Ultrasonography is becoming more available to small animal practitioners and is a valuable, non-invasive imaging modality with improved visualization and differentiation of soft tissue structures, compared with other imaging techniques such as radiography. Although abdominal ultrasonographic techniques and interpretation for canine and feline patients are well described, only a few reports describe the use of ultrasonography in reptiles. Compared with mammals, major anatomic differences of most reptiles include the lack of a diaaphragm, a 3-chambered heart, a renal portal system with or without a urinary bladder, and the presence of large fat bodies within the coelom. Additionally, there is substantial interspecies variability among reptile patients, which may complicate ultrasonographic examination and interpretation. A recent comparison of the CT and cadaveric anatomy of bearded dragons, green iguanas, and black and white tegus highlights this anatomic variability.

Bearded dragons (Pogona vitticeps) are among the most popular reptile companion animals in the United States, Europe, and Australia. Common health problems of bearded dragons include nutritional disorders, gastrointestinal impactions, parasitism, dystocia, and follicular stasis. Less commonly reported conditions include gastric neoplasia, hepatic neoplasia, renal failure, and viral infection. Ultrasonography is a valuable imaging modality to aid in the diagnosis of many of these conditions as well as to provide guidance for fine-needle aspiration of intracoelomic fluids or tissues. However, there are currently no published reports of studies describing the normal ultrasonographic appearance of the coelomic organs in this species.

The purposes of the study reported here were to determine which organs can be reliably visualized ultrasonographically in bearded dragons, describe their normal ultrasonographic appearance, and describe ultrasonographic techniques for use in this species.

**Objective**—To determine which organs can be reliably visualized ultrasonographically in bearded dragons (Pogona vitticeps), describe their normal ultrasonographic appearance, and describe an ultrasonographic technique for use with this species.

**Design**—Cross-sectional study.

**Animals**—14 healthy bearded dragons (6 females and 8 males).

**Procedures**—Bearded dragons were manually restrained in dorsal and sternal recumbency, and coelomic organs were evaluated by use of linear 7- to 15-MHz and microconvex 5- to 8-MHz transducers. Visibility, size, echogenicity, and ultrasound transducer position were assessed for each organ.

**Results**—Coelomic ultrasonography with both microconvex and linear ultrasound transducers allowed for visualization of the heart, pleural surface of the lungs, liver, caudal vena cava, aorta, ventral abdominal vein, gallbladder, fat bodies, gastric fundus, cecum, colon, cloaca, kidneys, and testes or ovaries in all animals. The pylorus was visualized in 12 of 14 animals. The small intestinal loops were visualized in 12 of 14 animals with the linear transducer, but could not be reliably identified with the microconvex transducer. The hemipenes were visualized in 7 of 8 males. The adrenal glands and spleen were not identified in any animal. Anechoic free coelomic fluid was present in 11 of 14 animals. Heart width, heart length, ventricular wall thickness, gastric fundus wall thickness, and height of the caudal poles of the kidneys were positively associated with body weight. Testis width was negatively associated with body weight in males.

**Conclusions and Clinical Relevance**—Results indicated coelomic ultrasonography is a potentially valuable imaging modality for assessment of most organs in bearded dragons and can be performed in unsedated animals. (J Am Vet Med Assoc 2015;246:868–876)
Ultrasonography—Coelomic ultrasonography of each bearded dragon was performed by 1 radiology resident (DSB). Imaging was completed immediately following echocardiographic examination for a separate study. Animals were manually restrained in dorsal recumbency for most of the examination, with the exception of sternal recumbency for a dorsal approach to the kidneys. A small amount of loosely applied nonadhesive compression bandage was placed around the front and hind limbs to minimize motion and facilitate ultrasonographic imaging. Chemical restraint was not used. All ultrasonographic examinations were performed by use of 1 ultrasound machine with a microconvex 5- to 8-MHz broadband array transducer as well as a 7- to 15-MHz compact linear array transducer. Sagittal and transverse still images of each coelomic organ were obtained as well as video capture of the coelomic structures. Visibility, echogenicity, margination, and size (length, width, and height) of each coelomic organ were recorded. Length, width, and height measurements were performed relative to the axis of the animal, such that length was the measurement from the most cranial to most caudal aspect, width was the measurement from the left edge to the right, and height was the measurement from the dorsal to the ventral limit. Measurements were made with electronic calipers at the maximal transverse and sagittal dimensions and were rounded to the nearest 10th of a millimeter. Measurements were not obtained if the measurement of interest could not fit within a single ultrasonographic image. For the stomach and small intestine, the transducer was oriented along the short axis of the organ to allow for accurate measurements of lumen and wall thickness. Wall thickness measurements for the heart and gastrointestinal structures were taken in the dorsoventral direction, at the midportion of the organ. Diameter was measured for vascular structures. Ultrasound transducer location on the subject was noted for each organ and recorded on a body map.

