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AVIAN RESPIRATORY AND THORACIC SURGERY

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Anatomy and Physiology

The respiratory system of birds is significantly different, both physiologically and anatomically, from that of mammals. These differences are a result of adaptations to the demands associated with flight resulting in an extremely efficient gas exchange system allowing them to breathe at high altitudes (low O2 levels) and maintain their high metabolic rate. The nares are the beginning of the avian respiratory tract and may be located anywhere along the beak from the tip (kiwis) to the base. Some species have an operculum to filter large particles from inspired air. Birds have three conchae (rostral, middle, and caudal). The infraorbital sinus is the only paranasal sinus of birds and has a rostral diverticulum within the beak, the preorbital diverticulum rostral to the eye, the infraorbital diverticulum ventral to the eye, the postorbital diverticulum caudal to the eye and the mandibular diverticulum that extends into the caudal mandible. The nasal passages and sinus communicate with the choana, a normal anatomic cleft in the roof of the mouth. The choana has fine papillae along its margins. During respiration, the glottis abuts the choana allowing birds to breathe through the nares. The glottis of birds is simple with no epiglottis making them more susceptible to foreign body aspiration. The glottis is located at the base of the tongue and is usually accessible even in awake birds but is not involved in sound production.

The trachea is long compared with mammals with complete cartilagenous rings it bifurcates just cranial to the heart as the syrinx. The syrinx produces sound and is composed of modified tracheal cartilages forming flexible membranes to which muscles attach. The muscles are used to cause vibration producing sound. The trachea becomes narrower progressing caudally with the syrinx being the narrowest portion of the trachea which predisposes foreign objects to lodge and granulomas to form there. Each primary bronchus enters one lung and divides into secondary bronchi which further subdivide into parabronchi. Inspired air moves from the parabronchi into atria which open along the walls of the parabronchi. Air then flows into air capillaries, the avian analog of alveoli being the gas exchange site. However, unlike mammalian alveoli, air capillaries communicate with each other and with other atria so air cannot become entrapped and emphysema does not occur in birds. The lungs of birds are fixed adhered dorsally to the ribs and vertebrae. They do not expand and collapse during respiration. The lungs are directly connected to the air sacs of which there are 4-5 sets (cervical, interclavicular, cranial thoracic, caudal thoracic, and abdominal). The cervicocephalic air sac communicates with the infraorbital sinus and not directly with the lungs.

The respiratory cycle in birds is complicated but the majority of air requires two complete breathes to make it through. Most of the inspired air bypasses the lungs and goes into the caudal thoracic and abdominal air sacs during the first inspiration. During the first exhalation, air moves from these caudal air sacs into the lungs where gas exchange occurs. With the second inspiration, air moves from the lungs into the cranial air sacs and during the second exhalation it leaves through the trachea. This creates a unidirectional flow of air through the lungs. Blood moves in a direction opposite to that of air flow creating a counter-current exchange which is very efficient for gas exchange. Air is moved through the respiratory system by movement of the sternum so if a bird cannot move its sternum it will not be able to move air.

Air Sac Cannulae

A tube inserted into an air sac can obviate, at least temporarily, the need for respiration through the trachea. This can be a life-saving procedure in birds with upper airway obstruction. An air sac cannula can also provide a means by which oxygen and anesthetic gases can be supplied to birds while working on the mouth, sinus, trachea, glottis, choana, and the cranial coelomic cavity. The tube can be placed either in the caudal thoracic or abdominal air sac using one of two insertion sites. To place an air sac tube into the caudal thoracic, a nick incision is made just cranial to the thigh muscles over the last intercostal space. The intercostal muscles are penetrated using a mosquito hemostat to create a hole large enough to insert the tube. If the bird has a respiratory obstruction, as soon as the hole is created, air can be heard passing into and out of the hole. The tube is only advanced a few millimeters so it does not butt against internal structures. Suture the tube in place using a finger trap or butterfly tape technique.

