

Small Mammal Imaging and Radiographic Cases

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- I. Introduction
 - a. Radiography of exotic pets can be challenging.
 - i. Small patient size makes restraint and positioning difficult.
 - ii. Small patient size and unique anatomy make interpretation of imaging confusion
 - iii. Even the slightest amount of motion artifact can complicate interpretation
 - b. Familiarity with normal anatomy is the basis for radiographic interpretation in any species.

- II. Restraint
 - a. Manual restraint is effective for radiographic imaging for some exotic pets
 - b. Factors for considering manual versus chemical restraint (sedation)
 - i. Overall patient condition
 - 1. Including stress level
 - 2. Dyspneic animals should almost always be anesthetized
 - ii. Radiographic equipment (speed of the X-ray generating equipment)
 - iii. Expertise level of staff restraining Dyspneic animals should almost always be anesthetized for radiography.

- III. Ferrets
 - a. Digestive system
 - i. Stomach
 - 1. Sits within the left cranial abdomen as in other mammals
 - 2. Very expansile
 - ii. Small intestine (SI)
 - 1. Approximately 180-200 cm
 - 2. There is no demarcation between the jejunum and ileum
 - 3. Lack an ileocolic valve
 - 4. Gastrointestinal transit time ~3 hours
 - iii. Sonography
 - 1. Stomach and SI can be visualized sonographically unless air-filled
 - 2. Rugal folds can be seen in many patients
 - 3. As many as 4 SI layers can be identified
 - a. Mucosa, submucosa, muscularis, serosa
 - b. The wall should be < 3 mm thick
 - 4. Colon
 - a. Only 3 layers can usually be seen
 - b. Should be < 1 mm thick

5. Lymph nodes
 - a. Gastric lymph node
 - i. Sits at the base of the mesentery
 - ii. Should be $\leq 12 \times 7$ mm but is frequently enlarged (this is not a good indicator of disease if this occurs as a solitary process)
 - b. Ferret mesenteric lymph nodes may appear larger relative to body size than most other mammalian species
- iv. Pathologic conditions that can be identified by imaging
 1. Bowel wall thickening
 - a. Infiltrative diseases of the bowel, including lymphoma and adenocarcinoma, generally produce generalized or segmental thickening or a mass effect
 - b. Inflammatory diseases is associated is generally associated with more symmetric, less severe, inflammation
 - c. Biopsy is always needed to differentiate
 2. Gastric or intestinal obstruction
 3. Ileus
 - a. Mechanical (obstructive disease): two distinct bowel populations are evident
 - i. Bowel that is oral to the obstruction will be markedly dilated
 - ii. Aboral bowel will appear normal
 - b. Functional ileus is usually less severe
 - c. Thromboembolic
 4. Intussusception
- b. Liver
 - i. The liver has two crura and is six into 6 lobes: right lateral, right medial, left lateral, left medial, quadrate lobe (central), and the caudate lobe.
 - ii. A gallbladder is present
 - iii. Normal sonography
 1. The liver should be hyperechoic when compared to the spleen, with sharply tapering margins
 2. Portal veins have hyperechoic walls
 3. The walls of hepatic veins are not visible
 4. Gallbladder
 - a. Round to slightly oblong, with an anechoic center
 - b. The wall is 2 layers thick and is normally 1 mm
 - c. Occasionally, echogenic debris is present in the absence of disease
 - iv. Pathologic conditions
 1. Decreased echogenicity of liver parenchyma
 - a. Differentials include neoplasia (such as lymphoma) and cardiovascular disease

- b. Evaluate the patient carefully for the presence of venous congestion.
 - 2. Increased hepatic echogenicity is increased
 - a. Differentials include hepatic lipidosis, cirrhosis, or lymphoma
 - b. Early lipidosis has been demonstrated to begin in ferrets in as little as 24 hours
 - 3. Hepatic cysts of varying sizes can occur, and polycystic disease has been reported
 - 4. Neoplasia
 - a. Tumor types are similar to other mammals
 - b. The most common hepatic neoplasm is lymphoma, which generally has a diffuse mottled appearance
 - c. Hepatocellular carcinoma usually has a focal appearance (at least initially)
 - d. Lobectomy can be performed if the tumor is isolated to one to two lobes
 - 5. Biliary pathology is rare, but wall thickening and obstruction can occur
- c. Spleen
 - i. Lies predominantly on the left side of the abdomen, running along the greater curvature of the stomach, attached by the gastrosplenic ligament
 - ii. Splenomegaly
 - 1. The spleen can vary greatly in size, depending on age and state of health
 - 2. An enlarged spleen can extend from the upper left all the way to the lower right of the abdominal cavity
 - 3. Isoflurane anesthesia can lead to profound splenic enlargement
 - iii. Sonography
 - 1. Finer in echotexture than other abdominal organs
 - 2. Can enlarge dramatically
 - 3. Nodules on the spleen may be...
 - a. Extramedullary hematopoiesis, which is common
 - b. Neoplasia
 - i. Can cause congestion and inflammation, leading to a hyperechoic appearance
 - ii. May cause bulging of the wall
 - 4. Infarcts will cause capsular indentations
- d. Urogenital System
 - i. The urinary bladder is similar to that of other species, with an apex, body, neck, and trigone region
 - ii. Females
 - 1. Ovaries are caudal to the kidneys

