

# Criteria for evaluation of kidneys by B-mode ultrasound in dogs and cats: A current state of knowledge

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### Summary

Ultrasound is an important part of the diagnostic management of patients with suspected kidney disease. Although it does not provide a measurable functional assessment of the kidney, it does provide a detailed assessment of its structure, which may reflect its function. Knowledge of the use of ultrasonography in the diagnosis of renal disease is growing, and new publications seek to make this examination more informative in diagnosing acute and chronic diseases of this organ. This review discusses selected criteria for the evaluation of the kidney on grey-scale (B-mode) ultrasound and presents the current knowledge in this field.

**Keywords:** ultrasound, kidney, dog, cat

The kidneys are paired, bean-shaped organs located retroperitoneally. They are the main organs of the urinary system, and their primary function is to produce urine as a product of blood filtration (34). To assess their function, urinalysis and analyses of serum biochemical parameters, including creatinine, urea, and phosphorus, are routinely performed. These are supplemented by diagnostic imaging, with ultrasound being the most widely used because it is safe, non-invasive, painless, and usually does not require the patient to be anaesthetized.

Although ultrasound provides a detailed assessment of renal architecture, it does not provide a measurable functional assessment and has variable specificity in diagnosing individual renal diseases (9, 10, 32). Nevertheless, knowledge about the potential of this technique to diagnose kidney disease is still growing. Recent publications seek to increase the informative value of this tool in the diagnosis of acute and chronic diseases of this organ. This review discusses selected criteria for the assessment of the kidney in grey scale (B-mode) ultrasound and presents the current knowledge in this field.

According to the guidelines for the standardization of abdominal ultrasound in dogs and cats issued in 2022 by the American College of Veterinary Radiology (ACVR) and the European Association of Veterinary Diagnostic Imaging (EAVDI), the examination of the kidneys should include the assessment of their length, shape, corticomedullary differentiation, both parenchymal layers (cortex and medulla), and the renal pelvis. In addition, local adipose tissue is routinely assessed. The guidelines pay little attention to the use of Doppler examination, noting only its potential utility in the assessment of infarct foci or other vascular lesions and in distinguishing a dilated ureter from a vessel (46).

### Kidney length

Size assessment is one of the primary components of ultrasonographic renal evaluation. Increased renal size has been associated with acute kidney injury (14) and neoplastic disease (51). It has also been described in feline infectious peritonitis (FIP) (27), leptospirosis (49), portosystemic shunts (19), and feline acromegaly (38). A reduction in size, on the other hand, usually

suggests degenerative disease, mostly associated with chronic conditions (9, 53).

However, the measurement must correspond to the largest segment of the kidney in the long axis (46) for the conclusion to be reliable. Oblique scans should be avoided, as they can lead to a false reduction in the length of the kidney. The organ can be measured in both dorsal and sagittal projections (3, 22). In dogs, assessing the length of the right kidney is more difficult due to the presence of intestinal gas and the more cranial position compared to the left kidney. The latter makes it sometimes necessary to assess the right kidney from the intercostal space (5).

Due to the high morphological variability of dogs, body weight must be considered for all kidney measurements (3). To standardize measurements, indices calculated as the ratio of renal length to aortic diameter (K/Ao) (40) or to the length of the fifth or sixth lumbar vertebrae (2) have been proposed. The first index has a rather wide range of normal values (5.5-9.1) compared to the more sensitive parameter using lumbar vertebral length (1.3-2.7). The latter index is an adaptation of a radiographic method described in the 1970s, which relates the length of the kidney to the length of the second lumbar vertebra (25). Of note is a recently published paper in which a parameter based on aortic diameter was determined for Whippet dogs, yielding a much narrower range of normal values (6.3-6.9), independent of the kidney studied and sex (16). Similar values characterize Miniature Schnauzer kidneys ( $6.75 \pm 0.67$ ) (48). The usefulness of the above index has also been tested on puppies of different breeds. The results obtained indicate that dogs less than 1 month old have relatively larger kidneys compared to older dogs (6, 12, 18 months) when their length is related to aortic diameter and body weight. However, the reproducibility of this measurement in this age group of dogs was negated (31).