The second site commonly used for insertion of an air sac cannula is caudal to the thigh muscles into the abdominal air sac. I find tubes placed in this location dislodge more easily. The leg is pulled cranially and a nick incision is made where the caudal thigh muscles cross the last rib. A mosquito hemostat is used to bluntly dissect just caudal to the last rib entering into the air sac. If the hemostat is too parallel to the body wall it will not penetrate the body wall but will dissect subcutaneously. Once the tube is inserted the leg is allowed to fall into a normal position and the tube is secured in place. It is probably best not to leave an air sac cannula in place more than 5 days and birds with air sac tube should be placed on a broad spectrum, systemic antibiotic.
Choanal Atresia

Choanal atresia has been reported mainly in African grey parrots. It is a failure of the choana to form during development. Patients present at an early age with a bilateral mucoid nasal discharge. In a normal bird, saline flushed in the nares should enter the mouth through the choana. In affected birds no saline enters the mouth. Instead, fluid enters the infraorbital sinus causing swelling around the eye. Reports are the early attempts to create a choanal opening into the rostral diverticulum routinely resulted in fatal hemorrhage. Dr. Don Harris reported a technique for creating a choanal opening. A 1/8th or 7/64th inch Steinmann pin is passed into each naris drilling through any bone to enter the mid-choanal slit in the roof of the mouth. The pin is removed and a length of 8 Fr red rubber is passed through the two openings created. The tip of the red rubber catheter is wedged into the end of a tomcat catheter which is stiffer and passes through the new hole in the bone easier than the red rubber. Minor hemorrhage may occur. Openings are cut into the side of the tube at the nares to allow mucus to drain through the tubes. The ends of the tube are crossed in the mouth and tied behind the head. A chin strap is made of tape to prevent the tube from slipping off the top of the head. The tubes are left in place for 4-6 weeks to allow the tracts to epithelialize creating permanent openings. The body must granulate and epithelialize along the tube tracts which can take months. As the scar tissue matures, it can stricture. Once the tubes are removed, the nares are flushed twice daily for 2 weeks to help keep the openings free of debris.

In some birds the openings close a day or two after tube placement. In these birds I have had success using a CO2 laser. The laser is set to achieve good coagulation which will cause more heat damage than when it cuts swiftly. As the soft tissues are cut, bone will be exposed. The bone is cut with a Steinmann pin or other device to create a large opening into the rostral diverticulum of the infraorbital sinus that will be too large to granulate closed. By diffusing the laser beam, hemorrhage can be controlled but can be significant. The surgeon should be prepared with blood or blood alternatives if needed. Packing thrombin soaked gauze into the new choanal opening will stop residual hemorrhage. The bird is already accustomed to not being able to breathe through its nose and the next day, under a brief period of anesthesia, the gauze packing is removed.

Sinusotomy

Sinusotomy is performed to curette caseous material, remove a mass, or debride a granuloma in patients with chronic, minimally responsive sinusitis. Often a nidus of infection is the cause of chronic nonresponsive sinusitis and if not found and surgically debrided, recurrence is common. In my study, birds had sinusitis for up to 8 yrs and were not responsive to various systemic antimicrobial medications. MRI or CT is very useful in localizing the lesion as the infraorbital sinuses of birds are very extensive. Knowledge of the anatomy of the sinus is vital. The infraorbital sinus (paired) is the only paranasal sinus of birds. It has numerous diverticula and communicates caudally with the cervicocephalic air sac. It opens dorsally into the middle and caudal nasal conchae.

To approach the rostral diverticulum (in the beak) a window is created with a bur through the lateral wall of the rhinotheca and underlying bone into the rostral diverticulum. A small curette is used to debride the lesion and collect samples for diagnostic testing (aerobic, anaerobic, fungal, histopathology). The defect is closed using a plastic or wire mesh (Beak Repair Kit, Ellman International, Inc.) glued to the rhinotheca and covered with a dental acrylic. With time, the defect will fill with granulation tissue, and epithelialize and keratinize, and the patch will be shed. Cosmetically the beak will appear normal. To approach the preorbital diverticula, an incision is made on the dorsal midline through the skin over the beak rostral to the beak-skull articulation but caudal to the keratinized beak and the cere. A bur is used to create an opening in the nasal bone which is enlarged with small rongeurs to expose the lesion. After samples are collected and the lesion is debrided, flushing drains are placed into the sinus to allow the area to be treated topically postoperatively. The bone is not replaced and the skin is closed.

