THE EXPLORATORY COELIOTOMY

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INTRODUCTION

Advances in both human and veterinary medicine have meant that in cases of coelomic disease in birds the clinician has access to a wide of diagnostic imaging tools. Digital radiology, Computerised Tomography (CT), Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET) scanning, and endoscopy have enabled avian veterinarians to better 'visualise' and diagnose coelomic disorders in birds.

But, better diagnostics does not always equate to better diagnosis. In a paper reviewing the diagnosis of insulinoma in dogs, Robben et al. (2005) concluded "Intra-operative inspection and palpation of the pancreas is more effective than any of the imaging techniques." In other words, the surgeon's eyes and hands remain one of the most sensitive and specific diagnostic tools at the disposal of veterinarians.

INDICATIONS FOR COELIOTOMIES

Coeliotomy is indicated for both the diagnosis and treatment of conditions detected by physical examination, imaging (radiography, ultrasound or endoscopy) or laboratory testing (biochemistry and haematology). It is also useful for the diagnosis of cases involving persistent, non-specific clinical signs that prove to be unresponsive to medical management, including weight loss or polyuria. Less invasive entry to the coelomic cavity, using rigid endoscopy, while allowing high magnification and access for biopsy (Hernandez-Divers, 2005) to most organs, does not give the breadth of surgical procedures when compared to a coeliotomy.

Some of the common indications for coeliotomy include (Bennett and Harrison, 1994):

1. **Reproductive disease**
    a. Hens:
        i. decreased egg production
        ii. unusual egg production
        iii. egg binding
        iv. yolk-related peritonitis

v. uterine/ovarian cysts
vi. neoplasia
vii. hernias

b. Cocks:
i. testicular neoplasia
ii. orchitis

2. **Gastrointestinal conditions**
a. foreign bodies (glass, metallic objects or fibrous)
b. biopsy of the liver, pancreas and gastrointestinal tract
c. Cloacopexy

3. **Miscellaneous abdominal conditions**
a. Renal biopsy
b. Ascites
c. Neoplasia
d. Abscesses

RELEVANT ANATOMY

Avian skin is attached to both the underlying muscles and to the skeleton. It consists of the thin epidermis (only 10 cell layers deep) and the thicker underlying dermis. Feather follicles originate from the dermis. True glands are absent from much of the skin, although epidermal cells may secrete a lipoid sebaceous material. The unique structure of avian skin is the feathers. These arise from feather follicles, arranged in tracts around the body known as pterylae. The featherless skin between these tracts is called apterylae. Wherever possible, skin incisions should be made through these apterylae.

Subcutaneous fat is present in many birds; most birds do not store fat in their pectoral region, but rather over their abdomen and flanks. Obese or overweight birds can carry significant deposits in these areas.
There are four abdominal muscles in two layers: the external layer is comprised of the external abdominal oblique and the rectus abdominus; the inner layer is comprised of the internal abdominal oblique and the transverse abdominal. All four muscles work together to compress the abdomen during expiration.

Muscle	Origin	Insertion
External abdominal oblique	Lateral surface and uncinate processes of the ribs	Costal margin of ribs, caudal sternal processes and *linea alba*
Internal abdominal oblique	Cranioventral pelvis	Caudal border of last rib
Transverse abdominal	Ventral pelvis and medial ribs	Linea alba, sternum
Rectus abdominus	Caudoventral pubis and inter-pubic ligament	Sternum, running parallel to *linea alba*

The only blood vessels of note when performing a coeliotomy are the superficial medial femoral artery and vein traversing (in a dorsoventral direction) the lateral abdominal wall, medial to the coxofemoral joint. These are superficial and are usually visible once the skin has been incised.

Once the coelom has been entered via a flank approach, the air sacs are encountered. The caudal thoracic airsacs are found caudal to the cranial thoracic airsacs and arise from the lateroventral secondary bronchi and primary bronchi. The abdominal airsacs arise from the lateroventral secondary bronchi and primary bronchi and lie between the caudal thoracic airsacs. They are the most variable in size, but are often the largest airsacs and carry air to the leg and pelvic bones. The airsacs are usually only minimally vascularised (if at all) and can be incised readily. This will, however, have the effect of lightening the patient's anaesthesia as it begins to inspire through the open abdominal wall. The air sacs are not immediately encountered on the ventral approach until viscera is reflected.

