**Avian Radiology**

Because avian anatomy makes abdominal palpation and cardiopulmonary auscultation difficult, radiographs are an essential diagnostic tool in avian medicine. Radiographs are useful in assessing intracoelomic structures for organomegaly or other problems and for monitoring disease progression and treatment. Radiographs can give a large amount of information, yet are non-invasive and cost effective. The internal anatomy of birds is significantly different from mammals and also differs among groups of birds. Therefore, it is essential for clinicians to have a thorough understanding of what is considered normal avian anatomy; both gross and radiographic, to get the most out of each radiograph. Several excellent sources of radiographic anatomy are available, both in many avian texts and as separate textbooks. The author often refers to *Radiology of Birds; an Atlas of Normal Anatomy and Positioning* by Silverman and Tell or *Atlas of Diagnostic Radiology of Exotic Pets* by Rubel, Isenbugel, and Wolvekamp. This lecture will review the radiographic anatomy of normal psittacines, since this group is most highly represented in clinical practice.

Contrast studies, fluoroscopy and other procedures are helpful and are used as they are in other species, with a few exceptions. The most notable exception is the use of contrast material to determine non-intestinal disease. Because of the relative lack of intra-abdominal fat in birds there is less contrast between tissues, thus less tissue detail in the normal patient. In patients with ascites or other intra-abdominal disease, the detail may be even poorer. In these situations, administering barium (2-3cc/100g of body weight) or other contrast material highlights the position of the gastrointestinal tract, which can aid in the diagnosis of other, non-intestinal organomegaly. For example, hepatomegaly will cause the proventriculus and ventriculus to be caudally and dorsally displaced, while enlargement of the reproductive tract will cause cranoventral displacement of the intestines. Fluoroscopy is useful in diagnosing motility disorders, such as proventricular dilatation disease or foreign bodies.

**Technique**

High-speed film and excellent machinery are important for diagnostic radiography in birds. Machines with a milliamperage output of 1000 or 1200 work best. Short exposure times of 1/60 to 1/120 seconds and low kV output of 40-50 kV yield excellent results.¹ Mammography machines and mammography film are excellent for optimal skeletal detail in our small avian patients. These machines use similar mA with slightly lower kV. Mammography film used table-top with the standard machine will yield better soft tissue detail in small birds. Dental films can also be used in small patients or on small body parts such as toes and feet. In cases where the higher speed films are not available, good quality radiographs can be made with 300mA, short times of 1/30-1/120 seconds, and
Digital radiography is extremely beneficial in avian medicine as it allows us to manipulate the images to improve detail by changing the contrast, brightness, and magnification. Machines may need to be adjusted with algorithms for very small patients and detail films should still be used.

**Patient Positioning and Preparation**

It is recommended to fast birds for several hours before performing radiographs to prevent regurgitation and aspiration, whether or not sedation or anesthesia is used. In general, small birds such as cockatiels and budgies should be fasted for 1-2 hours, while larger birds should be fasted for 2-6 hours. Patients are generally anesthetized with isoflurane anesthesia delivered via a mask or endotracheal tube. The use of a fast-acting anesthetic gives better positioning, thus more diagnostic films. Patients are generally less stressed by the anesthesia than they would be if restrained by hand or other method. This also reduced the risk of injury to the patient if they struggle. The time of anesthesia is generally brief (less than 10 minutes). Dyspneic patients usually do well with anesthesia because they are breathing 100% oxygen and the conscious stress part of their dyspnea is removed. Patients can be position directly on the screen or positioned on a clear, Plexiglas board (a.k.a. “bird board”) and restrained with masking tape, painter’s tape (or other low residue tape) or Velcro. There are commercial bird boards available with guillotines of varying sizes to hold the head and Velcro foot holders. For a ventrodorsal (VD) radiograph, birds are restrained on their backs with both wings equally extended and both feet equally extended. Symmetry is positioning of the wings and feet yield better radiographs. In lateral radiographs, the wings are extended dorsally (behind the back) and the feet are extended towards the tail. In general, the leg closest to the film is placed slightly cranial to the other leg.