For lesions in the infraorbital diverticulum, a dorsal midline approach through the frontal bone is used. The skin is incised and the bone is removed using a bur allowing access to the diverticulum. A flushing drain is placed through the frontal bone. Skin closure is as described above.

To access the suborbital, postorbital, preauditory or mandibular diverticula an incision is made in the skin ventral to the jugal bone on the affected side. It is best to place a speculum to keep the beak open which will enlarge the area accessible. The muscularis adductor mandibulae externus may need to be transected to access the lesion. It is repaired during closure. Penrose drains can be placed if needed. A subcuticular and a skin closure are used as there is little soft tissue support in this location.

Tracheotomy

Dyspnea can result from tracheal occlusion secondary to aspiration of foreign objects, formation of cellular and mucous concretions, or the presence of fungal granulomas. Some birds present with an acute onset of respiratory distress, while others may have a history of a change in vocalization and behavior, and progressive dyspnea. An air sac cannula will provide the patient with an airway until the obstruction can be relieved. Rigid and flexible endoscopes, suction, and balloon tipped catheters have been used to clear tracheal obstructions. In cases where less invasive methods fail, a tracheotomy is performed. Birds do not have recurrent laryngeal nerves innervating the abductors of the larynx. Instead, birds have only two
The patient is positioned in dorsal recumbency with the shoulders elevated 45° to provide visual exposure to the thoracic inlet. The skin over the specific area of the trachea is incised along ventral midline. The esophagus is to the right side of the midline and the crop bulges to the left at the coelomic inlet. Over the caudal portion of the trachea the crop must be dissected free from its subcutaneous attachments and retracted to the right to allow visualization of the trachea. The tracheotomy is made transversely through the ventral half of the animal between the sternal and vertebral ribs. The foreign object or granuloma is removed, the tracheotomy is closed.

If the object is located at the syrinx, a thoracic inlet approach is used. The skin is incised along the ventral midline of the thoracic inlet to the level of the clavicle. The crop is identified and dissected free from its attachments reflecting it to the right. The interclavicular air sac is broken down with further dissection will reveal the trachea which is easily identified by its complete rings. Sternotracheal muscles traverse obliquely along the trachea and attach to the sternum caudilaterally. These muscles are transected bilaterally to allow the trachea to be retracted farther orad. There is a blood vessel in each of these muscles which should be coagulated. Two stay sutures may be placed around tracheal rings orad to the obstruction to allow manipulations of the trachea following incision. A transverse tracheotomy is created 3–5 rings orad from the syrinx on the ventral surface to allow retrieval of the foreign material. All material is removed and samples are collected for diagnostics. An endoscope is passed per os and used to push any obstruction in the orad portion of the trachea into the tracheotomy incision. It may be passed through the tracheotomy to determine if an orad obstruction remains. Alternatively, a probang may be used to insure that the orad portion of the trachea is clear. Fine jeweler’s forceps and alligator forceps are useful for grasping objects. The fragility of the trachea is variable in birds. If the tracheotomy tears through or if rings are damaged beyond repair, a resection and anastomosis is easy to perform.

The trachea is closed using a fine, synthetic, nonreactive monofilament, absorbable material in a simple interrupted pattern. The tracheotomy is closed with as few sutures as possible with knots external to the lumen to minimize stricture formation. The sutures should be pre-placed and positioned at 45° circumferentially so that a 50% tracheotomy is closed with 2–3 sutures. They should encompass at least two rings on each side of the tracheotomy. Be gentle and careful. It is easy to pull rings off. Once the tracheotomy is closed, an endoscope is used to assure patency of the trachea. No effort is made to reattach the sternotracheal muscles and the remaining soft tissues are closed in a routine manner.