On entering the coelom the underlying viscera can be examined. This includes the gastrointestinal tract, the liver, the pancreas, the reproductive tract, the kidneys, and the spleen. The coelom is lined with a thin peritoneal layer, and many of the visceral organs are suspended within the coelom by folds and projections of the peritoneum.

There is no obvious boundary between the thoracic oesophagus and the proventriculus, other than a lack of internal folds. Between the proventriculus and the gizzard is the Intermediate Zone, a variably-developed region with a microscopic structure intermediate somewhere between the two. It may narrow to form an isthmus between the proventriculus and gizzard. The gizzard (or ventriculus) varies in size and shape between species. Those species that eat soft food (e.g. lorikeets) have smaller, rounder gizzards, which can be difficult to distinguish from the proventriculus. Other species have a thickened, biconvex gizzard.

The duodenum forms a narrow U-shape on the right side of the gizzard, with the descending duodenum proximal to the ascending duodenum. The jejunum and ileum is usually arranged in a number of narrow U-shaped loops at the edge of the dorsal mesentery on the right side of the abdominal cavity. The vitelline (Meckel's) diverticulum is the short blind remnant of the yolk sac; it can be used to differentiate jejunum from ileum. The large intestine is very short, separated from the ileum by the ileorectal sphincter. In some species, caeca arise from the rectum at the junction of the rectum with the ileum. Their form and size vary, and they are reduced or absent in parrots, swifts and pigeons.

The avian pancreas consists of three lobes. The dorsal and ventral lobes are supported and separated by the pancreatic artery within the duodenal loop, and the splenic lobe runs more laterally up to the spleen, as an extension of the ventral lobe.

The avian liver consists of the right and left lobes joined cranially in the midline. The right lobe is larger than the left, with each lobe having several small processes. The liver is enclosed in a thin and slightly elastic capsule of connective tissue, allowing its expansion. Blood is supplied to the liver by the right and left hepatic arteries and hepatic portal veins. The hepatic arteries arise from the coeliac artery, while the portal veins drain blood from the proventriculus, ventriculus, duodenum, pancreas, intestines and cloaca. Two hepatic veins join the caudal vena cava cranial to the liver, draining blood away from the liver.

The kidneys lie in the renal fossae of the synsacrum, each divided into 3 divisions (caudal, middle and cranial). The distinctions between these divisions are not always clear. The spinal nerves and sacral

plexus pass through the kidneys between middle and caudal divisions. The surface of the kidney is covered in rounded projections, the renal lobules.

Most birds only have one ovary, located beside the cranial division of the left kidney, adjacent to the adrenal gland. Some birds do, however, have a right ovarian remnant which can be physiologically active. The ovarian blood supply enters the ovarian hilus where it is close contact with the dorsal coelomic wall. The arterial supply come from the ovario-oviductal branch of the left cranial renal artery, while venous drainage is via two ovarian veins directly into the caudal vena cava. This vascular anatomy makes ovariectomy a difficult and dangerous procedure to undertake, requiring optical magnification and specialised ligating instruments.

The oviduct can be divided into five regions: the infundibulum, the magnum, the isthmus, the uterus (shell gland) and the vagina. It is suspended from the dorsal wall of the coelom by the dorsal mesosalpinx. A ventral mesosalpinx extends ventrally from the oviduct, but has a free margin. Smooth muscle in both ligaments is continuous with smooth muscle layers of oviductal wall and caudally the smooth muscle in the ventral ligament condenses into a muscle chord fused with the ventral surface of the uterus and vagina.

Like the female embryo, the male embryo initially develops a larger left testicle. Unlike the right ovary, however, the right testicle does not regress, so that while the left testis is often larger than right in immature bird, this changes after maturity so that both are similarly sized. Suspended by the mesorchium, the testicles are surrounded, but not cooled, by the abdominal air sacs. The epididymis lies on dorsomedial side of the testis and is relatively small compared to mammals. It enlarges during sexual activity, but has no distinct head, body and tail. The ductus deferens runs from the epididymis to the cloaca, entering the cloaca at the urodeum.

The paired avian adrenal glands are located anterior and medial to the cranial division of the kidney. They are flattened and lie close together, even fusing in some species. Their arterial blood supply comes from branches of the renal artery, and each gland has a single vein draining into the posterior vena cava.

The spleen is found on the right side of the junction between the proventriculus and the ventriculus. It varies in size and shape; it may be round, elongated or slightly triangular, depending on species of bird.