CT—Two bearded dragons (a male and a female) underwent non–contrast-enhanced whole-body CT examination for correlation with ultrasonographic findings to more accurately locate and identify coelomic organs. A publication describing the anatomy of coelomic structures on CT in bearded dragons was used as a reference. The animals were imaged in sternal recumbency without the use of chemical restraint. Gentle pressure was applied over the eyes with cotton balls and a nonadhesive compression bandage during the examination. The CT examinations were performed with a 16-slice helical CT scanner. Both examinations consisted of 0.625-mm contiguous, transverse, collimated images with a 10-cm field of view (kVp, 120; mA, 80). Images were reconstructed with both bone and soft tissue algorithms. The CT images were used to localize the structures in the male and female coeloms prior to and during the ultrasonographic examination. Images were reviewed by a radiology resident (DSB) and a board-certified radiologist (ALZ) to subjectively compare CT and ultrasonographic findings.

Statistical analysis—Descriptive statistics were calculated for each coelomic organ measurement (mean ± SD, range, and variance) among males, among females, and between these groups; F tests were performed for each measure and confirmed normality of the reported data. Pearson correlation coefficients (r) and associated P values were calculated to assess correlations between body weight and each measure. Comparisons between male and female groups for each measure were assessed by means of a Student t test. Measures were reported as mean ± SD. Values of P ≤ 0.05 were considered significant. Statistical analyses were performed with the aid of data analysis software.

Results

All coelomic organs identified with CT were also visualized ultrasonographically, although the presence of gas within the lungs or the gastrointestinal tract inhibited visualization of the entirety of some organs with the latter method. Coelomic ultrasonographic examination of bearded dragons under manual restraint with both microconvex and linear ultrasound transducers allowed for visualization of the heart, pleural surface of the lungs, liver, caudal vena cava, aorta, ventral abdominal vein, gallbladder, fat bodies, gastric fundus, cecum, colon, cloaca, kidneys, and testes or ovaries in all animals. The pylorus was visualized in 12 of 14 bearded dragons, and overlying gas within the gastrointestinal tract prevented identification of this structure in the remaining 2 animals. Small intestinal loops were visualized in 12 of 14 animals with the linear transducer, but could not be reliably identified with the microconvex transducer. The hemipenes were visualized in 7 of 8 males. The adrenal glands and spleen were not identified in any animal. Weight of males was significantly (P < 0.001) greater than that of females.

The heart was observed with both linear and microconvex transducers with transducer placement on the ventral midline in the cranial aspect of the coelom (transducer position 1; Figure 1). The sternum and ribs allowed visualization of the heart, although not reliably. The diaphragm was visualized in 13 of 14 animals with the microconvex transducer. The diaphragm was not identified in any animal. Weight of males was significantly (P < 0.001) greater than that of females.

The heart was observed with both linear and microconvex transducers with transducer placement on the ventral midline in the cranial aspect of the coelom (transducer position 1; Figure 1). The sternum and ribs were not visible due to slight gas within the lungs.
Figure 1—Location of coelomic organs in bearded dragons (Pogona vitticeps). A—Diagram depicting the coelomic organs of a bearded dragon as viewed ventrodorsally. B and C—Photographs labeled to show ultrasound transducer positions (1 through 13; black rectangles) used for image acquisition in 14 healthy bearded dragons from ventral (B) and dorsal (C) approaches. 1 = Transverse and sagittal views of the heart. 2 = Oblique view of the intrahepatic portion of the caudal vena cava. 3 = Sagittal view of the gallbladder. 4 = Sagittal views of the ventral abdominal vein and pyloric portion of the stomach. 5 = Transverse view of the gastric fundus. 6 = Transverse view of the cecum. 7 = Sagittal view of the small intestine. 8 = Sagittal views of the left and right ovaries or testes. 9 = Transverse view of the colon. 10 = Transverse view of the cloaca and cranial poles of the kidneys. 11 = Transverse view of the hemipenes (males). 12 = Sagittal views of the cranial poles of the left and right kidneys. 13 = Sagittal views of the caudal poles of the left and right kidneys. Ce = Cecum. Cl = Cloaca. Co = Colon. F = Gastric fundus. FB = Fat body. G = Gallbladder. H = Heart. Hp = Hemipene (male). K = Kidney. L = Lung. Li = Liver. Lt = left. Rt = right. P = Pylorus. T = Testis or ovary.