2. The uterus is comprised of two long horns, a short uterine body, and a single cervix
 3. The vulva is small.
- iii. Males
1. Penis contains a J-shaped os penis
 2. Prostatic glandular tissue is found at the base of the bladder and around the urethra
- iv. Sonography
1. Kidneys
 - a. Usually 2.4-3 cm in length
 - b. Consist of a cortex, medulla, renal pelvis, and renal sinus
 - c. Renal cysts are commonly seen via ultrasound
 - i. Appear as anechoic round structures within renal parenchyma.
 - ii. They may be of any size, and there may be single or multiple cysts
 - iii. Benign, considered incidental findings unless polycystic renal disease or renal compromise occur
- v. Pathologic conditions
1. Diffuse cortical hyperechogenicity (inflammatory or age-related)
 2. Renal masses
 3. Infarcts
 4. Pyelonephritis and hydronephrosis may also occur
 - a. Hydronephrosis is most commonly associated with urinary outflow obstruction secondary to prostatic disease, or less commonly, as a complication of surgery
 5. Cystitis
 - a. May lead to bladder wall thickening
 - b. Blood clots and calculi can also occur
 6. Prostatic enlargement secondary to adrenal disease is common
 7. Bladder wall neoplasms can occur less commonly
 8. Most ferrets are altered prior to purchase, and therefore true reproductive abnormalities in non-breeder animals are rare
 9. In ferrets with adrenal gland disease...
 - a. Prostatic enlargement can occur with subsequent urinary outflow obstruction
 - b. Stump pyometra can also occur if there is any uterine remnant
- e. Respiratory System
- i. Anatomy is similar to that of most mammals, however, the respiratory system is relatively elongated
 - ii. Lungs
 1. The left lung is comprised of cranial and caudal lobes
 2. The right lung has three lobes: cranial, middle, and caudal
 3. There is a 6th accessory lobe.

- iii. Pathologic conditions
 - 1. Congestive heart failure, heartworm disease, and lymphoma usually present with pleural effusion
 - 2. Sonography
 - a. Heartworm disease can be recognized by the presence of parallel lines within the heart
 - b. Neoplasia (e.g. lymphoma) will be evident as either one mediastinal mass or multiple lymph nodes throughout the cranial and caudal mediastinum
 - c. Thymoma is also reported

- f. Cardiovascular System
 - i. Heart
 - 1. Located further caudally than in most mammals, between the 6th and 8th ribs.
 - 2. There may be periapical fat, creating the radiographic appearance of elevation from the sternum on the lateral view
 - ii. Pathologic conditions
 - 1. Dilated cardiomyopathy is most commonly seen
 - 2. Hypertrophic cardiomyopathy, a mixed form of cardiomyopathy, valvular insufficiency, and valvular endocarditis (uncommon) may also be seen

- g. Musculoskeletal System
 - i. Unlike most mammals, the ferret has 15 thoracic, 5 lumbar, and 3 sacral vertebrae
 - ii. There are five toes with non-retractable claws on each foot

- h. Endocrine System
 - i. Pancreas
 - 1. Bilobed
 - a. The right limb is larger, located along the descending duodenum
 - b. The left limb extends between the stomach and spleen
 - 2. Pancreatic ducts extend from the central area of the pancreas to the duodenum
 - 3. Sonography
 - a. Left limb is rarely seen.
 - b. Right limb can also be difficult to visualize
 - c. The body of the pancreas can usually be identified at the cranial duodenal flexure
 - 4. Pathology
 - a. Insulinoma can be difficult to visualize as nodules can be quite small

ii. Adrenal glands

1. Lie cranial and medial to each kidney
2. The right adrenal gland is almost always adhered ventrally to the caudal vena cava