**The Gastrointestinal tract**

The crop is located at the thoracic inlet and is may contain a small amount of air on radiographs, especially when inhalant anesthetics are used. The thoracic esophagus connects the crop to the proventriculus. The proventriculus is located dorsal and to the left of the heart and courses through the abdomen at approximately a 45 degree angle to the ventriculus when viewed on the lateral projection. The ventriculus often contains stones or other radiodense materials. Metal densities may also be seen here and the contents should be examined closely. The ventriculus should be at the level of the hip joints on the left side, approximately half way between the keel and vertebral column. The intestines generally lie in the caudodorsal section of the coelom.

The liver is closely associated with the heart and forms the caudal portion of the hourglass shape called the “cardiac-hepatic waist.” The liver of most species will sit
between the greater trochanters on the VD view. The apparent size of the liver can be affected by insufflation of the air sacs as well as enlargement of the proventriculus. This can cause a shift in the liver to one side (the right side with proventricular enlargement) which makes the liver silhouette appear enlarged. The liver can be spread to both sides by cranial displacement from other organomegaly within the caudal coelomic cavity.

Diseases that cause radiographic changes with the GI tract include infectious disease, foreign bodies, neoplasia, metabolic disturbances, organ failures and others. Chlamydophila and other infectious diseases can cause hepatomegaly and splenomegaly. Mycobacterial infections can cause thickening of the bowel that may be visible on plain or contrast films. Foreign bodies, including heavy metals, may be visible on radiographs or may cause bowel dilation or other alterations.

**The Cardiopulmonary System**

The heart is located cranial to the liver and ventral to the lungs and is in contact with the sternum. The apex of the heart sits between the lobes of the liver and forms the cranial portion of the cardiohepatic silhouette. In some species, such as raptors and macaws, the heart will be wider than the liver on the VD view, but in most species, the liver is slightly wider than the heart. The major vessels (aorta, pulmonary trunk, and caudal vena cava) can be seen dorsal to the heart. These vessels should not be confused with pulmonary granulomas. The most common radiographic change in the heart is cardiomegaly, which can be caused by pericardial effusion or cardiomyopathies.

Because of the structure of the avian lung, the lungs appear as a reticular or honeycomb pattern dorsal to the heart in the lateral radiograph. This appearance is caused by end on views of the parabronchi. Most psittacines have nine air sacs, four paired and one unpaired. The four paired are the cervical, cranial thoracic, caudal thoracic, and abdominal. The unpaired air sac is the clavicular air sac which lies dorsal and caudal to the crop at the thoracic inlet. In some species the clavicular will fuse with the two cervical, creating one large air sac between the thoracic limbs. The air sacs are not usually distinguishable radiographically unless there is severe air sacculitis causing thickening of the air sac membrane. These ‘air sac lines’ can be seen best at the junction of the caudal thoracic and abdominal air sacs and appear as a thin line running between the body wall and liver. The tracheal syrinx or vocal box should be examined to evaluate for the presence of granulomas. Granulomas and tracheal foreign bodies may be seen on plain films or with the addition of a very small amount of iodinated contrast. Granulomas may also be seen with pulmonary infections, both as radiopaque areas in the lungs and air sacs. The air sacs may be hyper-inflated with obstructive pulmonary disease as well.

**Urogenital System**
The kidneys are located ventral to the pelvis (synsacrum) in the renal fossa. They are best visualized in the lateral view. The kidneys may have an increased radio-opacity with gout or other renal problems; however, this is a very subjective finding. The ureters are not usually visible. The cloaca is visible at the caudal coelom although it is typically difficult to distinguish unless it contains air or an egg. The cloaca may be gas-distended in cases of cloacitis or with severe dyspnea.

In most avian species, the female has only the left ovary and oviduct. These structures are rarely visible unless they are enlarged or contain calcified material, such as an egg. However, in most situations in which the female is reproductively active, the engorged reproductive tract will cause cranioventral displacement of other coelomic contents. Contrast films are often helpful in differentiating enlarged bowel loops from the reproductive tract. The ovaries may be visible in reproductively active birds, especially when using digital radiographs. The testicles of the male may be visible as round, opaque structures at the level of the cranial pole of the kidneys. In some species, such as passerines and waterfowl, the testicles may increase greatly in size during the breeding season, which makes them more easily visible. The author has seen several cases of dyspnea in ducks with enlarged gonads and a history of metabolic bone disease that has resulted in spinal kyphosis. This is thought to be caused by decreased air sac space and is responsive to hormonal therapy.