Figure 2—Sagittal ultrasonographic image of the cardiac ventricle of a bearded dragon acquired with a 5- to 8-MHz microconvex transducer. The left side of the image is cranial, and the top of the image is ventral. The cardiac muscle is isoechoic to the body wall, with a slightly coarse echotexture. Dorsal and ventral margins of the ventricle are indicated (X markers). The ventral ventricular wall is also shown (circles). A muscular septum is present within the ventricle, adjacent to the ventral ventricular wall. A small B-line artifact is evident in the aerated lung dorsal to the heart (arrowhead).

Figure 3—Oblique ultrasonographic image of the liver and intrahepatic portion of the caudal vena cava in a bearded dragon acquired with a 7- to 15-MHz linear transducer placed over the right side of the liver. The top of the image is ventral. The dorsal and ventral margins of the liver are indicated (X markers). A B-line artifact is visible in the aerated lung dorsal to the liver (arrowhead).
gle ventricle appeared hypoechoic to the adjacent ventricle with swirling echoes. The margins of the atria were indistinct from one another. The cardiac muscle was isoechoic to the body wall and had a moderately coarse echotexture (Figure 2). A muscular septum was visualized within the ventricle; this was oriented in the sagittal plane near the midline. Ventricular wall measurements were performed on the ventral aspect of the cardiac wall at the midportion of the ventricle and did not include the muscular septum. Cardiac length (mean ± SD) measured 2.42 ± 0.32 cm, width measured 2.19 ± 0.25 cm, and height measured 1.30 ± 0.15 cm. The ventricular wall thickness measured 0.27 ± 0.05 cm. Body weight was positively correlated with cardiac width (r = 0.603; P = 0.023), length (r = 0.706; P = 0.005), and ventricular wall thickness (r = 0.675; P = 0.008). Ventricular wall thickness in males (0.30 ± 0.04 cm) was significantly (P = 0.01) greater than that of females (0.24 ± 0.05 cm).

The ventral surface of the lungs, adjacent to the thoracic body wall, could be visualized in all animals through the ventral thoracic body wall on the left and right sides. The ventral margin of the caudal lung lobes could be visualized from the ventrum, extending along the dorsal surface of the liver. The surface was characterized by a slightly irregular hyperechoic soft tissue–gas interface. Multiple small hyperechoic B-line artifacts could be seen in all animals and were most pronounced in the caudal aspect of the thorax (Figures 2 and 3).

The liver was easily visualized in all bearded dragons. It was bordered cranially by the heart and lungs and caudally by the stomach, fat bodies, and cecum. The liver had a coarse echotexture relative to the adjacent body wall and fat bodies, with a few hypoechoic portal vessels within the parenchyma that had bright vessel walls. Hypoechoic hepatic veins and arteries could also be seen. The liver had sharp caudal margins in all animals. The liver was slightly hypoechoic to the adjacent fat bodies in 11 of 14 animals. It was slightly hyperechoic to the fat bodies in 2 animals and isoechoic to the adjacent fat bodies in 1. Mean liver height measured 1.95 ± 0.28 cm. The portal vein and ventral abdominal vein were visualized at the caudoventral aspect of the liver centrally and immediately deep to the body wall in all animals (transducer position 4; Figure 1). The ventral abdominal vein diameter measured 0.14 ± 0.03 cm, at a level immediately caudal to the liver. This was more easily visualized with the high-resolution linear transducer. The intrahepatic portion of the caudal vena cava could be visualized in all animals, passing through the right side of the liver in a caudolateral to craniomedial orientation (transducer position 2). It was the larg-
est vessel within the liver and had an anechoic lumen (Figure 3). The intrahepatic part of the caudal vena cava diameter measured 0.22 ± 0.04 cm.

