Ultrasonography of the Prostate Gland and Testes of the Dog

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INTRODUCTION

Ultrasonographic imaging is an important diagnostic tool because it allows assessment of the shape, size, position, margination and internal architecture of organs, as well as facilitating the study of vascular supply and vascularisation. There has been considerable development of B-mode, Doppler and contrast-enhanced ultrasound for examination of the reproductive tract of the dog, both for studying normal physiology and in the clinical setting. This article describes practical examination of the prostate gland and testes of the dog using a variety of ultrasound techniques and details the normal appearance and blood flow of these organ as well as changes that may be observed with common reproductive disorders.

IMAGING THE PROSTATE

Imaging the prostate can be achieved by placing the ultrasound transducer on the caudo-ventral abdomen, adjacent to the prepuce. Most dogs can be examined without sedation, being positioned either in dorsal or lateral recumbency, or in the standing position. A 7.5 to 10.0 MHz transducer is preferable and imaging is facilitated by the presence of urine within the bladder.

Imaging should always be undertaken in both the transverse and longitudinal plane, whilst the frontal (dorsal) plane is also useful. When the prostate lies entirely within the pelvis, trans-rectal imaging can be performed in large but not small dogs.

B-mode ultrasound

Normal prostate gland:

The prostate is an ovoid-shape bi-lobed gland positioned at the bladder neck which encircles the proximal urethra. The normal prostate is positioned within or immediately cranial to the pelvis and is bordered dorsally by the rectum. The gland is smoothly marginated and the parenchyma in entire dogs has a moderate homogenous echogenicity, with a fine to medium coarse echotexture (Fig 1 and 2). Prostatic size is often simply assessed by measurement of the maximum total prostatic width taken from images in the transverse plane (Fig 2) or by calculation of the prostatic volume using the formula for volume of an ellipse: Volume = length x width x height x 0.523.

Prostatic size varies significantly between dogs (Table 1). Importantly though, prostatic size is related to body mass (Fig 3a), although there is substantial variability, and prostatic size in normal dogs increases with age (Fig 3b).

It is often possible to image the prostatic urethra; in the transverse plane the mucosal and muscular components may be identified (in the conscious dog there is not normally urine within the urethra), although more commonly the urethra is recognised simply as a hypoechoic region between the two prostatic lobes (Fig 2).

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In normal castrated dogs, the prostate appears smaller compared with the entire dog (Table 1). After castration the prostatic parenchyma becomes more hypoechoic (Fig 4). The combination of reduced size and reduced echogenicity often make it difficult to differentiate the gland margins from the peri-prostatic fat. Prostatic size does not seem to relate to body mass in castrated dogs. It is noteworthy that castration is not protective of prostatic neoplasia and so imaging the prostate gland should be considered when clinical signs are appropriate.

Abnormal prostate gland:

It is important to recognise that many diseases of the prostate gland may produce a similar ultrasonographic appearance; further diagnostic tests including collection of prostatic fluid (by ejaculation or urethral lavage), urinalysis, haematology, fine-needle aspiration (which has a small risk of inducing tumour seeding) or prostatic biopsy, and further imaging for metastatic disease are often also warranted.

A common but non-specific finding is prostatomegaly, and whilst ultrasound may be useful for accurate measurement of prostatic size and calculation of prostatic volume, the substantial variation between dogs of similar sizes, and the additional effect of age may make this difficult to assess especially if changes are small and occur symmetrically. Asymmetrical enlargement is easier to detect and may also result in changes in outline / margination of the gland.

The prostate may succumb to both focal and diffuse parenchyma changes which may be hyperechoic, hypoechoic or of mixed echogencity. Again these changes are non-specific and will require further investigation that might include Doppler or contrast-enhanced

ultrasound imaging. Anechoic cystic structures which may be single or multiple, parenchymal and/or para-prostatic may occur in a number of different pathologies.

Benign prostatic hyperplasia:

Benign prostatic hyperplasia (BPH) is a spontaneous and age-related condition of intact male dogs and a common incidental finding in older dogs. BPH does not occur in dogs that are castrated and many changes seen in cases of BPH will regress in dogs following castration. In early cases there is commonly symmetrical enlargement of the gland, and usually an overall increase of echogenicity although this is often patchy and not homogenous in appearance (in many cases there are small 1 – 2 mm diameter anechoic cysts present). Usually the normal smooth outline of the prostate is maintained (Fig 5); however, if the enlargement is significant the gland may bulge outwards and lose its typical bi-lobed appearance. If the condition progress to a cystic form, the cysts appear as circular to irregular-shaped anechoic areas of variable sizes; commonly these are up to 2 or 3 cm in diameter. The cysts may increase in size with the progression and severity of the disease; sometimes the gland ultimately has honeycomb-like appearance.

