied to the wet skin to ensure good contact. The transducer head is firmly held at right angles against the abdominal wall to image the uterus.

During transrectal ultrasonography, the first structures to be evaluated are the body of the uterus and the uterine horns. The non-gravid, fully involuted, uterus is a muscular structure and generates an echogenic image which echogenicity depends on the uterine tone and luminal contents. Therefore, echogenicity differs during the luteal and follicular stages of the oestrous cycle. The ovaries appear elliptic, with a hyperechoic outline, of 10 - 15 mm in diameter depending on the reproductive stage. Identification of ovarian structures depends on the expertise and experience of technicians. The difference in accuracy between operators may vary up to a 20%, especially for corpora lutea detection. In anoestrous females, the ovary is small and contains follicles between one and five millimetres. Owing to the fluid in the antrum, follicles are identified as black structures with a smooth spherical outline. The diameter of a follicle is measured by freezing the image and placing the electronic callipers of the ultrasound machine in the borderline between the follicular wall and the ovarian stroma. In cycling females, preovulatory follicles may reach 6–7 mm in sheep and 8–9 mm in goats.

Immediately after ovulation, corpora haemorrhagica are anechoic as they are mainly composed of blood that filled the antrum; later, as luteinization process advances, corpora lutea appear as grey structures. The presence of a central cavity showing an irregular shape surrounded by a hypoechogenic pattern is observed in approximately one-third of the animals. Presence of cavities is more abundant during the early luteal phase (80% of the animals in goats treated with progestagen and gonadotrophins, as cavity tends to disappear later. The cavity is usually hypoechoic, but occasionally exhibits a slightly increased and diffuse pattern or the presence of echogenic lines; the former are the images of accumulations of haemolysed blood, whereas the latter are fibrin-like strands. It is, thus, necessary to distinguish between cavitated corpora lutea and luteinized follicles and luteinized cysts; evaluation of the ratio between cavity diameter and total luteal-tissue diameter is useful, to differentiate this structures.

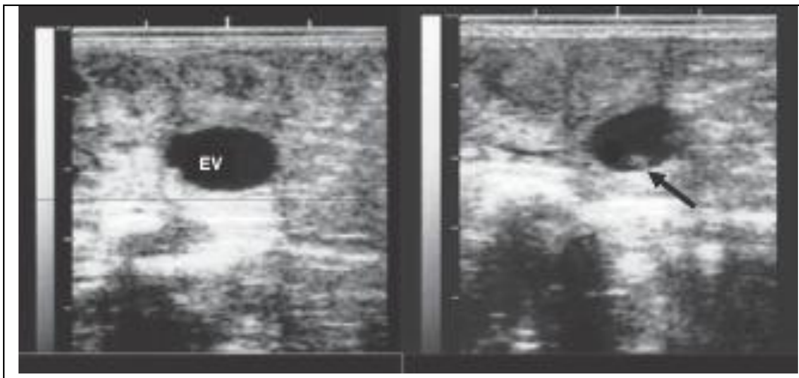


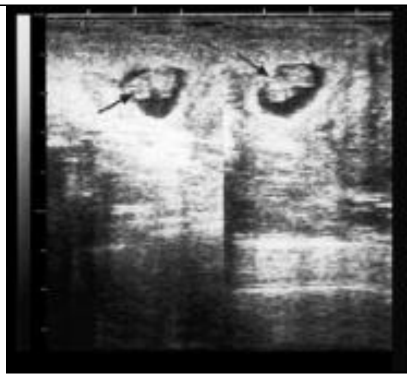
Small antral follicle	Preovulatory follicle	Corpus luteum

Pregnancy, gestation stage and fetal numbers

Ultrasonography has been successfully employed in small ruminant reproduction for the past 30 years to determine foetal numbers and gestation stage, permitting more precise feeding and management during late gestation.

This technique allows determination of pregnant status by visualization of embryo vesicles as fluid-filled dilatations in the uterine lumen from Day 12 of gestation. Visualization of the conceptus (concept that includes the embryo or the foetus as well as the extraembryonic membranes) may be performed from Day 16 in goats and from Day 19 in sheep. The accuracy at these early stages is, however, low. First, because of false negative diagnoses when the trophoblastic vesicle or the embryo are not detected; second, because of false positive diagnoses caused by intrauterine accumulation of fluids because of causes other than pregnancy or by confusion of embryo vesicles with intestinal loops, blood vessels or pathological conditions. Moreover, the incidence of embryonic losses in early pregnancies is high, increasing the number of false positive diagnoses. Thus, the pregnancy diagnosis should be carried out from Day 24 in practice, it is better to wait for Days 32–34, when efficiency reaches 85–100%, depending on operator experience.





Embryonic vesicle	Conceptus

At the same time, the optimal period for determining single and multiple pregnancies by transrectal ultrasounds starts around Day 27–30 of gestation, as the effectiveness for identifying single embryos reaches 100%, accuracy is 85% for twins and 70% for triplets. Determination of number of conceptuses by transrectal ultrasonography should be performed prior to Days 50–55; later, the large size of the conceptuses impedes a correct visualization of the entire uterus. In the field, transabdominal ultrasonography is preferred because of the combination of speed, accuracy for evaluation of pregnancy and number of conceptuses and easier management of animals. Using this technique, gestation can be diagnosed from 24 to 25 days of pregnancy by visualization of embryo vesicle. Embryos may be observed from Day 28; however, it is recommended to delay the examination until Day 35. In practice, pregnancy diagnosis is recommended to be performed after days 40–55 as efficiency in counting the number of conceptuses in multiple pregnancies reaches 100% .