The gallbladder was visualized in all animals and was present on the caudal border of the liver, slightly right of the midline (transducer position 3; Figure 1). The gallbladder wall was thin, measuring 0.07 ± 0.03 cm. The gallbladder measured 0.67 ± 0.19 cm in height, 0.73 ± 0.17 cm in width, and 0.97 ± 0.24 cm in length. The echogenicity of intraluminal contents varied among animals (Figure 4). Dependent, hyperechoic debris was seen in 8 of 14 animals. Well-demarcated, round to ovoid, hypoechoic-to-mixed echogenicity intraluminal structures (interpreted as concretions of bile) were seen in 3 animals. Three had only anechoic bile.

The fundic portion of the stomach was visualized in all animals, present in the left mid coelom, and immediately adjacent to the left fat body (transducer position 5; Figure 1). The pyloric portion of the stomach could be visualized in 11 of 14 animals, extending toward the midline and toward the mid coelom caudal to the liver (transducer position 4). Gas within the cecum obscured visualization of the pylorus in 3 animals. Discrete wall layering was detectable throughout, with a more prominent muscularis layer in the pyloric region (Figure 5). Stomach wall thickness, measured in the fundic portion, was 0.13 ± 0.04 cm. There was a significant (P = 0.005) positive correlation (r = 0.701) of fundus wall thickness with body weight as well as a significant (P = 0.01) difference in measurements between males (0.16 ± 0.04 cm) and females (0.10 ± 0.03 cm).

Portions of the small intestine were visualized in 12 of 14 animals in the mid cranial to right cranial aspect of the coelom, in close proximity to the fundus and cecum (transducer position 7; Figure 1). These were visualized only with the high-frequency linear transducer. Discrete wall layering was not discernible. Individual segments of the small intestine (ie, duodenal bulb, duodenum, jejunum, and ileum) could not be individually identified. The small intestinal diameter measured 0.31 ± 0.10 cm.

The cecum was seen in all bearded dragons and filled most of the mid coelom slightly right of the midline, extending from the right cranial aspect to the caudal aspect of the midline and terminating in the region of the testes or ovaries (transducer position 6; Figure 1). The cecum was thin walled, with a wall thickness of 0.11 ± 0.03 cm. The intraluminal contents varied among animals, ranging from well-formed to ill-defined hyperechoic ingesta, with a moderate amount of fluid, gas, or both (Figure 6). The ventral border of the cecum was easily assessed; however, owing to the presence of intraluminal gas and ingesta, the dorsal wall of the cecum could not be visualized in its entirety in any animal.

The colon was visualized in all bearded dragons, extending on the midline from the midcaudal aspect of the coelom at the level of the testes or ovaries to the pelvic canal (transducer position 9; Figure 1). It was thin walled with a wall thickness of 0.11 ± 0.03 cm and was subjectively smaller in diameter than the cecum. Intraluminal material varied among animals, ranging from

Figure 6—Transverse ultrasonographic image of the cecum in a bearded dragon acquired with a 7- to 15-MHz linear transducer. The left side of the image is to the animal’s right, and the top of the image is ventral. The wall of the cecum is hyperechoic relative to the adjacent fat body. The dorsal border of the cecum is not distinguishable owing to the presence of intraluminal contents. The ventral borders of the cecum are detectable in 2 areas (arrowheads). The dorsal and ventral margins of the right fat body are indicated (X markers).

Figure 7—Transverse ultrasonographic images of the colon in 2 bearded dragons acquired with a 7- to 15-MHz linear transducer (A and B). The left side of the image is to the animal’s right, and the top of the image is ventral. The thin walls of the colon conform to the adjacent fat bodies and are difficult to visualize. Visible margins of the colon are indicated (X markers). In panel A, notice fluid and formed material in the colon. In panel B, hyperechoic intraluminal material is moderately attenuating and obscures the dorsal border of the colon.
well-formed to ill-defined hyperechoic ingesta, with a moderate amount of fluid, gas, or both. The transition from cecum to colon varied in appearance between animals, with most having an indistinct cecocolic junction. In 3 animals, the colon contained strongly hyperechoic material that was uniform in appearance and strongly attenuating; this allowed for clear delineation of the colon from the cecum (Figure 7).