Cysts

Prostatic cysts may be intra-prostatic of para-prostatic. Small intra-prostatic cystic lesions are frequently found in asymptomatic dogs and likely represent early changes associated with BPH (Fig 6). Dogs with clinical signs of BPH usually have multiple anechoic cysts up to 2 or 3 cm in diameter. In long-standing cases a small number of these cysts may become very large and protrude from the margin of the prostate gland. Such structures are described as prostatic retention cysts. The large size of these cysts

means that they may have a similar appearance to a true para-prostatic cyst (fluid distention of a remnant uterus masculinus; i.e. persistent Müllerian ducts), and can be difficult to differentiate, although the former is usually associated with other prostatic parenchymal changes typical of BPH, and in some cases the wide base of attachment / origin of the cyst from within the prostate can be detected (in true para-prostatic cysts the cyst is attached only by a thin stalk-like structure). Large prostatic retention cysts or para-prostatic cysts have fluid that is anechoic but may become more echogenic and have obvious sediment. It is not uncommon for internal septation of the cyst cavity to be noted and for the cyst wall to become calcified (these cases have a very similar appearance to a prostatic abscess). Calcification may be present but not evident on ultrasound examination.

Other cystic changes are seen in cases of chronic prostatitis and prostatic abscessation (see later).

Prostatitis:

In cases of acute prostatitis, the gland may be enlarged, with a symmetrical or asymmetrical outline. The parenchyma is usually heterogenous and in acute prostatitis has a hypoechoic appearance, which is followed in more chronic cases by patchy increased echogenicity (Fig 7), with focal echogenic regions.

In chronic cases that do not resolve, patchy hypoechoic areas may appear and with time coalesce as small fluid-filled micro-abscesses form; these are more irregularly

marginated than the cysts seen with BPH, and often contain particulate material or hypoechoic fluid. Abscess cavities may increase in size (Fig 8), and as a larger lumen forms may develop calcification of the abscess wall. Occasionally prostatic abscesses contain gas which appears as scattered hyperechoic foci associated with reverberation artefacts. There may also be a low volume local peritoneal effusion and mesenteric lymph node enlargement.

Neoplasia

Prostatic neoplasia has a variable B-mode ultrasonographic appearance in both entire and castrated dogs. Early cases of neoplasia are often focal hypoechoic lesions and can be difficult to differentiate from other pathology including the patchy appearance seen in cases of BPH. Later in the disease the parenchymal changes are often diffuse, the gland is not symmetrical and the gland margin becomes irregular. Frequently there is a markedly hyperechoic heterogenous parenchyma, with frequent irregular anechoic regions and zones of calcification creating acoustic shadowing (Fig 9). Neoplasia is often locally aggressive and medial iliac lymph node enlargement may be prominent in such advanced cases. Common metastatic sites are liver and spleen as well as lung and bone.

Doppler ultrasound

Doppler ultrasound techniques involve simultaneous use of gray-scale ultrasound and either colour Doppler or pulsed-wave (PW) Doppler. With colour Doppler, the direction of movement within specific regions of interest is displayed as a colour superimposed over the grey-scale image; this can be used to locate a vessel and to look at perfusion

within an organ. With PW Doppler, the velocity of flow is measured within a specific window and displayed graphically as velocity vs time. Whenever Doppler is used it is important to consider the angle of the ultrasound beam which should preferably be less than 60 degrees away from the direction of flow to ensure accuracy of velocity measurement. PW Doppler graphs display velocity of flow within arteries that can easily be interpreted as systole and diastole. By measurement of the velocity at the peak of systole (peak systolic velocity; PSV) and at the end of diastole (end diastolic velocity; EDV), the down-stream resistance and pulsatility can be calculated. Resistance index (RI) = (PSV - EDV) / PSV and pulsatility index (PI) = (PSV - EDV) / M (where M is the mean of PSV and EDV). Both are useful tools for investigating organ perfusion.

Normal prostatic arterial blood supply:

The two lobes of the dog's prostate gland each have an independent vascular supply. The prostatic artery has an anatomically variable origin, but commonly arises from the internal pudendal artery. For each lobe various vessels can be identified; (1) cranial, (2) dorsal and ventral sub-capsular (also called lateral by some authors), (3) caudal, and (4) parenchymal (Fig 10 and 11). Tortuosity of the prostatic veins results in blood flow only being detected in short segments of the relevant vein.