Estimation of fetal age

The first measurements to be recorded are the internal transverse diameter of the embryonic vesicle (from Day 12 of pregnancy), the crown-rump length and the trunk diameter of the embryo (from Days 19 and 23 of gestation, respectively). At foetal stage (from Days 32 to 35 of pregnancy), occipito-nasal length, biparietal diameter, as well as the diameter of the trunk at the level of the last rib and the stomach can be determined. All these measurements have a high correlation with foetal age, but the head can be measured over a long period, from 36 to 38 days to almost delivery, when combining transrectal and transabdominal scanning. The skull usually remains in a good position for observation; occipito-snout length and biparietal diameter are easy to measure as it is easy to place the callipers on the hiperechogenic limits of the bones bordering the soft tissues. Other measurements – such as the width of the vertebrae and ribs, the longitudinal diameters of the stomach, kidney and urinary bladder, and the length of the femur – have lower correlations with age.

Fetal sexing

Ultrasonography is increasingly used for sexing the foetuses, by identifying the genital tubercle. Foetuses are identified as males when the genital tubercle is found next to the umbilical cord and female when the genital tubercle is found next to the tail. Studies performed by trans-abdominal ultrasonography on ewes between 60 and 69 days of pregnancy show that accuracy for detecting males is 100%, but diminish to 76% for females. Studies by transrectal ultrasonography have reported an earlier mean time of sexing, and earlier for sheep than for goats (41 vs 47 days), with no difference between sexes. Accuracy of sexing decreases as the number of foetuses increase, from 100% for single tons to 92.8% for twins and 62.5% for triplets.

Determination of pathological condition

Ultrasonography is especially useful for the diagnoses of pathological conditions in either pregnant or non- pregnant females, with that may compromise fertility and reproductive health. In animals that failed to conceive, the main causes of infertility are follicular and luteal cysts, at ovarian level, and hydrometra and metritis, at uterine level. Evidences and description of ovarian cysts in small ruminants, in contrast to the cow, are scarce.

Ovarian cysts

Ultrasonographically, follicular cysts appear the same as follicles but with a diameter of 10 mm, although they may become as large as 30 mm, and with little or no visible luteinization; luteal cysts are fluid-filled ovarian structures with a diameter of 10 mm or greater and with a thick luteal wall which may be up to 3 mm wide, indicating luteinization. Follicular cysts may be differentiated from paraovarian cysts; the later are anechoic spherical structures lying close to but outside of the ovary and has no negative effects on fertility.

Hydrometra

At uterine level, hydrometra is possibly the most common uterine pathology affecting fertility. Hydrometra is characterized by the accumulation of non-septic fluids in the uterine lumen concurrently with a persistent corpus luteum. Hydrometra is also called pseudopregnancy because the abdomen distendes and resembles advanced pregnancy. Fluid accumulation in uterus is responsible for the abdominal enlargement and large volumes up to 7 l may accumulate. It is regarded as an important cause of anoestrous, being more common in goats than in sheep. Ultrasonographic findings are related to volumes of fluid accumulated in the uterus; thus, the image corresponds with anechogenic areas, with different degrees of extension depending on the amount of fluids. The anechoic areas may traversed by hyperechogenic lines representing the thinly stretched uterine walls. Sometimes, it is possible to observe hyperechogenic dots moving in the uterine fluid (‘snow-storm’); these dots originate from desquamated endometrial cells. One or more corpora lutea may be identified in cases with hydrometra. Hydrometra should be differentiated from pregnancy, in the former there will neither be an embryo or a foetus nor placentomes.

Meteritis

The ultrasonographic image of the uterine content in a metritis, which allows a differential diagnosis, may be classified as anechoic, hypo-normoechoic and hyperechoic. Initially, metritis is characterized by a little anechoic uterine content and an increase in the thickness of the uterine wall; with endometritis, the myometrium is hypoechogenic because of presence of oedema. The presence of an abundant quantity of anechoic fluid with areas of diffuse hyperechogenicity suggests pyometra.

Finally, metritis with hyperechoic uterine content correspond to chronic processes caused either by evolution of a pyometra or by foetal death and mummification. In the latter, it is possible to observe the foetal bones as very hyperechogenic structures inside the hyperechogenic content of the uterus. In foetal maceration, it is possible to observe decreases of the echogenicity in areas of the foetal body.

Obstetrical problems

Ultrasonographic examination is of particular value, when trans-abdominal ballotment suggests the presence of a foetus in utero after delivery of lamb(s) some 12–48 h previously, but contraction of the cervix prevents further manual examination of the uterus. This situation may be compounded when the number of lambs delivered is less than the foetal number determined during a mid-pregnancy examination. It can prove difficult to differentiate the contracted uterus from a uterine horn containing a single lamb by trans-abdominal ballotment alone, but this problem can be easily resolved by ultrasonographic examination of the caudal abdomen. Ultrasonography has been used to monitor uterine involution post-partum, which was delayed in ewes after manual correction of dystocia and caesarean section.

Uterine torsion is a problematic diagnosis in sheep, because vaginal examination is restricted by the narrow diametre of the reproductive tract and will not identify a torsion involving the body of the uterus cranial to the cervix. Recent work has described the application of trans-abdominal ultrasound examination of the uterine wall as close to the cervix as possible (ventral midline immediately cranial to the pelvic brim with the probe head directed vertically) as a non-invasive means of detecting uterine torsion in. Oedema of the uterine wall following torsion resulted in a doubling of the thickness from 5mm to over 10mm. While a 7.5MHz scanner was used in this investigation, a 5MHz linear scanner should provide diagnostic quality sonograms. The early recognition of this condition and delivery of the lambs by caesarean section should significantly improve the surgical outcome.

Vaginal prolapse may contain the dorsal vaginal wall, urinary bladder, uterine horn(s) or both urinary bladder and uterine horn(s). Urinary bladder is readily identified as an anechoic (black) area on the sonogram, usually greater than 10cm in diametre and compressed dorso-ventrally. A fold in the bladder wall, which presents as a hyperechoic (white) line, can often be visualized in the ventral one-third of the anechoic area. Sections through the tips of uterine horn(s) appear as anechoic circles measuring 3–5cm in diametre bordered by the hyperechoic uterine wall; caruncles are not usually observed.