The cloaca was visualized in all animals, present on the midline in the caudal aspect of the coelom, and observed to extend into the pelvic canal (transducer position 10; Figure 1). Diameter of the cloaca was subjectively smaller than that of the colon. The wall of the cloaca measured 0.11 ± 0.03 cm in thickness. The luminal contents varied in appearance and were similar to those in the colon for each animal, and the junction between colon and cloaca was fairly indistinct in all animals (Figure 8).

The paired kidneys were elongated in shape and were present in the caudodorsal aspect of the coelom and dorsal aspect of the pelvic canal. The kidneys were visualized in all animals. A ventral approach in the transverse plane, with the ultrasound transducer angled caudally, allowed for visualization of the cranial poles of the kidneys, where they were located dorsal and lateral to the cloaca (transducer position 10; Figures 1 and 8). A dorsal approach with the linear transducer was then used to visualize the cranial and caudal poles of each kidney in the parasagittal plane. Ultrasonography, gel was liberally applied on the dorsum of the tail base, immediately cranial and caudal to the level of the hip joints, and the transducer was angled in a slightly dorsolateral to ventromedial orientation (transducer positions 12 and 13). In the transverse plane, the cranial pole of each kidney had an ovoid to bean-shaped appearance and measured 0.42 ± 0.09 cm in height and 0.511 ± 0.09 cm in width. In the parasagittal plane, the kidneys were thin and elongated. The cranial and caudal poles could be seen; however, the entire kidney could not be imaged with 1 transducer position. The kidneys were isoechoic to slightly hyperechoic to the adjacent muscle. The kidneys had a slightly coarse echotexture relative to the adjacent muscle (Figure 9). Two animals had mild hyperechoic stippling throughout this tissue. Measurements for each pole were taken at their midportion. The cranial pole height obtained in the parasagittal plane measured 0.34 ± 0.06 cm, and that of the caudal pole measured 0.32 ± 0.06 cm. There was a significant (P = 0.003) positive correlation (r = 0.724) of the caudal pole height with body weight as well as a significant (P = 0.024) difference in caudal pole height between males (0.35 ± 0.05 cm) and females (0.28 ± 0.05 cm).

The ovaries were visualized in all female bearded dragons as a cluster of follicles on either side of the colon and immediately ventrolateral to the caudal vena cava and aorta in the mid caudodorsal aspect of the coelom. These were best viewed in the sagittal plane, with a slight ventrolateral to dorsomedial orientation, to image around the overlying colon (transducer position 8; Figure 1). There were between 10 and 25 round follicles/side, ranging in diameter from 0.07 to 0.32 cm. The echogenicity of the follicles varied between and within animals, with the most common appearance of a hyperechoic outer rim with a hypoechoic center. However, some follicles appeared largely hypoechoic, with a smaller region of hyperechogenicity centrally (Figure 10).
The testes were visualized in all male bearded dragons as ovoid, smoothly marginated paired structures in the mid caudodorsal aspect of the coelom, located slightly dorsolateral to the colon and immediately ventrolateral to the caudal vena cava and aorta. They were hypoechoic to the adjacent fat body and had a slightly stippled echogenicity (Figure 10). There was mild asymmetry in size between the left and right testes within animals and marked asymmetry in size in 1 animal (left smaller than right). However, this asymmetry was not significantly different among males as a group. Left testis height was \(0.79 \pm 0.14\) cm, and right testis height was \(0.61 \pm 0.19\) cm (\(P = 0.053\)). Length of the left testis was \(1.65 \pm 0.32\) cm, and that of the right testis was \(1.51 \pm 0.33\) cm (\(P = 0.43\)). Left testis width was \(0.89 \pm 0.11\) cm, and right testis width was \(0.86 \pm 0.16\) cm (\(P = 0.66\)). Mean \(\pm\) SD height was \(0.70 \pm 0.13\) cm, width was \(0.88 \pm 0.12\) cm, and length was \(1.58 \pm 0.24\) cm. There was a significant (\(P = 0.049\)) negative correlation (\(r = -0.709\)) between body weight and testicular width.