	Left Adrenal Gland	Right Adrenal Gland
Shape	Oval	More elongate
Size	6-8 mm in length 4.3 mm in width (♀) 4.4 mm in width (♂)	8-11 mm in length, 4.1 mm in width (♀) 4.8 mm in width (♂)
Vascular supply	Adrenolumbar artery Adrenolumbar vein crosses the ventral surface of the gland	3-5 vessels that arise from the right renal artery, right adrenolumbar artery, and aorta

3. Sonography

- a. Look for the right adrenal gland medial to the cranial pole of the right kidney, cranial to the origin of the cranial mesenteric artery, and adjacent or adherent to the caudal vena cava
- b. The left adrenal gland is cranial and medial to the cranial pole of the left kidney, lateral to the aorta, and cranial to the left renal artery

4. Pathologic conditions

- a. Adenomas and adenocarcinomas can occur and cannot be differentiated without histopathology

IV. Rabbits

a. Gastrointestinal Tract

- i. Rabbits are hindgut fermenters, adapted to digest a low-quality, high-fiber diet, consisting mainly of grasses
- ii. The gastrointestinal tract of rabbits is quite long, making up 10-20% of body weight
- iii. Sonography

1. The stomach and SI can be visualized unless filled with air
2. Rugal folds can be seen in many patients
3. Small intestines
 - a. As many as four layers can be identified: mucosa, submucosa, muscularis, serosa
 - b. The wall should be < 3 mm thick
4. Colon can also be identified
 - a. Only 3 layers can usually be seen
 - b. Should be < 1 mm thick

5. Cecum
 - a. Often gas filled and may impede visualization of other structures
 - b. Contents are usually semifluid and may have a particulate or 'stellate' appearance
6. Lymphoid tissue cannot be identified sonographically
- iv. Pathologic conditions
 1. Gastric or intestinal obstruction, ileus (mechanical, metabolic and also thromboembolic)
 - a. Functional ileus is far more common in rabbits and usually less severe
 - b. Mechanical ileus (obstructive disease)
 - i. There will be two distinct bowel populations evident, as bowel that is orad to the obstruction will be markedly dilated, but aborad will appear normal.
 - ii. Most common sites for obstruction are the stomach and sacculus rotundus
 - c. Gastric obstruction
 - i. Usually more readily diagnosed radiographically
 - ii. Obstruction at the sacculus rotundus will not produce the two distinct bowel populations because it is the termination of the ileum
 2. Infiltrative diseases of the bowel are uncommon but may occur, typically creating a focal mass effect
- b. Liver
 - i. The liver has four lobes
 - ii. A gallbladder is present
 - iii. Sonography
 1. The liver should be hyperechoic when compared to the spleen, with sharply tapering margins
 2. Portal and hepatic veins can be identified
 - a. Portal veins will have hyperechoic walls
 - b. Hepatic veins will not have visible walls
 3. Gallbladder
 - a. Round to slightly oblong, with an anechoic center
 - b. The wall is two layers thick and is normally 1 mm
 - c. Echogenic debris is occasionally present in the absence of disease
 - iv. Pathologic conditions
 1. Differentials for decreased echogenicity of the liver parenchyma
 - a. Neoplasia (such as lymphoma)
 - b. Cardiovascular disease (evaluate carefully for the presence of venous congestion)
 2. Differentials for increased hepatic echogenicity
 - a. Hepatic lipodosis, can be difficult to document in rabbits