Scrotal contents

Sequential examination of the pampiniform plexus,the head of the epididymis, the testis and the tail of the epididymis is undertaken, as the linear array scan ner is moved distally over the lateral aspect of the scrotum. The pampiniform plexus is clearly visible as a collection of thin walled vessels (anechoic cylinders and circles bordered by hyperechoic walls). The normal testis appears as a uniform hypoechoic area with a Hyperechoic mediastinum clearly visible. The tail of the epididymis is distinct from the testis and considerably smaller in diametre (2–3cm compared to 6–7 cm) with an obvious capsule. The testis is much reduced in size (normal: >7cm in diametre, frequently 5cm for atrophy cases) and appears more hypoechoic than normal and contains many hyperechoic dots. These hyperechoic dots are thought to represent the fibrous supporting architecture, now more obvious due to atrophy of the seminiferous tubules. Ultrasonography was reported to be useful for the diagnosis of intra-scrotal abnormalities after experimental inoculation with Arcanobacterium pyogenes into the testicle, especially during investigation of the long-standing stage of the disease after clinical findings had subsided. Epididymitis caused by Brucella ovis or Actinobacillus seminis/Histophilus ovis is a major cause of ram infertility in many countries. Ultrasonographic examination in rams with epididymitis reveals a normal pampiniform plexus.

Typically, the swollen scrotal contents frequently appear as multiple 1–5cm diametre anechoic areas, containing many bright spots surrounded by broad hyperechoic lines (fibrous capsule), which extend up to 1cm in thickness typical of thick-walled abscesses. The abscesses generally involve the tail of the epididymis, but may extend to involve the body and head of the epididymis, respectively. The testis is embedded within fibrous tissue reaction and is much reduced in size and appears more hypoechoic than normal and contains many hyperechoic spots consistent with testicular atrophy (Karaca *et al.,* 1999). In unilateral epididymitis, the contralateral testicle is much smaller than normal and appears more hypoechoic.

Conclusion

Ultrasonography is a rapidly advancing technology and belongs to the most commonly used imaging systems in clinical practice, as well as in experimental investigations. However, except for pregnancy diagnosis, its use in small ruminant clinical practice is still limited, despite its great potential for diagnosis of various physiological and pathological conditions. This is due to un availability of trained persons and economic reasons. Ultrasound techniques are becoming increasingly important in animal reproduction, offering both a mean of diagnosis and a useful therapeutic tool. Accordingly, understanding the use of ultrasound technology is critical in contemporary animal sciences, since ultrasound examinations are now a routine component of diagnostic workups in reproduction. Ultrasound technology offers the assessment of pregnancy status and foetal viability early post breeding in order to identify animals that fail to conceive, improving reproductive efficiency; early identification of animals carrying twin foetuses, allowing for the, implementation of differential management strategies to avoid the negative effects of twinning on general health of the mother animal and also at parturition; and the visualisation of ovarian and uterine pathologies and allowing appropriate therapies to be implemented. In addition, determination of foetal sex in utero can be done by ultrasonography. The new information that has been generated through ultrasound has thrown light on therapeutic uses, thereby opening up new areas for research.

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REPRODUCTIVE ULTRASONOGRAPHY IN SMALL ANIMALS

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Ultrasonographic evaluation of the reproductive tract is an important component in the evaluation of the bitch and queen. Information is obtained concerning normal events involving the reproductive system (eg, ovulation, pregnancy) as well as pathologic conditions (eg, ovarian cysts, metritis). The appearance of the female reproductive tract normally changes with phases of the cycle; these changes need to be interpreted with knowledge of the ovarian cycle. Serial ultrasonographic evaluation of the diseased reproductive tract can be very helpful in evaluating response to therapy.

Transducer with 5-7.5 MHz frequency is adequate for most dog breeds while for large and giant breeds, 3.5 MHz transducer is ideal. 5.0 MHz transducer is commonly used for diagnosis of mid to late term pregnancy. Ultrasonography is usually performed in dorsal or lateral recumbency. Preparation of the site includes clipping of hairs and applying acoustic coupling gel to avoid air interference.

Diagnosis of Pregnancy

The uterine implantation vesicles, gestational sacs or embryonic yolk sacs can be imaged as early as 17 to 18 days after ovulation, and thus 18 to 19 days after the LH surge. The vesicles at this time appear as spherical anechoic structures within the lumen of the uterus. They are frequently 1 to 2 mm in diameter when first detected and tend to increase in size at a specific rate.

The embryo has a bipolar shape by day 28 of pregnancy and head region is identifiable as containing an anechoic area by day 30. An external transducer placed on the abdominal wall adjacent to the mammary glands, detects foetal heart sound as early as 29 days of gestation. The limb buds are usually identifiable from day 32 to 34 of pregnancy. The crown-rump length of the embryo remains less than the length of the placental girdle until at least day 36. The foetal skeleton is evident by day 34 of pregnancy, and thereafter, foetal bones appear hyperechoic and cast acoustic shadows. The bones of the head appear first, followed by other axial and appendicular skeleton. At this stage, the hyperechoic heart valves can be imaged and are seen to be moving. The great vessels can be traced cranially and caudally. In general, from day 38 to 40 onwards, the trunk diameter exceeds to that of the head. The skeleton becomes more obvious in late pregnancy and the skull, spinal column and ribs are easily identifiable. In last 20 days of pregnancy, kidneys can be imaged and it is more echogenic than observed in the adult animal. In late pregnancy, the intestines may be detected between 57-63 days. In cross section view, the vertebrae appear as hyperechoic elements dorsal to the aorta. Liver and stomach can be identified as echogenic and anechoic elements respectively.