Colour Doppler ultrasound is useful for identification of the location of the prostatic arterial supply and vessels may be imaged in the transverse or longitudinal plane (Fig 10). Flow characteristics vary according to the region of the prostate artery. PW Doppler shows that the cranial (Fig 12) and caudal arteries have a high resistance to

flow with a biphasic pattern; a sharp narrow systolic peak and low antegrade diastolic flow, typical of many normal small arteries.

Prostatic parenchymal arteries have low velocities, with a monophasic flow pattern (Freitas and others, 2015) (Fig 12). Velocity decreases between the cranial prostatic artery and the parenchymal prostatic artery. In the normal gland RI and PI are low and differ between different regions of the artery (Table 2).

Abnormal prostatic arterial blood supply:

Measurement of prostatic artery blood flow using PW Doppler is a recent development in small animal reproduction and currently few studies have been published. Nevertheless, it is clear that dogs with BPH frequently show increased PSV and EDV compared with normal dogs (Fig 13). Interestingly, there does not appear to be any change of RI in dogs with BPH.

In cases of prostatic neoplasia, it may be possible to detect increased blood flow to the gland. However, microvascularization of prostatic tumours is better visualized by using colour and contrast-enhanced ultrasound (see below).

Whilst to date there are few studies detailing the relation between prostatic artery blood velocity measured using PW Doppler and disease, it is clear that colour-Doppler can be a particularly useful technique to highlight lesions within the prostate gland (Fig 14). In these cases increased vascularisation within a lesion can be readily detected, or there may be an increased vascular supply around a focal lesion. These changes may be useful for documenting the location of a lesion for ultrasound-guided fine needle aspiration or biopsy. Unfortunately there is currently no ability of colour-Doppler ultrasound to distinguish between benign and malignant focal lesions.

Contrast-enhanced ultrasound

Contrast-enhanced ultrasound (CEUS) is a relatively new technique whereby micro-bubbles (of high molecular weight and low water solubility gases) are injected intra-vascularly such that arterial supply, the vascular bed and venous drainage can be accurately imaged, generally using a low frequency transducer. Harmonic imaging technology is also helpful and this may not be available on all ultrasound machines. Commonly second generation contrast agents such as sulphur hexafluoride (SonoVue®) are used and must be matched by an ultrasound beam of appropriate frequency. Images can be directly observed and show vascular detail, or may be subject to quantitative analysis of specific regions of interest using commercial software, allowing assessment of peak flow, time to reach peak, persistence within the vascular bed, and time for complete clearance of the contrast media.

Contrast-enhanced ultrasound of the normal prostate gland:

After injection of the contrast agent there is opacification of the prostatic arteries that are clearly defined from the surrounding tissue. The sub-capsular (also called lateral) arteries can be imaged entering the dorso-lateral surface of the prostate and have a dorsal and ventral component. These arteries branch into many small parenchymal arteries, which have a diffuse symmetrical pattern directed medially towards the urethra (Fig 15). There is then increased echogencity/enhancement of the prostatic parenchyma during the vascular bed phase which is normally homogenous (Fig 16) except for the prostatic capsule which becomes more echogenic. Finally there is gradual clearance of the contrast from the parenchyma during the wash-out phase (Fig 17). Prostatic veins

are highlighted but of lower echogenicity compared to the arteries because persistence within the vascular bed results in a longer wash-out than wash-in period.

CEUS offers advantages over Doppler ultrasound in that prostatic artery branches and parenchymal perfusion are readily observed and with qualitative methods can be measured. Reliable data are available about the use of CEUS in normal anaesthetised dogs using standard protocols for administration of the contrast agent (Table 3) (Russo and others, 2009; Bigliardi and Ferrari, 2011; Vignoli and others, 2011) however more work is needed to document variations in perfusion kinetics and to establish more rapid protocols that can be applied to conscious dogs.

Contrast-enhanced ultrasound of the abnormal prostate gland:

A great opportunity for CEUS is its ability to document parenchymal perfusion that might be able to highlight focal lesions and possibly differentiate malignant from benign lesions.

Interestingly, prostatic tumours can indeed be detected with CEUS and there are trends in perfusion parameters between tumour types (Table 4). For example, PPI and TTP values are higher in prostatic carcinoma than in leiomyosarcoma. Also, different features during the wash-in and wash-out phase can be observed. For example, in cases of prostatic carcinoma, there is hyper-perfusion of the tumour during the wash-in phase and hypo-echogenicity during the wash-out phase, when compared to normal dogs. Leiomyosarcoma can be characterized in all phases by an homogenous anechoic non-perfused area with surrounding highly vascularized parenchyma (Fig 18).