- b. Cirrhosis
 - c. Lymphoma and other neoplasms (tumor types are similar to other mammals)
 - d. Hepatic cysts of varying sizes can occur
 - e. Biliary pathology is rare.
- c. Spleen
 - i. Very small, flat, and elongated
 - ii. Lies on the dorsolateral surface of the greater curvature of the stomach.
 - iii. The normal spleen in most rabbits is approximately the size of the “pinkie finger” of an average person.
 - iv. Sonography
 - 1. Difficult to evaluate
 - 2. When visible, the spleen is finer in echotexture than other abdominal organs
 - v. Splenic abnormalities or diseases are extremely rare
- d. Urogenital System
 - i. Rabbit kidneys are unipapillate
 - ii. The urinary bladder is similar to that of other species, with an apex, body, neck, and trigone region
 - iii. Urethra
 - 1. Female rabbit urethra empties into the proximal end of a deep vaginal vestibule
 - 2. Expression of the bladder when the animal is in dorsal recumbency can lead to retrofilling of the vaginal vault, which may be a source of confusion when performing ultrasound of the female reproductive system
 - iv. Does have long curved uterine horns, two separate uterine horns and two cervixes opening into the vagina
 - v. The vagina is large and flaccid, and a vaginal vault may be identified even in spayed females
 - vi. Sonography
 - 1. Kidneys consist of a cortex, medulla, renal pelvis, and renal sinus
 - 2. The renal pelvis may have a stellate appearance
 - 3. The uterus can be identified as a tubular structure between the colon and the bladder, which lacks gas and peristalsis. It can usually be traced to the ovaries, caudal to the kidney on either side.
 - vii. Pathologic conditions
 - 1. There may be diffuse cortical hyperechogenicity (inflammatory or age-related), renal masses, or infarcts
 - 2. Diffuse stellate foci in the cortex may be a sign of past *Encephalitozoon cuniculi* infection
 - 3. Nephroliths may occur, resulting in hydronephrosis
 - 4. Pyelonephritis and renal mineralization may also occur

5. Probably the most common bladder-associated pathology is cystitis with bladder wall thickening secondary to chronic calciuria
6. Pathology of the uterus is common
 - a. Neoplasia is most common pathology
 - b. Endometriosis and aneurysms may both occur. Male reproductive pathology is uncommon, although testicular neoplasia is reported.
7. Normal pregnancy can be identified. This may be mistaken as pathology, as many owners do not know the sex of their rabbits and may unknowingly be housing males and females together

e. Respiratory System

- i. Rabbits are obligate nose-breathers (mouth breathing is a very poor prognostic sign)
- ii. Lungs have three lobes, and the cranial lung lobes are small (left smaller than right)
- iii. The thoracic cavity is small in comparison with the large abdominal cavity
 1. Breathing is mainly diaphragmatic
 2. Significant respiratory compromise may occur if a rabbit is placed in dorsal recumbency when the stomach or cecum are greatly distended.
- iv. Large amounts of intrathoracic fat are often present
- v. Thymus persists in the adult rabbit and lies ventral to the heart, extending into the thoracic inlet
- vi. Pathologic conditions
 1. Diseases of the respiratory system are most often infectious in etiology.
 - a. Abscesses of the lungs may occur and may have the appearance of multiple masses, mimicking metastatic disease
 - b. Pleural effusion may occur as a result of chronic pneumonia or lower respiratory infection
 2. Thoracic masses generally are either thymoma or lymphoma.

f. Cardiovascular System

- i. The heart is relatively small and lies cranially in the thoracic cavity
 1. The heart itself is small relative to total body size, comprising only 0.3% of the total body weight.
- ii. Both the right and left atrioventricular (AV) valves are bicuspid and consequently are named the right and left AV valves
- iii. Rabbits have the most muscular pulmonary artery of any species, which contributes to their predisposition for pulmonary hypertension
- iv. The rabbit aorta has neurogenic rhythmic contractions.
- v. Sonography
 1. Comparable to other mammals

2. Although cardiac disease is rarely documented in rabbits, there is probably a higher incidence than is diagnosed or reported

g. Musculoskeletal System

- i. The forelimbs have five digits but the hind limbs only have four
- ii. Nails are long and narrow for digging and burrowing, but are not retractable, and rabbits should not be declawed
- iii. Vertebral formula
 1. C7 T12 L7 S4 C16
 2. Thirteen thoracic vertebrae are seen in some animals

h. Endocrine System

i. Pancreas

1. The pancreas is diffuse
2. Located in a pocket formed by the transverse colon, stomach and duodenum
3. Pancreatic diseases of rabbits are uncommon

ii. Adrenal glands

1. Large relative to body size
2. Anatomic and sonographic location of the adrenal glands is similar to ferrets.
3. Pathology of the adrenal glands is extremely rare.
 - a. I have seen two adrenal masses in rabbits, both of which were at least three times the size of the contralateral gland

V. Rodents

A. Guinea pigs, chinchillas

a. Digestive Tract

- i. The stomach has a glandular epithelial lining
- ii. The intestinal tracts of both species are long, with a prominent cecum.
- iii. Gastric emptying time 2 hours (guinea pig)
- iv. GI transit time ~ 20 hours (guinea pig)
- v. Coprophagy can prolong transit time

b. Urogenital System

i. Male guinea pigs

1. Os penis
2. Open inguinal canals
3. Large, paired vesicular glands that extend for up to 10 cm in the abdominal cavity and can be mistaken for uterine horns.