The hemipenes were visualized in 7 of 8 males. They were best viewed in the transverse plane, with the high-frequency transducer placed on the ventral aspect of the base of the tail (transducer position 11; Figure 1). They had a C-shaped appearance in cross section and were isoechoic to the adjacent muscle. They were surrounded by a very small amount of anechoic fluid in all 7 animals in which they were visualized (Figure 11). The hemipenes could not be distinguished from the surrounding tissue in 1 animal. The hemipenes measured \(0.50 \pm 0.9\) cm in height and \(0.67 \pm 0.14\) cm in width.

Fat bodies were easily visualized in all bearded dragons as large, paired, hyperechoic structures extending down the length of the left and right lateral aspects of the coelom from the caudal surfaces of the liver to the level of the cloaca. Small, thin hyperechoic lines were observed within the fat bodies oriented perpendicular to the transducer. Small blood vessels were present coursing across the caudal aspects of the fat bodies bilaterally. The fat bodies had a somewhat triangular appearance in cross section, with relatively sharp margins cranially. The fat bodies measured \(2.23 \pm 0.27\) cm in height.

Small, variable volumes of hypoechoic or anechoic free coelomic fluid were seen in 11 of 14 animals. This fluid was often found between the fat bodies and body wall. It was also seen adjacent to the liver, testes, and colon.

**Discussion**

Coelomic ultrasonography with manual restraint allowed for visualization of the heart, pleural surface of the lungs, liver, caudal vena cava, aorta, ventral abdominal vein, gallbladder, fat bodies, gastric fundus, cecum, colon, cloaca, kidneys, and testes or ovaries in bearded dragons. Visualization of the pyloric portion of the stomach was possible in most animals, with limitations attributed to gas-filled visera. The compact, high-resolution linear transducer was required to observe the smaller or more superficial structures in this study, such as the small intestine and hemipenes. The spleen was not visualized with these methods in any
animal. This may have been because the spleen had an ultrasonographic appearance similar to the fat bodies and could not be reliably differentiated; it is also possible that organs were positioned such that gas within the overlying intestinal tract inhibited visualization. The adrenal glands were also not visualized, likely owing to the small size of these structures. It is possible that coelomic ultrasonographic examination may be more sensitive in detecting these organs in bearded dragons with pathological processes that substantially alter echogenicity or size, making them more conspicuous.

Few published references are available describing the coelomic or gastrointestinal anatomy of bearded dragons. Among these references, there is discrepancy in anatomic nomenclature for gastrointestinal segments. The most recent of these publications proposes gastrointestinal nomenclature based on the anatomic description and functional information acquired from contrast radiography. In the present study, we used nomenclature provided in that report, with the following gastrointestinal segments in order from orad to aboral: stomach (cardia, fundus, and pylorus), duodenal bulb, duodenum, jejunum, ileum, cecum, colon, and cloaca.

Coelomic ultrasonography is a potentially valuable diagnostic tool in evaluating commonly encountered disorders in bearded dragons. Reproductive disorders, including dystocia and follicular stasis, are common. Visualization of the reproductive structures was easily performed in all animals. The ultrasonographic examinations in the present study were performed in October and November, a portion of the year when bearded dragons are not reproductively active; so the reproductive structures were likely to be smaller and less conspicuous than in late winter and spring. This suggests that ultrasonography could be used for sex determination in this species at any point in the reproductive cycle, assessment of pregnancy status, and evaluation for evidence of reproductive disease. Gastrointestinal abnormalities, including colonic urate impaction, are common in bearded dragons. Coelomic ultrasonography could potentially serve as an effective imaging modality to diagnose this condition, given the ease of visualization of the colon in all animals in our study. Less commonly reported disorders include gastrointestinal foreign body, gastrointestinal neoplasia, or adenovirus infection. Although the entirety of the gastrointestinal tract could not be visualized owing to overlying gas or small size of some structures, pathological processes may cause intestinal or gastric dilation or architectural changes, which may improve visibility of these organs. Ultrasonography is also of potential value for evaluation of bearded dragons with renal or hepatic disease, given the ready visualization of these organs in the present study; however, further studies characterizing the ultrasonographic changes seen with pathological changes in these organs are required.