IMAGING THE TESTES

Ultrasonographic examination of the testes allows the detection of focal and diffuse abnormalities of testicular tissue and it should be performed whenever there is a clinical concern of testicular pathology. It also may be used as a routine evaluation of male animals for infertility investigation, in breeding soundness evaluations and to locate testes that are not present within the scrotum. Ultrasound images can be achieved in the non-sedated dog in lateral recumbency or in the standing position. Clipping of the scrotal hair should be avoided as it is commonly followed by excessive licking and subsequent development of scrotal dermatitis. Instead, copious amounts of ultrasound gel should be used. The testes are imaged in the longitudinal, transverse and dorsal planes.

B-mode ultrasound

Ultrasound of normal testes:

The testicular parenchyma has a hypoechoic background texture overlaid by a homogenous medium echogenicity stippled appearance. The parietal and visceral tunics appear as a hyperechoic peripheral echogenic capsule. The mediastinum testis appears as a hyperechoic central line when imaged in the longitudinal plane and as a central circular focal echogenic 'spot' when imaged in the transverse plane (Fig 19). In pre-pubertal dogs, the echogenicity of the testes is more hypoechoic compared with adult dogs, and the mediastinum testis can be easily identified. Usually, no differences in echogenicity between the right and left testis is observed, however, differences in testicular volume between the right and left testis have been seen in some studies.

Testicular volume can be accurately calculated using the formula: Volume = length x width x height x 0.5236. Interestingly, a number of studies have demonstrated a positive association between testicular volume and dog body mass (Fig 20). Also a significant age-related trend of increasing testicular dimensions, which peak at 6 years of age and then subsequently decrease, has been observed (Mantziaras and others, 2014).

The epididymis can be identified as a circular and moderately hypoechoic structure, relative to testicular parenchyma running along the dorso-lateral aspect of the testis. The tail of the epididymis can be consistently visualised in the dorsal imaging plane caudal to the testis; it is less echogenic than testicular parenchyma (Fig 21). Measurements of epididymal diameter for all breeds range from 0.6 to 1.3 cm (mean 0.88 ± 0.20) for the tail; 0.4 to 0.8 cm (mean 0.67 ± 0.16) for the head, and 0.2 to 0.7 cm (mean 0.39 ± 0.17) for the body (Pugh et al., 1990).

Ultrasound in abnormal dogs:

Ultrasound may be used to investigate dogs with poor semen quality as well as for a wide variety of testicular abnormalities including neoplasia, inflammatory disease, testicular trauma and atrophy.

Relation between testicular appearance and semen quality in fertile dogs:

There are a small number of reports that document a positive correlation between testicular width and daily sperm output, and a positive correlation between total testicular volume and total sperm concentration in the ejaculate of normal dogs. However, dogs with abnormal semen quality may have testicular volumes within the

normal range. Nevertheless, changes in parenchymal appearance may be detected with ultrasound; dogs with poor semen quality have lower parenchymal echogenicity and lower homogeneity (i.e. more hypoechoic and less homogenous testes are found in dogs with poorer semen quality). Importantly though, azoospermic dogs do not always have changes in testicular volume or echogenicity.

Neoplasia:

Testicular tumours are the second most common tumour affecting the male dog. These tumours may be benign or malignant and may be endocrinologically active or not. Whilst B-mode ultrasound is exceptionally useful for the detection of testicular tumours (Fig 22), the ultrasonographic appearance of testicular tumours varies and is not specific to the tumour type. Testicular tumours can range from circumscribed small nodules to large complex masses with a heterogeneous echopattern and disruption of normal anatomy. Sertoli cell tumours and seminomas are usually large with mixed echogenicity; they may cause generalised testicular enlargement. Interstitial cell tumour may appear as well defined focal hypoechoic lesions. However, in all tumour types, areas of haemorrhage and necrosis may occur, which can be seen ultrasonographically as disorganised hyperechoic and hypoechoic regions. Other findings that can be associated with testicular neoplasia are areas of calcification within the testicular parenchyma that appear as hyperechoic foci producing acoustic shadowing.

Inflammatory disease:

Orchitis often occurs together with epididymitis in dogs. It may arise following haematogenous spread, bacterial colonisation (e.g. from urinary tract, or prostatic

inflammation) or scrotal trauma. In long standing cases abscess formation may occur. Ultrasonographically, inflammatory disorders may have variable characteristics, ranging from irregular often poorly defined anechoic areas to a diffuse patchy hypoechoic echopattern (Fig 23). Usually there is enlargement of the testis and epididymis, and fluid may accumulate between the visceral and parietal tunic within the scrotum.