Tracheal Resection and Anastomosis
Resection and anastomosis of the trachea is indicated for birds with partial obstruction due to localized tracheal collapse, traumatic avulsion, stricture formation, neoplasia, or granuloma. The trachea is generally quite long in birds and removal of a section of tracheal wall is easy to accomplish without placing undue tension on the anastomosis. Since there are no recurrent laryngeal nerves to be concerned with, a section of the trachea can easily be removed and an anastomosis performed. Anesthesia is administered through an air sac cannula. The approach to the trachea is as described above. The adventitia surrounding the trachea is carefully dissected from the surface of the trachea to preserve the blood supply to the remaining trachea. A no.11 scalpel blade is used to transect the trachea both cranial and caudal to the diseased section to be removed. The ends are then held in approximation while 4–6 sutures are repositioned circumferentially in a manner analogous to that described above. The dorsal sutures are tied first while access is easier. Stricture may occur at the anastomosis site but has been rare in my experience generally occurring during the maturation phase of healing 3–6 weeks postoperative.

Lateral Thoracotomy
Lateral thoracotomy is indicated for management of diseases of the syrinx, bronchi, lung, pericardium, or thoracic air sacs. The approach will vary with the location of the disease process being investigated. In most cases an intercostal approach with resection of a portion of the 2nd and 3rd ribs will provide exposure to the ipsilateral syrinx, bronchus, lung, and the heart. The patient is positioned in lateral recumbency with the wings extended dorsally over the back and the legs retracted caudally. The caudodorsal border of the superficial pectoral muscle is palpated and the skin incision is made along this muscle border. The insertion of the pectoral muscle is incised and the muscle is elevated allowing it to be retracted ventrally. A curved hemostat is inserted under the pectoral muscles until it can be felt dropping into the thoracic inlet. It is then pulled caudally over the ribs so that each rib can be felt. This will assure that the appropriate ribs are accurately identified. The intercostal vessels course along the cranial border of each rib. A window will be created by removing a segment of 2–3 ribs. The appropriate ribs are identified and the intercostal vessels are coagulated using bipolar electrosurgical forceps at the dorsal and ventral aspects of the proposed window. They are then transected with scissors ventral to the uncinate process and as close to the junction of the sternal and vertebral ribs as possible. The large pectoral muscles make it difficult to achieve ventral exposure and will need to be retracted ventrally. If the ribs are cut too far dorsally, the lungs will be damaged. The section of ribs is removed allowing access to the thoracic cavity. An endoscope can be inserted into the thoracotomy to allow visualization of the intrathoracic structures. The
endoscope provides magnification and can pass into tight spots providing visual access to locations the surgeon cannot see directly. A moist cotton tipped applicator is used to gently dissect air sacs and other structures to allow visualization of blood vessels, heart, syrinx, bronchi and lung. Dissection between the jugular vein, pulmonary artery and branches of the subclavian artery will allow visualization of the syrinx.

**Bifid Sternum**

Since this syndrome was published, I am aware of bifid sternum in 4 African grey parrots, a wild pigeon, a Quaker parakeet (*Myiopsitta monchus*), and an umbrella cockatoo. It is characterized by a failure of the two halves of the sternum to close during embryonic development. The bird’s heart is visualized beating just under the skin. In adult birds, apposition of the two halves is not possible because the sternal bone is too hard; however, in young birds it is often possible to pull the two halves of the sternum together with sutures.

The skin is incised along the ventral midline being careful not to damage the heart immediately below the surface of the skin. The liver is visualized at the caudal aspect of the incision. The pectoral muscles are elevated from the sternum using a periosteal elevator. Dissection is continued laterally until the entire muscle is freed from the sternum and ribs. The existing portions of the keel are cut off using scissors. The pectoral muscles are advanced to midline and sutured in a simple interrupted pattern. Because of the unique avian respiratory anatomy, this is accomplished without respiratory compromise. The skin is closed routinely. This provides a thick pectoral muscle pad to protect the heart. It is not likely that this defect will cause cardiopulmonary dysfunction as it does in humans.

In human infants surgery is performed within the first few days of life. During this time, the sternum is more pliable and the two halves are simply affixed together at midline. Dr. Michele Curtis has done a similar procedure in a neonatal bird. The two halves of the sternum were pulled together with sutured establishing a more normal rib and sternal cage.