Non–contrast-enhanced CT was used in conjunction with coelomic ultrasonography in 2 bearded dragons to aid in reliable identification of the locations of coelomic organs. We did not identify any coelomic organs by CT that could not be identified via ultrasonography. Although CT is likely superior to ultrasonography for identification of pulmonary or osseous pathological changes and CT imaging and is not affected by gas shadowing, the inherent increased spatial resolution of high-frequency ultrasonography may provide better visualization of soft tissue structures within the coelom in some cases.

There was a positive correlation between body weight and cardiac width, length, and ventricular wall thickness as well as wall thickness of the fundic portion of the stomach and height of the caudal poles of the kidneys. A positive correlation between body weight and height or kidney size has also been demonstrated in mammalian species and is likely attributable to increasing requirements for cardiac output with increasing body mass. Increasing gastrointestinal wall thickness with body weight has been reported in humans, dogs, and boid snakes. However, a study in green iguanas did not find a correlation between wall thickness and body weight. The correlations identified in the present study should be considered when developing normal reference ranges for bearded dragons because body weight can vary substantially between adult individuals.

Ventricular wall thickness, fundus wall thickness, and height of the caudal poles of the kidneys differed significantly between male and female bearded dragons in the present study. Given the large difference in mean body weight between males and females in this study, it is likely that these differences were attributable to differences in size, rather than physiologic differences between sexes.

The negative correlation between body weight and width of the testes was an unexpected finding. However, the results of this study represent values obtained only at a single time point, and there may be slight variability in the reproductive stage or in the ages of the animals. A longitudinal study assessing changes in the ultrasonographic appearance of the reproductive tract of bearded dragons may help to better understand changes in the reproductive tract over time.

In this study, a few ultrasonographic findings that could be interpreted as representing pathological processes in other species were repeatedly seen in apparently healthy bearded dragons. Multiple B-line artifacts were seen when assessing the pleural surfaces of these animals. Although this artifact can be associated with pulmonary disease in dogs, it can routinely be observed on ultrasonography of clinically normal animals of other species, such as horses. Similarly, anechoic free coelomic fluid was present in most animals imaged in this study, which can be associated with a number of underlying pathological processes in small animal patients of other species. Finally, the contents of the gallbladder varied among animals, with most having echogenic intraluminal debris and formed concretions of bile evident in 3. Given the repeatability of these findings in our group of clinically normal animals, it is likely that these findings are normal for this species.

In 3 bearded dragons, the liver was isoechoic or hyperechoic to the adjacent fat bodies, which was an unexpected finding. It is feasible that this also represents normal variation for this species, given the otherwise similar appearance to the livers of other animals in...
the study. Alternatively, this may have been an indicator of hepatic lipidosis, which is well recognized and common in captive reptiles. It is possible that animals with mild hepatic lipidosis would not have overt signs of disease.

There were some limitations to the present study. All bearded dragons were presumed to be healthy on the basis of clinical history and physical examination findings. However, it is possible that subclinical disease was present. Correlating ultrasonographic findings with biochemical results and histopathologic findings would be ideal to ensure that only truly normal organs were being imaged and described. Additionally, the animals included in the study had been acquired from a breeding facility and were young. Including a larger sample size with bearded dragons of different ages and sizes would help to more accurately describe the normal appearance of the coelomic viscera in a more heterogeneous population, and thus more accurately represent the population of animals that small animal practitioners may treat. The bearded dragons in this study were transported from the breeding facility and were housed on campus for ≥1 week prior to imaging to minimize effects from stress associated with shipping. If the animals had periods of anorexia or hyporexia associated with transport, it is possible that this could have contributed to subclinical hepatic lipidosis. Additionally, changes in temperature can influence timing of reproductive cycles in reptiles. Temperatures were maintained within the preferred optimal temperature zone during captivity; however, it is possible that subtle environmental alterations between the breeding and research facilities may have affected the reproductive cycles of the animals in this study.

Our results suggest that coelomic ultrasonographic examination can be a valuable diagnostic tool for assessment of bearded dragons, allowing for visualization of most coelomic structures, and can be performed without the use of sedation.

References

9. Johnson J. What veterinarians need to know about bearded dragons. Exotic DVM 2008;8:38–44.