Testicular degeneration:

Testicular degeneration (also called testicular atrophy or acquired gonadal dysfunction) is not uncommon although the cause is often unknown because the initiating testicular insult (e.g. raised scrotal temperature, exposure to toxins or endocrine disturbances) likely occurred many months previously. The condition is commonly bilateral but may be unilateral. Early in the disease, testes have focal or regional areas of increased echogenicity; often there are hyperechoic foci or significant hyperechoic lines that radiate outwards to the periphery of the testis (Fig 24). Later in the disease testes volume gradually decreases (often to half the normal volume for breed) and the parenchyma becomes hypoechoic.

Torsion of the spermatic cord:

Torsion of the spermatic cord (often called testicular torsion) commonly results in significant testicular enlargement and can be diagnosed by B-mode ultrasonography although Doppler ultrasonography is more specific, since the latter technique allows documentation of testicular artery blood flow. B-mode ultrasound is often used to clarify differential diagnosis of other causes of scrotal enlargement such as scrotal hernia. Early changes of testicular torsion include enlargement of the epididymis and

presence of hydrocoele, which is a non-specific finding and may be mistaken for epididymitis. Other findings include enlargement of the spermatic cord, testicular enlargement and decreased parenchymal echogenicity (Fig 25). In the sub-acute phase (within 10 days after the torsion) there may be more distinct signs including loss of normal architecture and mixed echogenicity of the affected testicle.

Abnormalities of the epididymis:

Epididymal lesions may be difficult to assess clinically however ultrasound evaluation allows the detection of lesions which cannot be palpated including those which occur as a result of inflammatory disease and spermatic cord torsion (see above). In both cases there are increased dimensions of the epididymis and changes in echogenicity. Fluid distended and enlarged epididymides may also occur in dogs that have been vasectomised (Fig 26).

Undescended testes:

Undescended testes have a similar ultrasonography appearance to normal testes although they are usually small and hypoechoic. A characteristic feature is the longitudinal mediastinum testes that has been previously described. Ultrasound examination may confirm the presence of undescended testes and document the precise location with high accuracy (Felumlee and others, 2012) as well as identifying torsion and neoplasia of abdominal testes (for further details of the diagnosis of these conditions see later).

Doppler ultrasound

The testis and epididymis are supplied with blood from the testicular artery. The arterial segment within the spermatic cord has a thicker wall and smaller lumen to allow for stretching; this section is often convoluted and is termed the supra-testicular artery (Fig 27A). The testicular artery that emerges from the spermatic cord has a thinner wall and larger lumen, and it extends through the epididymal margin of the testes, near the capsule, generally running with a linear course without any branches; this is termed the marginal artery (Fig 27B). The terminal segment penetrates the testicular parenchyma, and the intra-testicular arteries are directed toward the mediastinum (Fig 27C). Centripetal arteries within the testicular parenchyma and their recurrent rami may be identified using colour-Doppler ultrasound in oblique planes to the standard longitudinal and transverse planes.

Normal testicular arterial blood supply:

Characteristics of blood flow within the testicular artery assessed by PW Doppler ultrasound change depending upon the segment that is assessed (Fig 28). In the supra-testicular region, because of the tortuous characteristic of the artery in this region, two waveform patterns may be visualised. First, a biphasic waveform, with a diastolic notch followed by a diastolic peak; second a monophasic waveform, characterised by a slow systolic increase followed by a decreased diastolic flow. The other two regions (marginal and intra-testicular regions of the artery) have a low resistance flow with monophasic waveforms; this pattern is typically seen in arteries that irrigate parenchymal structures.

PW Doppler parameters (peak systolic velocity = PSV; end-diastolic velocity = EDV; resistance index = RI and pulsatility index = PI) show differences according to the

region of the artery that are measured. Higher velocities are present within the supra-testicular region, decreasing through marginal and intra-testicular regions. Also, these parameters are different between post-pubertal and pre-pubertal dogs (de Souza and others, 2015) and between dogs of different sizes (Souza and others, 2014). Interestingly, a relationship between PW Doppler measurements and semen quality may be observed; lower values of PSV (e.g. less than 14.0 cm/s) and higher values of RI and PI (e.g. greater than 0.66 and 1.00 respectively) are associated with poor semen quality (Zelli and others, 2013).