Absolute measurements of kidney length may be more reliable in cats because of their less variable body conformation. Their normal kidney length is assumed to be around 3.0-4.5 cm, but can reach up to 5.3 cm (11, 20-22). Extreme values usually occur in very large breeds (Maine Coon, Highlander) and very small ones (Munchkin, Singapore Cat) (11). Larger kidneys are also found in males regardless of reproductive status (50).

Following the example of procedures developed for dogs, attempts have been made in recent years to establish more universal indices for ultrasound assessment of kidney size in cats. Among others, a reference to the length of the sixth lumbar vertebra (1.76-1.86) has been proposed. This index is independent of age, body weight, sex, and reproductive status (41). Another study demonstrated the usefulness of this marker in kittens and young cats (< 3 years of age) and found it to be the most valuable in assessing kidney length in

this species (11). In young, neutered cats (irrespective of sex), the kidney should be considered small if the value of the index is < 1.6 and enlarged for values > 2.3. A recent study showed that an index value based on the ratio of kidney length to aorta of less than 10.71 is an indicative parameter (80% sensitive and 80% specific) for chronic kidney disease (CKD) in cats. This ultrasonographic measurement has also been shown to better reflect the functional status of the kidney than the ratio of its length to the second lumbar vertebra on radiography (30).

### **Kidney shape**

The normal kidney has an oval or bean-shaped appearance with a smooth, even, and well-defined contour (17, 20, 42). The renal capsule is typically visible as a thin hyperechoic layer, outlining the organ. However, it may not be apparent at the poles where the renal surface is more parallel to the ultrasound beam (20).

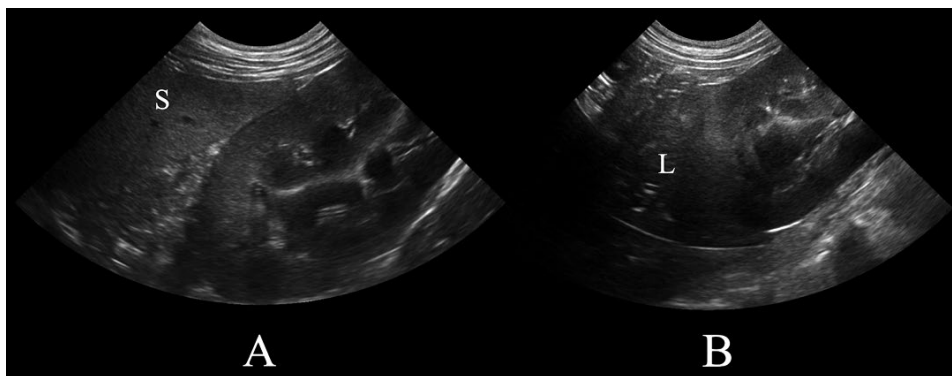
Changes in kidney shape or contour have been associated with congenital, inflammatory, neoplastic, and degenerative diseases (9). The recent study suggests that changes in kidney shape may indicate reduced renal function. The study demonstrated that changes in shape and contour had the highest specificity in detecting low glomerular filtration rate (GFR) in dogs, as calculated by scintigraphy (42). Changes ranged from mild, as a single contour indentation, to severe, where a bean shape could not be recognized because of severe bumps or indentations. The accentuation of the lobulation may be explained by cortical thinning due to scarring and fibrosis, which is especially common in end-stage kidney disease (9, 42).

Chronic renal infarction is a common incidental finding associated with capsule collapse and subsequent renal deformation. It is typically observed as a wedge-shaped hyperechoic area extending from the capsule to the cortico-medullary junction. Additionally, there may be some clinically irrelevant anatomical variations in kidney shape (9).

### **Echogenicity of the cortex**

Increased cortical echogenicity is a common sign of both chronic and acute kidney disease in dogs and cats (10, 14, 43). However, it is difficult to clearly define the boundary between normal and pathological images. This is influenced by the subjectivity and experience of the examiner, the settings of the ultrasound machine, and the inconsistency of results in the published literature (1, 29, 36, 52).