Estimation of Gestational Age

The timing of the first ultrasonographic appearance of certain organs may be even more useful for the estimation of gestational age and prediction of parturition. For example, the kidneys are only visible within the last 20 days of gestation when imaged using 5.0 MHz transducer and the first abdominal organ to be developed is stomach which is around 33 days and then bladder around 34 days.

➢ For pregnancy < 40 days: GA = (6 x GSD or ICC) + 20

Where GA = Gestational Age, GSD = Gestational sac diameter and ICC = Inner chorionic cavity diameter.

➢ For pregnancy > 40 days: GA = (15 x BPD or HD) + 20

Where, HD = head diameter and BPD = biparietal diameter.

The gestational age of the embryos determined at the time of an ultrasound examination conducted to confirm or diagnose pregnancy, typically performed 4 to 5 weeks after mating, can be estimated by measuring 3 or more of the following parameters for 2 or more foetuses:

- Gestational sac (or chorionic cavity) diameter in early pregnancy
- Crown-rump length
- Body (abdominal) diameter at the level of liver and stomach
- Biparietal diameter after mid-gestation

Between days 20 to 37 and 38 to 60 chorionic cavity (or gestational sac) diameter and head (bi-parietal) diameter are the best predictors of gestational age, respectively.

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INTRODUCTION TO APPLICATION OF COLOUR DOPPLER ULTRASONOGRAPHY IN INFERTILITY DIAGNOSTICS

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The blood supply to any organ is closely related to the function of that organ and reproductive tract is no exception. Consequently, assessment of blood flow characteristics is an important evaluation parameter of reproductive function.

Basic principles of Doppler ultrasonography

Qualitative assessment of blood flow in capillary networks draining reproductive organs can be carried out non-invasively by colour Doppler imaging ultrasonography and the quantitative parameters of blood flow can be assessed by pulsed/spectral Doppler ultrasonography (Ginther 2007). Blood flow to the organ is displayed in colour superimposed on a two-dimensional, gray-scale ultrasonographic image (colour Doppler) or as a graph depicting pulsed Doppler-spectral analysis of blood velocity in a small area of a large blood vessel (spectral Doppler).

Transducer should be placed as close as possible to the ovary and colour blood flow mapping of the ovarian structures is conducted in various transverse sections. In the ultrasound equipment, activation of the colour Doppler mode enable the examiner to identify the blood flow as coloured signals on the ovaries, tubular genitalia and the blood vessels in the adjacent region like middle uterine arteries, ovarian arteries etc.,. The colour mode determined the direction of blood flow and the blood flow area within the structure. Basically the Doppler signals are viewed in a range from red to blue colour. The variations in colour signals do not represent the arteries and veins, but it represents the direction of blood flow.

- **When the blood flow towards the probe, it appears as red to orange in colour**
- **When the blood flows away from the probe, it appears as blue in colour.**

Since the uterine (mesometrial, endometrial and myometrial) and ovarian (mesovarium, luteal and follicular) arteries have a tortuous anatomy, blood flow usually appears as red and blue colour adjacent to each other. The arteries and veins can be differentiated based on spectral Doppler study. Normally the arteries will be evincing pulsations but the veins are devoid of pulsation.

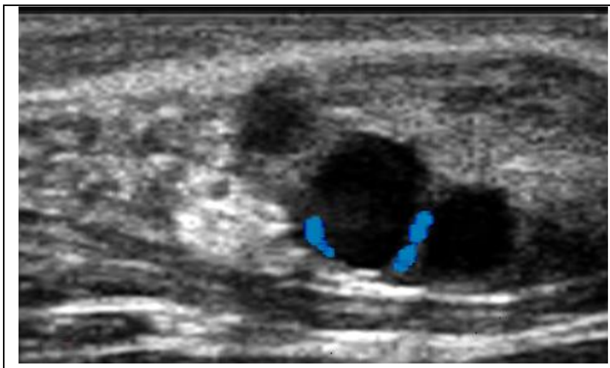
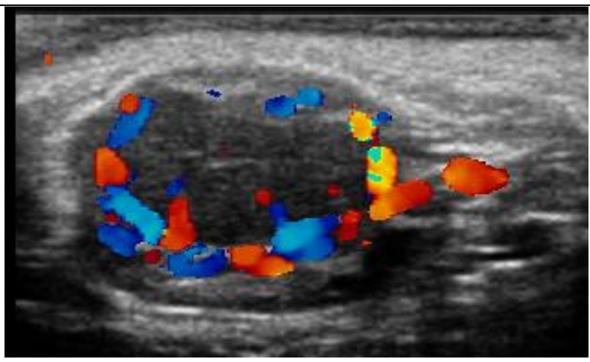
Blood flow parameters

Switching over to pulsed wave spectral Doppler mode, the Doppler gate is positioned over the blood vessel and a spectral mode waveform is taken for calculating an array of velocimetric indices recorded during the systolic and diastolic stages of the cardiac cycle. In the spectral mode, blood flow velocity variations are represented as a graphic wave form called spectrum (Fig.23). By convection, wave forms above and under the baseline indicate the red blood cells moving toward and away from the transducer, respectively. The spectrum provides peak systolic (PSV), end diastolic (EDV) and time-average maximum (TAMV) velocities in m / sec or cm / sec (Ferreira et al. 2011). Doppler pulse duration (DPD) can be recorded by measuring the linear distance between two subsequent EDV points and is expressed in milli seconds – ms.