Abnormal testicular arterial blood supply:

There are only few descriptions of testicular blood flow in abnormal testes.
In cases of orchitis, testicular artery blood flow has been shown to increase, and this is associated with an increase of RI and PI within the testicular parenchyma. Colour-Doppler may demonstrate increased testicular parenchymal perfusion (Fig 29).

Torsion of the spermatic cord is most common in undescended testes often when there is testicular neoplasia, but may occur in young active males with scrotal testes. Doppler ultrasonography in these latter cases shows an absence of blood flow to and within the affected testis (Fig 30). In cases of incomplete torsion it may be possible to observe decreased rather than absent perfusion.

There is no information about testicular arterial flow in cases of testicular neoplasia, however with colour-Doppler an increase in blood flow is observed within and around most tumours (Fig 31). Whilst this is useful for tumour detection, the changes noted are not specific for tumour type.

Contrast-enhanced ultrasound

Reports on contrast-enhanced ultrasound to evaluate the testes are scarce. However, the possibilities of using this technique are promising. Contrast-enhanced ultrasonography is sensitive to changes in micro-vascularisation within the testes and therefore it allows exceptional visualisation of testicular lesions, and may provide potential for better classification of lesions than using B-mode and colour-Doppler ultrasound.

Contrast-enhanced ultrasound of the normal testis:

Contrast-enhanced ultrasound (CEUS) offers advantages over Doppler ultrasound in that testicular artery branches and parenchymal perfusion are readily observed and can be measured using qualitative methods.

After injection of the contrast agent there is opacification of the tortuous supra-testicular arteries followed by clear highlighting of the marginal arteries, and finally the intra-testicular arteries with flow directed towards the mediastinum testis. There is then increased echogenicity of the testicular parenchyma during the vascular bed phase followed by gradual clearance of the contrast from the parenchyma during the wash-out phase. Testicular veins are highlighted but are of lower echogenicity compared to the arteries because persistence within the vascular bed results in a longer wash-out than wash-in period.

There are reliable data about the use of CEUS in normal dogs using standard protocols for administration of the contrast agent (Volta and others, 2014), however limitations include the high costs of the contrast material and the need for specialised ultrasound equipment. Quantitative measurements for normal testes in anaesthetised dogs show a

wash-in phase of approximately 27 seconds, peak perfusion intensity of a mean of 16.6%, time to reach peak intensity of 35 seconds and a wash-out phase of 40 seconds. Further studies are needed to document variations in perfusion kinetics and to establish more rapid protocols that can be applied to conscious dogs.

Contrast-enhanced ultrasound of the abnormal testis:

Normal testes are characterised by a homogeneous moderately enhanced parenchyma during the rapid wash-in phase. Generally, non-neoplastic lesions (e.g. chronic orchitis, degeneration or atrophy) show a homogeneous pattern, with lower enhancement than non-pathological tissue. Neoplastic lesions (e.g. seminomas, Sertoli cell tumours) have a heterogenous appearance with a hyper-enhanced pattern and persistent inner vessels (Fig 32).

NEW TECHNIQUES

Recent work in man has documented that acoustic radiation force impulse elastography can be useful for the evaluation of the prostate gland and testes. With this method the velocity of propagation and attenuation of ultrasound waves are related to the rigidity and viscoelasticity of tissues, such that subtle changes in tissue properties which occur with some disease conditions may be detected. Recent work has established reference values for the prostate gland and testes of normal dogs (Feliciano and others 2015) but as yet no clinical diagnostic studies have been performed.

CONCLUSION

Although B-mode imaging of the prostate gland and testes of the dog has been undertaken clinically for more than 30 years, there has been substantial improvement in ultrasound equipment technology, and recent studies of arterial blood flow and vascularisation using Doppler and contrast-enhanced ultrasound have added to our knowledge base. There is no doubt that these advanced ultrasound techniques are now increasingly common as diagnostic tools for the investigation of prostatic and testicular disease of dogs.

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Table 1

Approximate prostatic size in entire and castrated dogs of different breeds.

Status	Median prostatic dimensions (range)		
	Length (cm)	Height (cm)	Width (cm)
Entire dogs	2.7 (1.6 – 3.9)	2.4 (0.8 – 3.2)	2.7 (1.2 – 3.6)
Castrated dogs	2.4 (2 – 5.5)	1.5 (1 – 3.5)	1.7 (1.2 – 4.2)

Adapted from Atalan and others (1999) who examined 60 entire and 17 neutered dogs of different breeds.

Table 2

Approximate Doppler ultrasound measures of normal prostatic blood flow, according to region of the artery.