EQUIPMENT

The majority of the equipment needed for an exploratory coeliotomy can be found in the ophthalmic surgical pack in most small animals. This includes instruments such as iris scissors, straight Castroviejo's corneal scissors, small and medium Mayo scissors, small haemostats and artery forceps (straight and curved), micro adson forceps, adson dressing forceps (no teeth), and needle holders. Eyelid retractors can be used, but the authors find they frequently 'clutter up' the surgical site. Lonestar® retractors offer a better alternative (Mehler, 2011), giving better exposure without impeding the surgeon's operating field.

Cotton-tipped swabs are very useful in avian surgery for both swabbing a surgical site and for blunt dissection. Along with gauze swabs, they are an essential item in an avian surgical kit.

Radiosurgery and haemoclips are frequently employed by some – but not all – surgeons. Familiarity and experience with their use is essential.

The choice of drapes is the surgeon's preference, with clear plastic (adhesive or non-adhesive) or cloth drapes both been available. The clear plastic drape has the advantage of transparency, making patient monitoring easier, but tend to be cumbersome and, unless adhesive, move frequently during the procedure. The cloth drapes, on the other hand, do not move as freely but can make patient monitoring problematic.

The requirements for a suture in avian surgery are that it must provoke minimal tissue reaction while still been absorbable, and provide good knot security. Monofilament sutures are preferred by many to braided sutures, which sometimes act as a wick to allow transport of serum and bacteria. Chromic gut produces a marked, granulocytic inflammatory response with a prolonged presence (>120 days) and is not recommended. Polyglactin 910 (Vicryl®) is a synthetic, braided, absorbable suture of glycolic acid and lactic acid. It produces an intense inflammatory reaction but is readily absorbed (60 days). Polydioxanone (PDS®) is a monofilament, synthetic, absorbable polymer of paradioxanone. It has minimal reactivity but retains its integrity for long periods. Nylon is a monofilament suture. It produces some degree of fibrosis, haematoma, seroma, and caseogranuloma formation. Newer suture materials (e.g. Vicryl Rapide) are becoming available but have not been evaluated fully in avian surgery as yet.

Other equipment such as biopsy forceps, culture swabs, and formalin bottles, etc should be readily available if biopsy is contemplated as part of the coeliotomy.

ANAESTHESIA

Some coeliotomies require only a brief anaesthetic, for example to drain fluid or to explore one particular aspect of the coelom. For these short procedures maintenance of anaesthesia via a face mask may be all that is required. For longer procedures intubation may be advisable. It must be noted once an air sac is open to room air; spontaneous ventilation through the open air sac will result in a lightening of the anaesthetic depth and the exposure of staff in the operating theatre to anaesthetic gases.

Birds have a high surface to body volume ratio and will lose body heat quickly when not active or when their metabolic rate slows. The rate and amount of heat loss is directly proportional to the size of the patient (the smaller the bird, the faster and greater the heat loss). Opening the coelomic cavity worsens the temperature drop. Numerous techniques have been devised to prevent hypothermia in anaesthetised patients and are listed below. It must be noted, though, that regardless of the thermal support provided, the patient's body temperature will start to decline after approximately 20 minutes of anaesthesia. One of the most important means of minimising this heat loss is to have a plan and preparations in place before inducing anaesthesia to minimise the anaesthetic time. Other techniques that have been advocated include:

- Warmed intravenous fluids throughout the procedure
- Warmed and humidified anaesthetic gases
- Radiant heat from overhead heat lamps
- Heated air units (e.g. the Bair Hugger®)
- Heat pads do not appear to be overly effective in providing heat support to avian patients

With prolonged anaesthesia for coeliotomy (especially in patients that develop hypothermia, hypoglycaemia, or hypovolaemia), the patient's respiratory rate may slow and even stop. Cardiac arrest usually follows soon after. Adequate respiratory support, in the form of supplemental ventilation, is therefore essential for most avian anaesthetics. Intermittent Positive Pressure Ventilation (IPPV), performed either manually or by a ventilator, should be instituted early in the anaesthetic process, rather than waiting for problems to develop.

SURGICAL APPROACHES TO THE COELOMIC CAVITY

The two common approaches for a coeliotomy are the ventral mid-line and the left flank approaches. The ventral mid-line approach allows the visualisation of the majority of the ceolomic organs but does not allow easy access to the proximal reproductive tract nor the proventriculus. All coeliotomies carry a moderate risk of fatality with neither approach having a higher survival rate nor a lower level of complication. Complications on entering the coelomic cavity via the ventral mid-line approach include iatrogenic damage to the intestine and cloaca while on the ventral mid-line approach damage to the proventriculus may occur. Iatrogenic damage to an enlarged liver is possible on either approach.