- ***PSV is the maximum point along the length of the spectrum.***
- ***EDV is the ending point of the cardiac cycle.***
- ***TAMV is the average of an espectral maximum blood flow velocities.***
- ***DPD is the duration of a cardiac cycle and is indirectly proportional to the pulse frequency***

Apart from these velocity and duration indices, Doppler device automatically calculates pulsatility index (PI) and resistance index (RI) based on inbuilt formulation. These indices have negative correlation with the vascular perfusion of the tissue downstream from the sample gate and indicate the resistance to the blood flow. A PI and RI value of < 1 usually reflects the decreased resistance and free flow of the blood supply to any organ**.**

Intensity of the follicular and luteal blood flow is graded by visual evaluation of the proportion of the peri-follicular and CL area filled with colour Doppler signals and are subjectively expressed as low, medium, high and very high.

	
Vascularity of ovulatory follicle	**Vascularity of corpus luteum**

Blood flow parameters in relation to ovulation

The blood flow not only determines the selection of OF, but it also have a definitive role on the ovulation. It is confirmed that the cascade of events induced by the LH surge in pre-ovulatory follicles was closely associated with a local increase in the peri-follicular blood flow, a functional adaptation that is important for the impending ovulation to occur.

- **The lesser DPD (< 929 ms) and PI (< 1) values on the day of oestrus are positive indicators of normal ovulation process and any deviations in these blood flow parameters delayed the timing of ovulation.**

This finding is a valuable diagnostic parameter and is an important consideration for future studies involving regulation of follicular vasodilation to hasten the ovulation process in cattle.

Blood flow parameters in relation to anoestrum

Blood flow in OA is related to the vascularity of intra-ovarian arteries and the ovarian follicles. The PI, RI and DPD indices of the OA ipsilateral to the ovary having the largest follicle were higher in anoestrus than in oestrus group of animals (Satheshkumar et al. 2017). Thus, increased flow resistance (indicated by high PI and RI) and slow pulsation (indicated by high DPD) of the blood flow in OA of anoestrus animals are the major factors affecting the vascular perfusion of follicles. Thus, altered blood flow parameters of OA are proved to be a predisposing factor for deficient follicular development and maturation in anoestrus cattle.

Blood flow parameters in relation to cystic degeneration

Doppler signals of blood flow were less in walls of persistent follicles than in normal DFs. As described earlier, there will be variation in the wall thickness between the follicular and luteal cyst. The Doppler technology shows the blood flow in the wall, and the area of the blood flow therefore gives a clearer view of the thickness of the wall.

INTRODUCTION TO APPLICATION OF X-RAY DIAGNOSTICS IN SMALL ANIMAL REPRODUCTION

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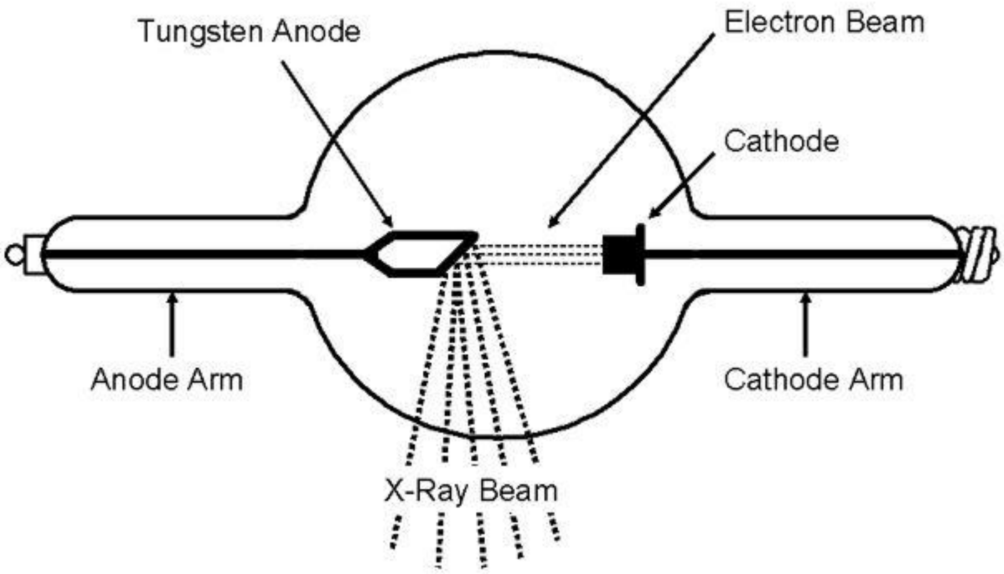
Radiography is the art and science of using radiation to obtain images of body parts with special emphasis to diagnose physiological or pathological condition. Radiography includes diagnostic radiography as well as additional imaging modalities such as mammography, computed tomography, magnetic resonance imaging, PET-CT, PET-MRI, cardiac/vascular interventional radiology, nuclear medicine and radiation therapy. Radiography is considered as an indispensable diagnostic tool of modern medicine. Radiography is an imaging technique using X-rays , gamma rays or similar ionizing and non ionizing radiation to view the internal form of an object.



Discovery

X-rays were discovered by William Conrad Roentgen on November 8, 1895.