The echogenicity of the renal cortex is routinely compared with that of the spleen and liver parenchyma (Fig. 1), but this comparison assumes that the echogenicity of these organs is normal (1). For the echogenicity reference to be meaningful, the compared organ areas should be assessed at similar depths and with the same image adjustment. As the right kidney



**Fig. 1.** Quantitative comparison of the echogenicity of the kidney with the echogenicity of the spleen (A) and the liver (B)



**Fig. 2.** Scan of a kidney of a cat diagnosed with IRIS (International Renal Interest Society) grade III chronic kidney disease. Among other features of chronic kidney disease, the absence of the cortical anisotropy backscattering artifact (CABA) is notable; the echogenicity of the cortical layer at both poles of the kidney is similar to that of the cortical layer in other areas of the parenchyma

is recessed within the renal fossa of the caudate lobe of the liver, these two structures could be compared simultaneously. Similar observations apply to the relationship between the spleen and left kidney (17). Ivancić et al. (29) showed that the echogenicity of the renal cortex in healthy dogs can be higher than that of the liver. Another study, however, came to a different conclusion when it looked at Beagle dogs (36), in which the echogenicity of the renal cortex was lower than that of the liver. Similar observations were made by Drost et al. (23) in cats. Non-clinically relevant lipid accumulation in the renal tubular epithelium may occur in this species, resulting in increased echogenicity of the renal cortex (55). The echo intensity of the cortical layer may also be affected by the type of probe used (52).

Noteworthy is a recent work by Chou et al (13), who revisited the cortical anisotropic backscattering artefact (CABA) in cats in the context of assessing renal parenchymal echogenicity. As a result of anisotropy, the cortical layer at both poles of the kidney, where the renal tubules are perpendicular to the beam axis

of the transducer, has a higher echogenicity than in the central areas of the parenchyma, where the tubules are parallel (45). As a result of the overall increase in the echogenicity of the cortical layer, this artifact is absent in cats with chronic kidney disease (13). Its absence is a fairly sensitive (87.5%) and specific (88.9%) indicator of CKD in cats (Fig. 2). A recent paper also showed that CABA is present in more than 90% of healthy cats (54).

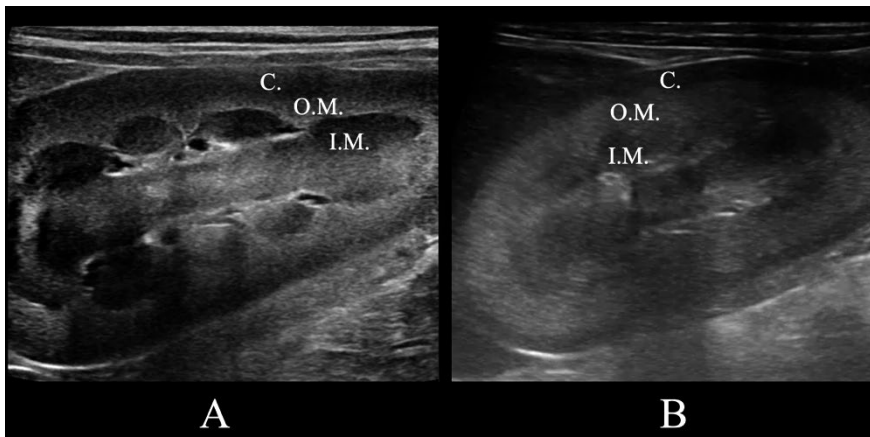
Selecting the cortical area with CABA for comparison, the echogenicity of the renal cortex in healthy cats was higher than that of the spleen, which in turn was higher than that of the liver (54).

Zotti et al. (56) proposed a quantitative assessment of renal cortical echogenicity using a mean grey value. The uselessness of this method in the diagnosis of canine renal inflammation and degeneration has been demonstrated. On the other hand, a positive linear relationship was found between the echogenicity of feline kidneys and the intensity of both inflammatory and degenerative changes. However, that method is not routinely used in daily clinical practice.

### Corticomedullary differentiation

As effacement or loss of the corticomedullary junction is a commonly described non-specific feature of renal disease, its assessment is an important part of renal evaluation (43, 47, 51). Under physiological conditions, the cortex and medulla should be distinguishable. Compared to the medulla, the cortex is thought to be hyperechogenic (9).