Parameters	Cranial region	Sub-capsular region	Parenchymal region	Caudal region
PSV (cm/s)	25.5	22.0	15.5	23.5
EDV (cm/s)	4.3	6.2	6.7	4.2
RI	0.8	0.7	0.6	0.8
PI	2.5	1.5	0.9	2.3

PSV = peak systolic velocity; EDV = end diastolic velocity; RI = resistance index; PI = pulsatility index.
Adapted from Freitas and others (2015).

Table 3

Quantitative parameters of contrast-enhanced ultrasound for normal prostate perfusion in anaesthetised dogs.

Parameters	Normal range
Peak perfusion intensity (PPI) (%)	15.5 - 17.6
Time to reach peak intensity (TTP) (s)	29.9 - 37.5
Wash-in phase (s)	10 – 15

Adapted from Russo and others (2012).

Table 4

Perfusion values of qualitative contrast-enhanced prostatic ultrasound in benign and

malignant lesions.

Parameters	Benign lesions	Malignant lesions
Peak perfusion intensity-PPI (%)	14.2 - 16.9	14.1- 23.7
Time to reach peak intensity-TTP (s)	25.9 - 31.9	26.9 – 41.3

Adapted from Vignoli and others (2011) who examined 21 dogs with benign lesions
(including benign prostatic hyperplasia, mixed benign pathology and prostatitis) and 5
dogs with malignant lesions.

LEGENDS TO FIGURES

Figure 1

B-mode ultrasound image, longitudinal plane, of a normal prostate gland (arrow). Central hilar echogenic regions are prominent within a moderately echogenic parenchyma.

Figure 2

B-mode ultrasound image, transverse plane, of a normal prostate gland. Two symmetrical lobes (arrows) are separated by the urethral region, which appears as a hypoechoic area between the lobes. There is shadowing distal to the urethra. The dotted line shows measurement of total prostatic width.

Figure 3

The relationship between prostatic volume and weight (A) and prostatic volume and age (B) for 82 clinically normal entire dogs. Prostatic volume increases with age and bodyweight (unpublished).

Figure 4

B-mode ultrasound image, longitudinal plane, of prostate gland (arrows) in a neutered dog. The ellipsoidal-shaped prostate gland appears hypoechoic and is outlined by the thin but echogenic prostatic capsule.

Figure 5

B-mode ultrasound image, transverse plane, of a 3.5 year old German shepherd dog
with benign prostatic hyperplasia. Enlargement of the prostate gland (dotted line) is
present, there is a heterogenous appearance to the parenchyma, and the gland is more
rounded than normal but the smooth outline is maintained.

Figure 6

B-mode ultrasound image, transverse plane, of the prostate gland of a 6 year old golden
retriever, showing the presence of small anechoic structures (arrows) within the
prostatic parenchyma, characterized as clinically insignificant cysts.

Figure 7

B-mode ultrasound image, transverse plane, of an intact 5 year old mixed breed dog
with prostatitis. The prostate gland is irregularly outlined and has a faint hypoechoic rim
(arrow) which may be oedema or cellular infiltration. Overall the parenchyma has an
increased echogenicity with non homogeneous texture. There is an acoustic shadow
distal to the urethra.

Figure 8

B-mode ultrasound image, longitudinal plane, of a 7 year old Italian Bracco with
prostatic abscessation. The prostate is enlarged and misshapen, with irregularly shaped
cavities contain slightly echogenic fluid (arrows) that upon aspiration contained pus.

Figure 9

B-mode ultrasound image, longitudinal plane, of a 9 year old **neutered** Beagle with a prostatic adenocarcinoma. The prostate gland has an irregular margin and the parenchymal echotexture is heterogenous with scattered echogenic foci and irregular hypoechoic lesions.

Figure 10

Colour Doppler ultrasound image, longitudinal plane, of the prostate gland of an entire 5 year old male dog. Note the dorsal prostatic artery running close to the prostatic capsule.

Figure 11

Colour Doppler ultrasound images of the prostatic artery, showing the artery in the (A) cranial, (B) subcapsular, and (C) parenchymal (intra-prostatic) regions.

Figure 12

PW Doppler ultrasound images of the prostatic artery in the (A) cranial and (B) parenchymal (intra-prostatic) regions. Note differences in the waveform between regions of the artery.

Figure 13

PW Doppler ultrasound image of a 6 year old golden retriever dog with benign prostatic hyperplasia. Waveforms from the cranial prostatic artery show increased peak systolic velocity.

Figure 14

Colour Doppler ultrasound image of prostatic neoplasm showing an irregular increased vascularization of the entire gland.