Steps involved

Beam of X-rays produced by the X-ray machine is passed through the body

↓

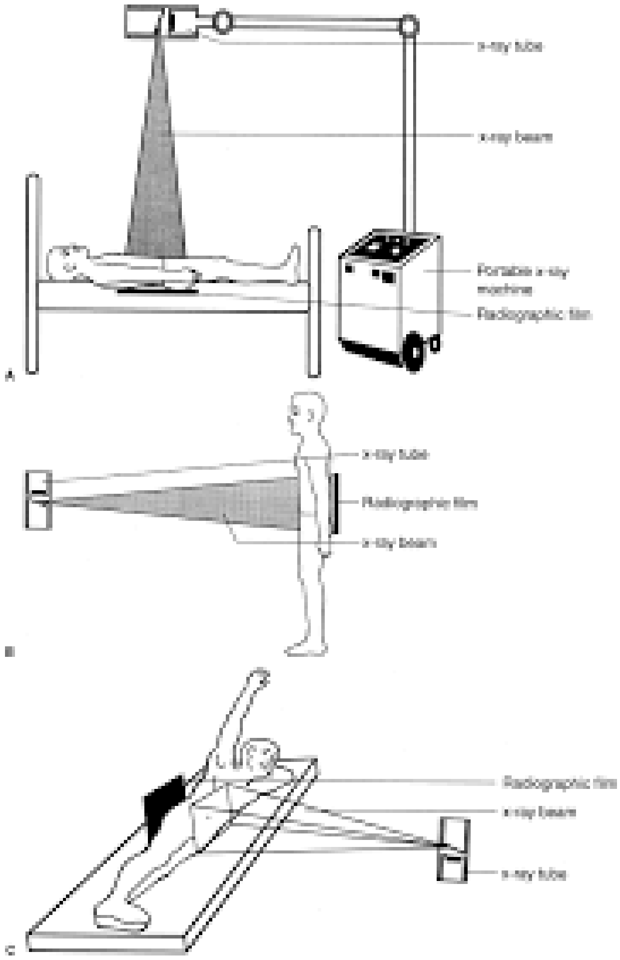
Certain amount of X-rays is absorbed by the body parts

(Depending on the density and structural composition)

↓

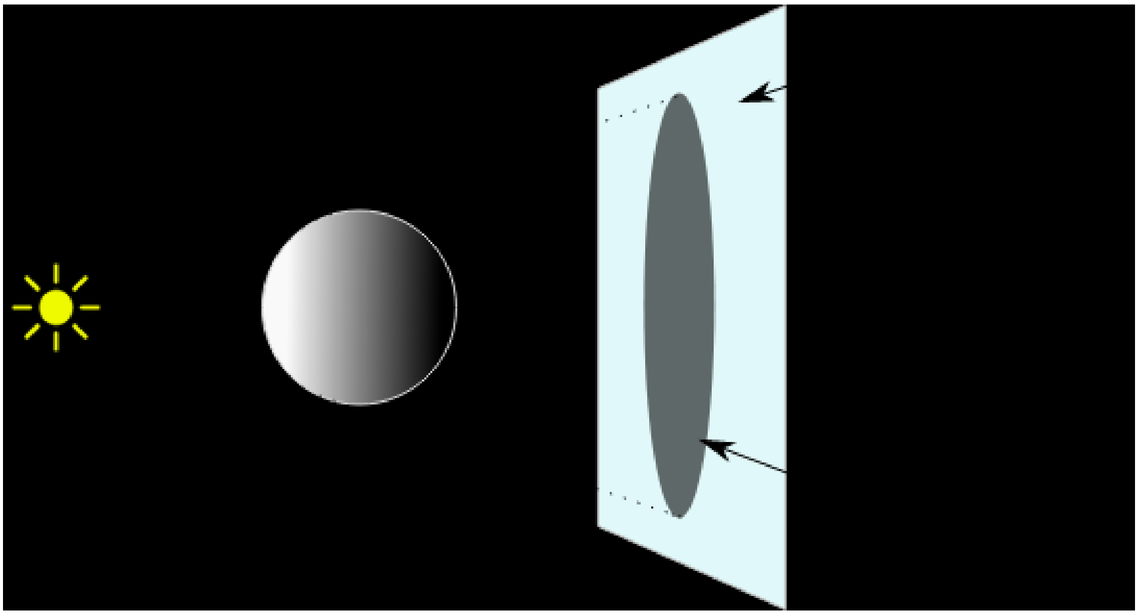
X-rays coming out through the body or captured behind the object

(By a detector photographic film or a digital detector)

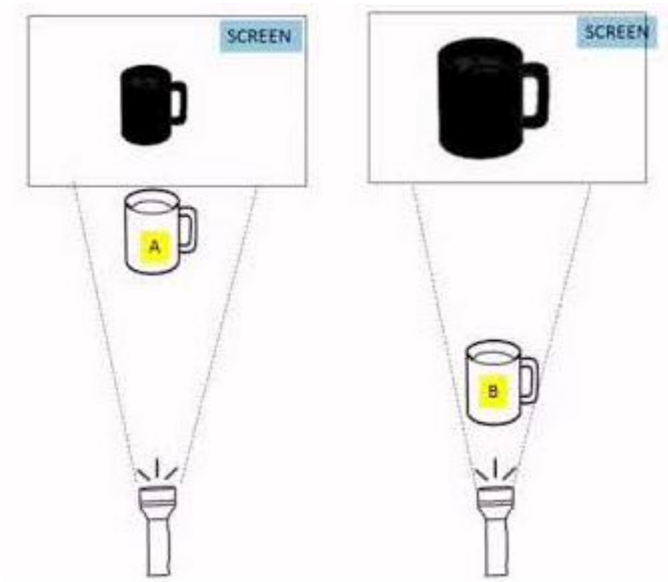


Projectional Radiography

Generation of a two dimensional 2D images of a three-dimensional 3D body parts



Part Film Distance and Magnification Illustration



Computed Tomography (CT)

X-ray source and its associated detectors rotate around the moving subject/patient and x-ray beam reaching the detectors are computed and further processed to produce a three-dimensional image. Previously known as CAT scan, “A” standing for “Axial”. “Tomo” meaning “slice”, CT images look like as though the patient was sliced like bread.

Fluoroscopy

Visualization of fluorescence caused by X-rays . The technique provides moving projection radiography. Fluoroscopy is mainly performed to view movement of object studied. Biplanar fluoroscopy displays two planes at the same time.

Angiography

Use of fluoroscopy to view the cardiovascular system wherein iodine based contrast is injected into the bloodstream and watched as it travels around.