ii. Female guinea pigs

1. Paired uterine horns
 2. Single cervix
 - iii. Male chinchillas
 1. Lack a true scrotum
 2. Testes are freely mobile
 3. There is no os penis but the penis is easily exteriorized
 - iv. Urine of both species is alkaline and may have crystals
 - v. Sonography
 1. The uterus can be identified as a tubular structure between the colon and the bladder, which lacks gas and lacks peristalsis
 2. Seminal vesicles in guinea pigs appear as bilateral tubular soft tissue opacities dorsal to the bladder, which may also have hypoechoic or anechoic fluid
 - vi. Pathologic conditions
 1. Pathology of the uterus is common
 - a. Neoplasia is most common
 - b. Endometriosis and aneurysms can also occur
 2. Cystic ovarian disease
 - a. Most commonly diagnosed reproductive disorder in female guinea pigs
 - b. Frequently bilateral
 - c. Usually associated with abdominal distension and bilaterally symmetrical alopecia
 3. Male reproductive pathology is uncommon, although testicular neoplasia may occur.
 4. More commonly, the seminal vesicles are mistakenly identified as pathology
- c. Respiratory System
- i. The right lung is comprised of cranial, middle, caudal, and accessory lobes
 - ii. The left lung is comprised of a cranial, middle, and caudal lobes
 - iii. In both species, the thoracic cavity is small in comparison to the abdominal cavity
 - iv. Pathologic conditions
 1. Diseases of the respiratory system are most often infectious in etiology
 - a. Abscesses of the lungs may occur and may have the appearance of multiple masses, mimicking metastatic disease
 - b. Pleural effusion may occur as a result of chronic pneumonia or lower respiratory infection
- d. Cardiovascular System
- i. The right AV valve is tricuspid, and the left is bicuspid

- ii. Mild heart murmurs may be present in chinchillas without significant cardiac disease
- iii. Sonography
 - 1. Cardiac evaluation of the heart is comparable to other mammals
 - 2. Cardiac disease is rarely documented, but the same diseases as other species are all possible
 - 3. I have seen several cases of dilated cardiomyopathy and valvular insufficiency; most of these have responded very well to therapies utilized in other companion animal species
- e. Musculoskeletal System
 - i. There are four digits on the front limbs, and three digits on the rear limbs
 - ii. Chinchillas have four toes on all feet.
- f. Endocrine System
 - i. Guinea pigs have the largest adrenal glands relative to body size of any mammalian species
 - 1. The left adrenal gland is more elongated and has a concave surface dorsally where it contacts the renal vessels
 - 2. The right adrenal gland also has the concave surface, but is not in contact with the vessels
 - 3. In cross-section, both adrenal glands will have a triangular appearance
 - ii. Adrenal neoplasia is reported in guinea pigs

B. Mice, Rats, Hamsters, Gerbils

- a. Digestive tract
 - i. Dental Formula: 2(I1/1 C0/0 PM0/0 M3/3). The incisors of these species are used for gnawing, and the lower incisors are approximately three times the length of the upper incisors. The incisor teeth are yellow and are open rooted.
- b. Urogenital System
 - i. Females
 - 1. Paired ovaries
 - 2. Single cervix
 - ii. Males
 - 1. Develop testicles which descend into a scrotal sac through inguinal canals which remain open
 - 2. Os penis
- c. Musculoskeletal System

- i. Gerbils have five front toes and four rear toes
- ii. Hamsters, mice, and rats have four toes in the front and five on the rear feet.

VI. Sugar Gliders, unique features

- a. The typical “ossa marsupialia” (marsupial bones, epipubic bones which articulate with the pelvic bones) that are characteristic of most marsupials, are absent in sugar gliders
- b. Newborns do possess a continuous cartilaginous arc in the shoulder girdle, which provides support for the newborn to climb into the pouch. These bones break down immediately after birth.

VII. Hedgehogs, unique features

- a. Dorsal spines, but ventral fur. Spines can create artifact in radiographic interpretation
- b. Male hedgehogs
 - i. Prominent seminal vesicles lie dorsal to the bladder and are responsible for production of secretions
 - ii. Paired Cowper’s glands lie adjacent to the penis
 - iii. These glands may be visualized sonographically and can be mistaken for pathology

VIII. Case examples