Care must be taken to avoid compromising the airsacs either by compression during and post coelomic surgery or by allowing the pooling of fluid within the airsacs. Subcutaneous emphysema may be an occasional post coelomic surgical complication of coelomic airsac incision.

Ventral mid-line approach

The ventral midline approach allows access to the abdominal air sacs, oviduct (Nemetz, 2010), intestinal tract, liver, and pancreas (Doneley, 2008). The kidneys and gonads may also be accessed after elevating the intestines.

Place the bird in dorsal recumbency with the cranial end of the body elevated 30^{o}-40^{o}. (This helps to reduce the risk of fluid entering the lungs once the air sacs are opened.) Incise the midline of the abdominal skin from 2-5 mm distal to the sternum and continue towards the prepubic space. Avoid incising distally into the peri-cloacal blood vessels. To allow greater exposure, the incision can be extended laterally at the proximal and distal ends of the incision to create flaps. This will form a "C" shaped incision with a unilateral flap or an "I" shaped incision with bilateral flaps. (Lateral flaps increase abdominal viscera visualisation but they also allow increased anaesthetic gas and heat loss through the open abdominal cavity.) Many species have a relatively large superficial vein located subcutaneously on the ventral abdomen. This vessel needs to be ligated or cauterised prior to entering the coelomic cavity. (If an abdominal hernia is suspected, care must be taken to avoid iatrogenic damage to intestines adhered to the internal abdominal skin. When adhesions are present, break them down with a cotton tip or find an alternative incision site.) The linea alba is tented and incised in a cranio-dorsal direction to avoid the underlying viscera. If reproductive disease is present, caution should taken on incising into the coelomic cavity to avoid possible visceral adhesions to the abdominal musculature and coelomic cavity wall.

Left flank approach

The left flank approach allows access to the gonads, left kidney, oviduct, proventriculus, and ventriculus (Bailey, 2001).

Place the bird in right lateral recumbency with the cranial end of the body elevated 30 ^{o} – 40^{o} to prevent fluid entering the lungs. Extend the wings dorsally and secure into place. Abduct the left leg and draw it slightly forwards.

Incise the inguinal skin web between abdominal wall and left leg and abduct the leg further. Continue this incision from the 6th rib to the level of the left pubic bone. Cauterise the superficial medial femoral artery and vein where they transverse (in a dorsoventral direction) the lateral abdominal wall medial to the coxofemoral joint. Tent the muscles (external, internal abdominal oblique and transverse abdominal muscles) up and make a stab incision with pointed scissors while protecting the underlying viscera. Extend this incision from the pubic bone to the 8th rib. This will require transecting the last 2 ribs, which is done by passing bipolar forceps around the rib, cauterising the intercostal blood vessels and then cutting the ribs with scissors. Use a retractor to allow visualisation of internal organs. The air sacs will need to be transected to access the gonads and abdominal viscera. Be aware of the effect this will have on inhalation anaesthesia.

WOUND CLOSURE

Regardless of the approach used, closure is performed in 2-3 layers. Firstly the muscle is closed with absorbable sutures in continuous or interrupted pattern. Then, if necessary, the subcutaneous fat is apposed, and then finally the skin in separate layers. No attempt is made to rejoin transected ribs or the peritoneum.

POST-OPERATIVE CARE

Birds recover quickly from gaseous anaesthesia. To avoid self trauma from uncontrolled wing flapping during the excitement phase of recovery, some birds need to be partially restrained in a towel. The bird should be placed in a cage with minimal fixtures and with no food or water until the bird is upright. Supplemental heat should be supplied post surgery until the bird is capable of maintaining thermal homeostasis. There may be some advantage in administering a small amount of glucose or recovery supplement (e.g. Polyaid®, Vetafarm) as soon as the bird is perching. Once awake, the bird should be closely monitored for signs of distress or haemorrhage, for at least 1-2 hours, and regularly monitored for a period of 6-12 hours. If mild haemorrhage is present, it can often be contained with a light abdominal pressure bandage. Analgesia should be provided in the recovery period (Divers, 2010). Non-steroidal anti-inflammatory drugs should not be used peri-operatively or in dehydrated birds. Antibiotic therapy may be required if infection is suspected or sterility has been compromised during the surgery. Skin sutures are removed (if desired) 12-14 days after surgery.

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