Contrast Radiography

Radiographic technique wherein a radio contrast agent is administered to make the structures of interest stand out visually from their background.

Positron Emission Tomography (PET Scan)

Functional imaging technique that uses radioactive substances known as radiotracers to visualize and measure changes in metabolic processes of the body part studied.

Goal of radiography

To attain high quality radiographic image that yield maximum diagnostic information

Decisive Factors

Positioning and amount of radiation are the two major factors that determine the quality of diagnostic image.

Radiographic Factors

Technical quality of radiograph is determined by kVp, mA and time

kVp Determine the power and strength of X-Ray exposure (Quality of the X-rays).

mAs Determine the number of X-Ray photons produced by the X-ray tube (Quantity of X-rays).

Time Determine How long the exposure lasts.

kVp controls the penetrating strength of the X-ray beam. Beam quality controls the amount of contrast.

An increase of two kVp for every additional cm of tissue thickness is required to ensure adequate penetration of X rays.

15% increase in kVp is roughly equivalent to doubling the mAs

15% decrease in kVp is roughly equal to cutting the mAs to half

Higher kVp settings produce more scattered radiation and reduce the image details and increase patient dose.

Radiographic contrast is defined as the overall differences in optical densities seen in the radiographic image. Radiographic contrast enables to see / find details within the image clearly.

High contrast indicates white and black areas on the film with very few Greys in between (Short scale of contrast or narrow contrast latitude).

Low contrast indicates numerous shades of greys ranging from very light to very dark (Long scale of contrast or wide contrast latitude).

Time directly affects the density an exposure. Time of 10 milliseconds or less is recommended. Shortest exposure time in combination with the highest mA should be used for exposures to reduce the motion artifacts.

Modified Sante's Rule

kVp = (Measured thickness in cm x 2) + 40

Underexposed film - Increase kVp by 10% or double the exposure time.

Skeleton is optimally viewed using a low kVp technique. Thorax is studied using a high kVp technique. Tissue thickness should be measured at twelfth rib.

Application of X-ray in small animal reproduction

Although the fetal skeleton begins to calcify as early as day 28, it is not detectable by routine radiography until approximately day 42–45 and is quite prominent by day 47–48. Radiography at this time is not teratogenic. Late gestational radiography (>55 days) is the best method to determine litter size.

Foetal dentition becomes visible at term, and its appearance can be used to confirm fetal development adequate for an elective cesarean section when ovulation timing is not available and breeding dates are vague or spread over many days.

HANDLING X-RAY EQUIPMENT AND ACCESSORIES AND INTERPRETATION OF RADIOGRAPHIC IMAGES

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Radiography are the main basic diagnostic technique for diagnosing various diseases and disorders. Conventional radiography, Computerized and digital radiography are being used in veterinary Practice.

Electrical components of X-ray machine.

Filament in the cathode

High voltage Circuit

Two transformers: Autotransformer and Step-up transformer

Low Voltage circuit called as filament circuit.

Timer Switch

Three phase generator

Control panel /Console

Control panel /Console

It is separated unit connected electrically to the X-ray machine. It contains meters and switches to select kVp, mA and exposure time. The control panel vary with the type of X-ray machine but most often following components are present,

1. On/Off
2. Voltage Compensator
3. Kilo Voltage Selector
4. Milli Ampherage Selector
5. timer and
6. Exposure Buttons.

Collimotor

Restrictor device used to control the size of the primary X-ray beam. It serves to prevent unnecessary irradiation of the patient and to reduce scattered radiation.

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* Assistant Professor and Head ** Assistant Professor

Tube stand

Holds the X-ray tube Apparatus supports X-ray tube. Tube stand should be durable and sturdy.

Types of X-ray apparatus:

1. Portable X-ray machines- Portable machines are equipped with small sized low weight transformer attached and maximum output varies from 70 – 110 KV & 15 – 35 mA .
2. Mobile X-ray machines – These machines have higher output than portable and have rotating anode with output of 90-125kV & 40-300mA.
3. Fixed X-ray machines - These units are installed in a room specially constructed for the purpose. Output of these machines vary from 120-200 KV & 300-1000 mA. These are ceiling fixed.

X – RAY ACCESSORIES:

a. Beam Collimator

Refers to the regulation of the X-ray beam by beam restricting devices to restrict it to the site of the part of the patient under examination. This process is called as collimation.

b. Grid

It is a device placed between the patient and the radiographic film that is designed to observe Non-image forming X-rays (Scatter radiations). Grid composed of alternating strips of lead and spacer material.

The grid may be placed on the top of the cassette, build in to the cassette or placed directly under the X-ray table between the patient and the cassette.

Most of the grids are used when the part thickness exceeds 10cm and mAs must be increased 2-4 times.

c. Air Gap Technique

It is an alternative method to the use of grid to control the quantity of scatter radiation It increses the distance between the patient and film upto 6-9 cm, thus reduces the quantity of scattered radiation interfering with the film.

d. Filters

The primary purpose of placing filter between X-ray tube and patient is to remove less energetic i.e. soft X-rays from primary beam which have no chance to reach the film. The filtered X-ray beam decreases the exposure dose of the patient and scatter radiation.

IMAGE RECEPTORS:

1. Cassette / Film Holder
2. Intensifying Screen
3. X-ray film
4. Film screen systems

1.Cassette

. The cassette front is made of radiolucent material of polycarbonate (backlite), aluminium, Magnesium and Carbon fibres (because there are radiolucent materials. A cassette sizes corresponds to available films sizes.

2. Intensifying screen:

A sheets of luminescent phosphor crystals bound together or mounted on a card board or plastic base. The intensifying screen interacts with the X-ray beam that has penetrated the patient and reach to the cassette and converts most of the radiant energy (95%) into visible light that has almost same information as original X-ray beam. The intensifying screen has four layer and thickness is about 0.4mm.

a. Base or support
b. Reflecting Layer
c. Phosphor layer
d. Protective layer

3. X- ray film:

The purpose of X-ray film is to provide a permanent record containing essential diagnostic information. X-ray film provides information not only for the present use but also for later evaluation.