Interestingly, Hart et al. (28) showed that the sonographic image of the renal cortex in dogs consists of both the cortical layer and the outer region of the renal medulla. In healthy dogs, the medullary layer can assume an echogenicity equal to or higher than that of the actual (externally located) renal cortex (Fig. 3A). This finding provides an excellent explanation for the kidney images of some miniature breed dogs (less frequently of larger breeds), in which the cortical layer on examination often shows a much lower echogenicity than that of the outer part of the medulla, which is hyperechoic (Fig. 3B). Recognized in most publications and used as the standard by practitioners, the corticomedullary boundary appears to correspond to the boundary between the inner and outer areas of the renal medulla, which is defined by the bases of the renal pyramids. A more reliable indicator of the corticomedullary junction could be the arcuate blood vessels (28, 53). However, imaging of these vessels may be influenced by various factors, such as the quality of the ultrasound machine, the type of the probe used,



**Fig. 3. Outer medulla in a dog kidney**

Explanations: A) Longitudinal scan of a canine kidney showing clearly distinguishable inner medullar (I.M.) and outer medulla (O.M.); C – cortex. B) Longitudinal scan of a kidney of a Chihuahua dog. In this anatomical variant, the outer region of the medulla (O.M.) has a much higher echogenicity than the cortex (C); I.M. – inner medulla

the pre-processing of the image, and the experience of the operator.

Considering the “new” boundary between cortex and medulla, a corticomedullary distinction scale has been proposed, divided into three grades: clear (1), ambiguous (2), and elusive (3). In dogs, the degree of distinction between the cortex and outer medulla is related to renal function, including the estimated glomerular filtration rate (eGFR) (37).

### Thickness of the cortex

In human ultrasound, it has been shown that variations in cortical thickness may be a better indicator of kidney disease than length. The renal cortex tends away from swelling in the acute state and towards thinning due to fibrosis in the chronic state (6, 33). Because of the above, new indices for the assessment of renal cortical thickness have been proposed in recent years.

In dogs, the thickness of the cortical layer (averaged from three measurements) in the long axis of the kidney should be divided by the diameter of the aorta just behind the exit of the left renal artery. The cortical measurement should be perpendicular to the renal capsule and represent the shortest distance between the capsule and the base of the renal pyramid. The normal value of the index in dogs is approximately 0.7 and is independent of body weight and the body condition score (BCS) (35). In a work by Choo et al. (12), the index described above was tested on dogs with kidney disease. Values were presented to distinguish between the chronic ( $< 0.6$ ) and acute ( $> 0.79$ ) nature of the disease (12). Importantly, it was also shown that the value of the index increases when chronic disease is exacerbated.

In cats, the absolute measurement of cortical thickness was the parameter best correlated with serum creatinine concentration (53). Absolute values were determined below which CKD may be suspected (left

kidney 4.7 mm, right kidney 4.5 mm). In the aforementioned publication, thickness was measured in the transverse section of the kidney at the level of the arcuate vessels (53). Indicators based on the cortical thickness may prove to be more sensitive than other previously known criteria for renal assessment.

It is important to note that the proposed measurement in dogs, according to Hart et al. (28), includes both the cortex and the outer medulla. This measurement is easy to perform because of the clear visibility of the pyramids of the kidneys. While the absolute measurement proposed in cats may be more sensitive to true changes in cortical thickness, it may be more difficult

to reproduce, as identifying the arcuate arteries can be challenging. Another commonly used index is based on a comparison of the thickness of the cortex and the medulla, using the base of the renal pyramids as the boundary. A 1 : 1 ratio of the renal layers is considered the correct value (43).

### Medulla

As ultrasound continues to evolve, new variations of renal imaging are being described, and the meaning of long-standing images is changing. This also applies to the medullary layer, where hyperechoic bands, first described in 2023 in cats, may be present (7). Microscopically, these bands correspond to foci of fibrosis in the renal medulla. Clinically, however, this sign has been associated with proteinuria and urinary tract inflammation, which may be a potential result of inflammation or renal tubular dysfunction. Interestingly, a similar image has previously been described in Cairn Terriers with preclinical renal dysplasia, but this was not characterized histologically at the time (47).