Figure 15

B-mode ultrasound image, transverse plane (left) and corresponding contrast-enhanced ultrasound image (right) of a normal prostate gland. The contrast-enhanced image was taken early during the wash-in arterial phase at 8 seconds post contrast injection and shows the dorsal (large arrows) and ventral (small arrows) sub-capsular arterial supply.

Figure 16

B-mode ultrasound image, transverse plane (left) and corresponding contrast-enhanced ultrasound image (right) of a normal prostate gland. The contrast-enhanced image was taken 12 seconds post contrast injection and shows a homogeneous enhancement throughout the prostatic parenchyma. The dorsal and ventral sub-capsular arteries remain prominent (compare with Figure 15).

Figure 17

B-mode ultrasound image, transverse plane (left) and corresponding contrast-enhanced ultrasound image (right) of a normal prostate gland. The contrast-enhanced image was taken 31 seconds post contrast injection and shows the wash-out phase of the prostatic parenchyma and persistence of the contrast within urethral mucosa and submucosa.

Figure 18

Contrast-enhanced ultrasound image of a 6 year old Jack Russell Terrier dog with a final diagnosis of prostatic leiomyosarcoma. The image was taken late in the wash-in phase 33 seconds after contrast injection. A non-homogeneous enhancement is present showing as a hypoechoic lesion compared with surrounding tissue.

Figure 19

B-mode ultrasound image, longitudinal plane (A) and transverse plane (B) of a normal testis. Note the mediastinum testis appears as a hyperechoic line in the longitudinal plane and a small central hyperechoic region in the transverse plane.

Figure 20

The relationship between total testicular volume (TTV) measured with ultrasound and bodyweight for 86 normal dogs (unpublished).

Figure 21

B-mode ultrasound image, longitudinal plane, of a normal testis. The epididymal body runs alongside the dorsal surface of the testis (closed arrows) [appears ventral in this image because the transduced is placed on the ventral surface of the testis] and the hypoechoic epididymal tail is located caudally (open arrows)

Figure 22

B-mode ultrasound images of two different Leydig cell tumours.

Longitudinal plane (A) and transverse plane (B) images of a 7-year old Labrador testis, showing a circumscribed hypoechoic mass with two small anechoic regions. An acoustic shadow from the mediastinum testis is present in image B.

Longitudinal plane (C) and transverse plane (D) images of a 4-year old German shepherd dog testis, showing a well circumscribed mass with multiple anechoic cavities.

Figure 23

B-mode ultrasound image, longitudinal plane, of a 6-year old Rottweiler testis with orchitis. Note that there is a diffuse hypoechoic pattern evident predominantly within the testicular parenchyma in the near field. A thin hypochoic rime with is presumably fluid surrounds the testis.

Figure 24

B-mode ultrasound image, longitudinal plane (A) and transverse plane (B) of a 3-year old German shepherd dog with testicular degeneration showing gross distortion of testis architecture with echogenic lines radiating toward the mediastinum.

Figure 25

B-mode ultrasound image, longitudinal plane of a normal testis (A) and transverse plane of contralateral testis with torsion of the spermatic cord (B). Note the combination of decreased background echogenicity with scattered hyperechoic regions within the abnormal testis.

Figure 26

B-mode ultrasound image, longitudinal plane, of the testis and epididymis of a 6 year old vasectomized dog. The epididymis which runs along the border of the testis is enlarged and comprised of multiple tubular anechoic regions (arrows) representing the distended epididymal lumen.

Figure 27

Colour-Doppler ultrasound images of the testicular artery in the supra-testicular region (A), marginal region (B) and intra-testicular region (C).

Figure 28

PW Doppler ultrasound images of different regions of the testicular artery. Biphasic (A) and monophasic (B) waveform may be observed in the supra-testicular artery. Other

regions of the artery (C = marginal; D = intra-testicular) show a monophasic flow pattern.

Figure 29

Power-Doppler ultrasound image, longitudinal plane, of a dog with orchitis showing increased blood flow within the testicular parenchyma.

Figure 30

Colour-Doppler ultrasound image of a testis with normal vascular perfusion (A) and contralateral testis with torsion of the spermatic cord showing absence of perfusion (B).

Figure 31

Colour-Doppler ultrasound image, longitudinal plane, of a testis containing a focal neoplasm. There is increased blood flow within and around the tumour.

Figure 32

B-mode ultrasound image (A) and contrast-enhanced ultrasound image (B) of a dog with an interstitial cell tumour. There is a poorly demarcated focal lesion that is difficult to appreciate on the B-mode image but has a marked enhanced appearance after the injection of the contrast material.