Types of X-ray films: Two general categories of film used in diagnostic radiograph are screen and non-screen films.

RADIOGRAPHIC INTERPRETATION

Radiographic interpretation is based on the visualization and analysis of opacities on the radiograph. The radiopacity of various objects and tissues results in different radiopacity , and hence they can be differentiated .Radiopaque tissue/object results in whiter image; less radiopaque objects results in blacker image .

The radiopacity depends on :

1. *Atomic number*: higher the atomic number, more the radiopaque the tissue /object
2. *Physical opacity*: Air, fluid and soft tissue have approximately the same atomic number, but specific gravity of air is only 0.001 ,whereas that of fluid and soft tissue is

1.there fore air will appear black on the radiograph, compared with fluid and soft tissue, which appears more grey.

3. *Thickness:* The thicker the tissue, the grater the attenuation of x-rays and more white the image will be.

Basic tissue radiographic opacities:

1. ***Mineral opacity:***
   - Bone is composed primarily of calcium and phosphorus.
   - There is a normal variation in radiopacity within the same bone and between bones because of the difference in opacity

     Compact vs spongy bone

     Trabecular bone vs intertabecular spaces

     Cortical bone vs medullary canal
   - Disease bone may be more sclerotic or less (porotic)opaque than the normal bone.
2. ***Soft Tissue/Fluid opacity:***
   - Both soft tissue and fluids have the same radiopacity(heart, liver, spleen, urinary bladder)
   - Variation in volume ,thickness and degree of compactness of soft tissue creates a pattern of various densities on the radiograph.
3. ***Fat opacity:***
   - Fat is more lucent than the bone or soft tissue, but is more opaque than gas
   - Fat produces radiographic contrast for differentiation and visualization of many organs and structures in that fat surrounding an organ or structure will allow it to be delineated.
   - In immature and thin animals, the lack of fat results in poorer contrast in the radiograph.
4. ***Gas opacity:***
   - Gas is the most radiolucent material visible on the film. This lucency provide contrast to allow visualization of various structures, eg. heart and great vessels outlined against the air filled lungs in the chest.
5. ***Metal Opacity:***
   - This is the most opaque shadow seen on radiograph, and may be seen as

     Contrast agents: barium, water soluble iodine media

     Orthopedic implants

     Metallic foreign bodies

Artifacts, eg. metal on collar and lead chain.

6. ***Only these five radiographic opacities are visible on the radiograph***

There is some variation in opacity within groups for instances, a small cystic calculus (Mineral opacity) may be difficult to identify in the bladder full of urine(soft tissue opacity),but will be more readily apparent in pnemocystogram since it contrast with air(gas opacity) in the bladder.

In positive contrast cystograme the calculus will appear relatively radiolucent as it is less opaque than the iodine containing contrast medium(metal opacity)

Radiological Interpretation:

1. Viewing the radiograph
2. Three dimensional concept:
3. Routine assessment of radiographs:

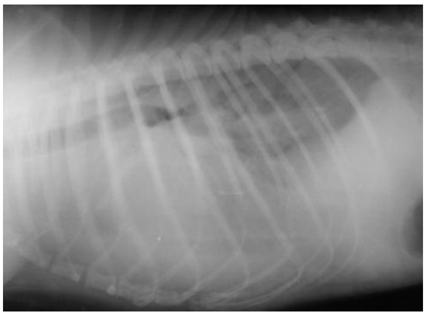
Evaluation of the radiograph:

Every shadows visible in the radiograph must be evaluated to:

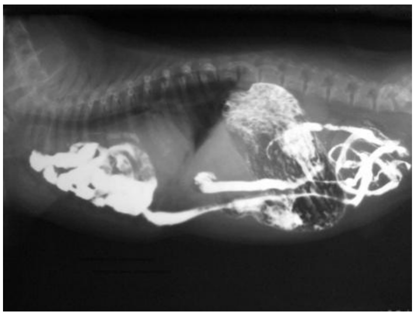
1. Determine whether an abnormality exists:
2. Define the anatomical location of the abnormality
3. Classify the abnormality according to roentgen signs
4. Make a list of differential diagnosis (gamut's) by considering what disease could cause the observed roentgen signs.

Description of radiological abnormalities to tissue /organ/objects (*Roentgen signs*):

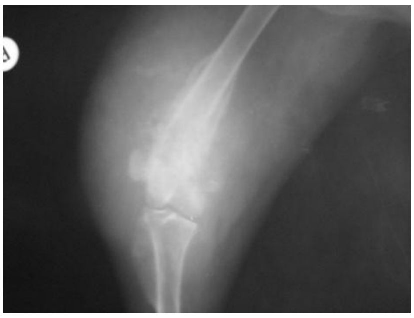
1. Change in size of an organ or structure
2. Variation in contour or shape
3. Variation in number of organs
4. Changes in position of an organ or structure
5. Alterations in the radiopacity
6. Alteration in the architecture pattern of an organ or structure
7. Alterations in the normal function of organ



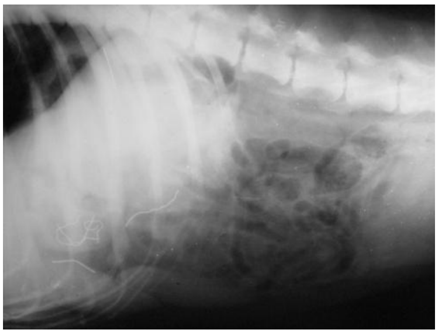
Plural effusion



Change in position



Osteosarcoma



Metallic foreign body

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