**The Axial Skeleton**

The normal avian skeleton is lightweight as an adaptation for flight and the most notable radiographic finding is the relatively thin cortices and trabecular pattern seen in the axial skeleton. The humerus and the femur (in some species) are pneumatic, meaning the medullary cavities are contiguous with an air sac. This makes the medullary cavity even more radiolucent than the other bones. The number of cervical vertebrae in birds is not consistent as it is for mammals and varies between species. Generally, the longer the neck the more cervical vertebrae present. The thoracic vertebrae are associated with ribs and number eight in most psittacines. The lumbar vertebrae have been fused with the sacrum and several caudal vertebrae to form the synsacrum. The caudal vertebrae are present, with the most caudal bone being called the pygostyle.

The thoracic girdle is made of the coracoid, scapula, clavicle, and humerus. The coracoid is attached to the base of the keel, which is a ventral projection of the sternum. The coracoid functions to stabilize the shoulder joint for flight. The clavicles do not articulate with the shoulder joint but provide support during flight. The ulna is larger than the radius in birds. The secondary feathers are attached to the periosteum of the ulna. There are two carpal bones, the radiocarpal and the ulnarcarpal bones. The metacarpals are called the major and minor metacarpals, based on their size. The primary flight feathers are attached to the periosteum of the major metacarpal. The digit is composed of the major and minor proximal phalanx and the distal major phalanx.
The pelvic limb is composed of the femur, tibiotarsus, tarsometatarsus, and digits. The tarsal bones have fused with the tibia proximally and metatarsus distally, accounting for the unusual naming of these bones. The avian patella is very small and not usually visible radiographically. The fibula is present but incomplete and can be seen on the lateral surface of the tibiotarsus. Psittacines are zygodactyl, meaning there are two toes oriented cranially and two toes oriented caudally. This allows them to pick up and manipulate food and other items better than animals that are anisodactyl (three cranial toes, one caudal toe). The digits are numbered in a clockwise direction with the caudomedial digit being digit one. The number of phalanges in each digit is one greater than the number of that digit.

The most common boney change, other than fractures, in birds is hyperostosis from chronic egg-laying or hormonal stimulation. This is most commonly seen in small parrot species, but can occasionally be seen in larger parrot. There is loss of distinction from the cortices to the medulla, which resembles panosteitis in mammals.

Radiology of Ferrets and Rabbits

Radiography in ferrets and rabbits can be somewhat challenging but is also rewarding as the images are useful in assessing intra-abdominal and intra-thoracic structures for organomegaly or other problems and for monitoring disease progression and treatment. Interpretation of radiographs implies an understanding of normal anatomy. Several books and articles deal with the normal anatomy of rabbits and ferrets and should be kept at hand when performing these procedures. \(^5\-^8\)

Radiographic Technique

High-speed film and excellent machinery are important for diagnostic radiography in ferrets and rabbits. Machines with a milliamperage output of 500 to 1000 mA works best. Short exposure times of 1/60 to 1/120 seconds and kV output of 40-70 kV yield excellent results. \(^5\) Mammography machines and mammography film are excellent for optimal detail in small patients or small patient parts. These machines use similar mA with slightly lower kV. Dental films can also be used on small body parts such as toes and feet. In cases where the higher speed films are not available, good quality radiographs can be made with 300mA, short times of 1/30-1/120 seconds, and high detail film. Fine or detail intensifying screens and cassettes should be used to maximize detail. Most cassettes are used tabletop with the patient positioned directly on the cassette. Standard views include dorsoventral or ventrodorsal and lateral. The whole body is typically incorporated into each view because it allows a quick and easy assessment of the entire patient. Digital radiography is very useful in ferrets and rabbits and allows for better visualization by altering and enhancing the radiographic contrast. Systems and algorithms used for cats usually work well for ferrets and rabbits.

Contrast radiography can be done in rabbits and ferrets as in other mammals. Gastrointestinal disease, such as obstruction and foreign body, can be delineated in an upper gastrointestinal examination. Administer 10-15 ml/kg of barium sulfate liquid orally or by stomach tube. Mixing the barium with a human enteric supplement can
increase acceptance without changing the properties of the barium greatly. Radiographs are taken at 15-30 minute intervals until the contrast material reaches the colon. Iodinated contrast agent (2 ml/kg IV) can be used for excretory urograms to evaluate for urinary tract problems such as renal, ureteral, cystic, or urethral calculi. A urinary catheter can be placed to inject this material into the bladder for cystography. Expanding the urinary bladder to palpable turgidity allows detection of filling defects, diverticulae, ruptures, or aberrant bladder location.