There is also a new approach to the medullary rim sign (MRS), a hyperechoic line in the renal medulla close to the corticomedullary junction that has been known for decades (8). MRS has been associated with a variety of pathological conditions, such as purulent granulomatous vasculitis in FIP, chronic interstitial nephritis, acute tubular necrosis of the kidney (ethylene glycol intoxication), hypercalcaemic nephropathy, and leptospirosis, although it has also been found in asymptomatic patients on clinical observation (4, 8, 26, 39, 55).

In recent years, two independent teams have revisited the medullary rim signs found in cat kidneys and reached similar conclusions (15, 24). A distinction was made between thin ( $< 2.5$  mm or about 1 mm) and thick ( $> 2.5$  mm or  $> 2$  mm) medullary rims. The

latter were referred to as a band sign. A thin rim (Fig. 4A) should be considered an incidental sign, not necessarily associated with any pathology. The second type (Fig. 4B), on the other hand, is more common in cats with renal disease (15) or with azotaemic kidney disease (24). In the context of FIP, with which this sign has been associated, it has been shown that the thick medullary rim can be a complementary sign when the disease is suspected.

### Renal pelvis

The examination should include an assessment of the renal pelvis for dilatation and abnormal contents. Normally, the pelvis is not visible, but when dilated, it appears as an anechoic fissure in the centre of the renal sinus (17). In the transverse plane, the lumen of a mildly dilated pelvis is referred to as Y-, V-, or crescent-shaped (17, 44). As the pelvis widens, its shape becomes more oval, and the pelvic recesses are accentuated.

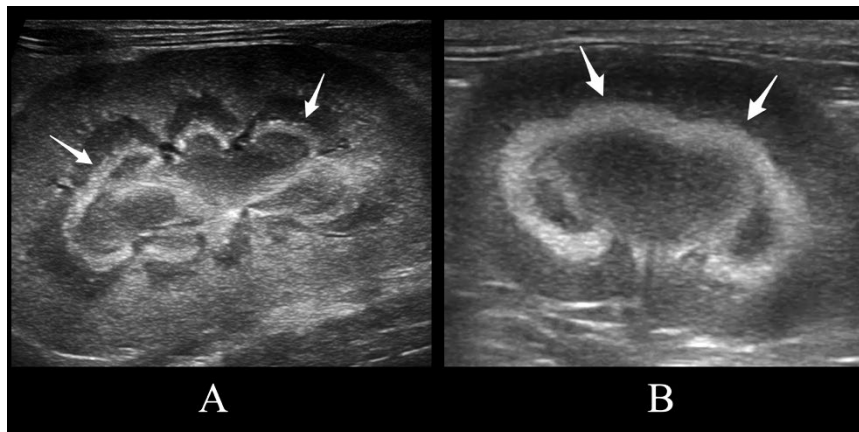
After identifying the dilatation, the measurement should be taken in a transverse plane at the widest point of the pelvis to avoid inclusion of the proximal ureter (46). This will minimize the possibility of oblique measurements.

Although renal pelvic dilatation is often associated with urinary tract disease in both dogs and cats, mild pelvic dilatation has also been observed in animals with normal renal function or with generalized disease leading to increased diuresis (18, 44). Therefore, in the scientific literature, pyelectasia is often considered to be present when the pelvic height exceeds 3 mm (43, 46).

Ultrasonography is a field of veterinary diagnostics that continues to evolve, and not only in terms of the development of technology and the use of new imaging techniques. In renal diagnostics, attempts are still being made to face questions about the relevance of basic ultrasound imaging methods. New knowledge makes it possible to use information provided by ultrasound imaging of the kidney more completely, although image interpretation still depends on history, clinical status, and laboratory findings. It is important to fully understand the potential and limitations of this imaging modality in the diagnosis of kidney disease. The development of understandable, easy-to-use, and maximally objective criteria for renal assessment can make reliable renal assessment feasible not only for experienced sonographers but also for physicians with less ultrasound experience.

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**Fig. 4. Different types of the medullary rim sign (arrows). Longitudinal scan of a feline kidney showing a thin medullary rim sign (A) and a thick medullary rim sign (medullary band sign) (B)**

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