**Patient Positioning and Preparation**

Ferrets are active by nature and don’t hold still well for radiographs unless they are ill. You can try manual restraint with sand bags and tapes if you provide slow, steady pressure to position the animal, especially the limbs. The author finds midazolam (0.3-1.0 mg/kg IM) to be an excellent sedative for mildly stressed or fractious patients. Ferrets are often well-sedated with the low dose of midazolam or butorphanol (0.3mg/kg IM). Ketamine (5-10 mg/kg IM or IV) can be added for skull films or unruly patients. Gas anesthetic alone may be adequate although it can be difficult for the animal to be still enough while being masked under. Using the lowest level of gas for 30 seconds, then slowly increasing by small amounts every 15 seconds tends to work the best in the author’s experience.

Rabbits are usually cooperative patients but can be stressed with improper or prolonged handing and restraint, especially if they are ill, therefore, proper restraint is necessary for patient safety and films of diagnostic quality. Moving slowly and quietly when positioning rabbits is usually adequate for orthongonal views of the thorax or abdomen. Debilitated animals may need supportive care before radiographs are attempted as their response to the stress may be detrimental. Anesthesia or sedation may be necessary for stressed or fractious patients, or for skull or spinal films. The choice of anesthetic agent varies with the practitioner and the area of interest. Isoflurane can be used by mask induction and can be maintained via facemask for most procedures. Again, start low and build up to the appropriate level of gas anesthetic. Ketamine (10mg/kg IV) and diazepam (0.5mg/kg IV) in rabbits provides excellent short-term sedation for skull films or CT scan. Skull films may require intubation or the mask can be quickly removed for the exposure then replaced immediately to maintain anesthetic depth.

**Thoracic Radiographs**

Ferrets have a long thoracic cavity and the heart is positioned more caudally than one might expect. The tracheal is long and bifurcates just dorsal to the heart. Cardiomegaly, with dorsal deviation of the trachea, is a common radiographic finding in ferrets with heart disease. There is usually a small amount of fat surrounding the heart in normal and obese ferrets. The apex of the heart touches the sternum, but does not usually have a large amount of contact with the sternum in the normal animal. The heart may be small in dehydrated patients. Lung pathology of ferrets is similar to other species.

Rabbits have a small thoracic cavities and large abdominal cavity compared to other companion animals. The normal heart is often slightly rounded and relatively wide. The cranial mediastinum may be prominent. Pneumonia is usually characterized by increased
thoracic opacification and pulmonary atelectasis. Differentiation of the pulmonary patterns is more difficult than in larger mammals. Neoplastic diseases appear as focal nodules early in the disease but progress to diffuse opacification. Pulmonary abscesses appear as consolidated areas within the lung parenchyma.

**Abdominal Radiographs**

The abdominal cavity of the ferret is relatively longer, but similarly structured to other companion animals. Male ferrets have a J-shaped os penis. A large fat pad may be seen around the kidneys and in the sub-lumbar area in obese ferrets. Splenomegaly is a common, usually non-pathogenic, finding in older ferrets. There is typically a moderate to large amount of intraperitoneal fat, which helps to improve visualization of abdominal contents. It is normal for ferrets to have some gas in the intestinal tract, but unusual for gas to be in the stomach.

The normal rabbit abdomen has a greater gas component than other mammals. The normal stomach should contain food. Gas should appear throughout the gastrointestinal tract in small, discrete pockets, but a large segment of distended bowel is abnormal. Poor serosal detail is common. The pattern of gas and digesta may make abdominal masses difficult to distinguish until they are fairly large. Rabbit urine may contain a large amount of calcium and may be appear as a contrast cystogram. Urinary calculi contain calcium in most cases and are easy to visualize. A urinary sludge can sometimes form instead of a discrete stone, this sludge settles out as a denser area ventrally.

**Computed Tomography**

Computed tomography (CT) scans have the same uses in ferrets and rabbits as in other species. CT scans are particularly useful in rabbits with dental disease. A spiral CT scan is often faster and provides detailed information about each tooth and tooth root, as well as the nasal cavity and bullae. We now prefer CT scans over skull films for routine examination in rabbits with dental disease.

**References:**