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Original Study

Outcomes and Complications Associated With Caudal Thoracic and Abdominal Air Sac Cannulation in 68 Birds

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Abstract: Air sac cannulation is used both as an emergency procedure in avian patients with severe upper respiratory compromise, as well as a means of routine ventilation for surgery of the head and neck. The objective of this retrospective study was to describe and quantify the complications associated with air sac cannulation in birds. Medical records were retrieved for all patients that underwent caudal thoracic or abdominal air sac cannulation at a single center between August 2004 and October 2020. Patient signalment, indication for air sac cannulation, location of air sac cannula (ASC) placement, occurrence and category of complications encountered, and survival data were recorded. Eighty-four ASCs were placed in 68 birds across 6 orders; 95.2% (80/84) of cases survived general anesthesia for initial ASC placement. The side and position of ASC placement were known in 33.3% (28/84) and 21.4% (18/84) of cases, respectively. Survival to ASC removal was known in 91.3% (73/80) of cases; 43 (58.9%) of these 73 cases survived to ASC removal. Complications were observed in 32.5% (26/80) of cases, and 11.5% (3/26) of cases died as a direct result of the complication. The most common reported ASC complication was loss of patency in 23.8% (19/80) of cases. Increased likelihoods for complications were seen in cases where exercise intolerance ($P = 0.04$) or abnormal respiratory sounds ($P = 0.04$) were reported at presentation. Increased likelihoods for survival to ASC removal were seen with intercostal placements ($P = 0.049$) and peri-interventional antibiotic therapy ($P = 0.005$). Decreased likelihood for survival to ASC removal was seen in cases where voice change was reported at presentation ($P = 0.02$). This study demonstrates a moderate risk of ASC complication, with a guarded overall prognosis for survival to ASC removal.

Key words: respiratory, complication, air sac cannula, avian

INTRODUCTION

The unique features of the avian respiratory system allow for the strategic bypass of the upper respiratory tract. Because the action of ventilation is separate from the process of gas exchange in birds, inhaled gases can enter the respiratory system caudal to the lungs and still participate in pulmonary gas exchange.[1,2] Air sac cannulation is a well-described technique in avian medicine and surgery; indications include the emergency maintenance of respiration in patients with airway obstruction cranial to the lungs, and for routine air sac perfusion anesthesia to facilitate research or surgery of the skull, beak, and soft tissues of the head and neck.[3–6] Air sac cannulation can be utilized in the management of cases of tracheal obstruction, including inhaled foreign bodies, fungal granulomas, diphtheritic plaques, tracheal strictures, and tracheal stenosis. The placement of an air sac cannula (ASC) also permits the use of air sac perfusion anesthesia, whereby gas anesthetic agents are delivered directly to the air sacs in cases where endotracheal intubation would interfere with a surgical procedure or patient positioning, or where controlled apnea and complete patient immobilization is desired.[7]

Despite being a well-described technique, little information exists that describes patient outcomes after ASC placement. Although the placement of an ASC is discussed in several case reports, and

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utilization of the technique has been a feature of several studies, a review of patient morbidity and mortality associated with air sac cannulation in the clinical setting has not been reported.[8–13] The types of complications that may be encountered with air sac cannulation have been well described; however, no studies describe the rates, or implications, of ASC complication.[6,14] The purpose of this retrospective study was to evaluate the data available to describe the outcomes, prevalence, and types of complications seen in avian patients after abdominal or caudal thoracic air sac cannulation and to identify any known variables that may affect these factors. The hypotheses for this study were: 1) complications following air sac cannulation are commonly encountered in avian species due to the inherently invasive nature of this procedure, 2) patient and intervention variables impact the likelihood of a patient to encounter ASC complication(s), 3) mortality rates following air sac cannulation are high due to the severity of the disease indications for air sac cannulation, and 4) patient and intervention variables, as well as whether or not a patient encounters any ASC complications, impact patient mortality following air sac cannulation.

MATERIALS AND METHODS

Medical records for all avian patients that underwent caudal thoracic or abdominal air sac cannulation at a single first opinion with referral to an avian and exotic species veterinary hospital in the United Kingdom between August 2004 and October 2020 were screened. Patient records were retrieved through veterinary practice database software (RxWorks Veterinary Software, Brisbane, Queensland, Australia) by searching and manually filtering through the records of any avian patient that had been billed the standard procedure billing code for, or that had medical notes pertaining to, air sac cannulation. Any avian patient that underwent caudal thoracic or abdominal air sac cannulation, or both, was included in the study.

Every avian patient included in this study was induced and maintained under general anesthesia with isoflurane in a 100% oxygen flow. The veterinary hospital's protocol for ASC placement was to prepare a surgical site aseptically in the region of the paralumbar fossa by plucking feathers (if required), followed by cleaning of the skin with a 1:1 or 1:2 diluted chlorhexidine solution. The exact procedure for air sac cannulation will have varied between clinicians, although it was generally encouraged at the veterinary hospital to place ASCs on the left side between the last 2 ribs, and to secure the cannula at a depth of approximately one-third the thoracic width by means of a single suture placed around the last rib before skin closure. All ASCs at the hospital were single use and purpose made through the modification of uncuffed, bevel-tipped, polyvinyl chloride endotracheal tubes; the modifications included the creation of at least 2 fenestrations at the terminal end of a shortened endotracheal tube (similar to the Murphy eye found on endotracheal tubes), and the circumferential placement of a length of monofilament nylon suture before packaging and thermal sterilization (Fig 1). Packaged ASCs were resterilized approximately every 6 months after initial sterilization if they remain unused. All ASCs were manually inspected to ensure integrity before placement, and any that had become rigid, brittle, or deformed with repeat autoclave cycles were discarded.

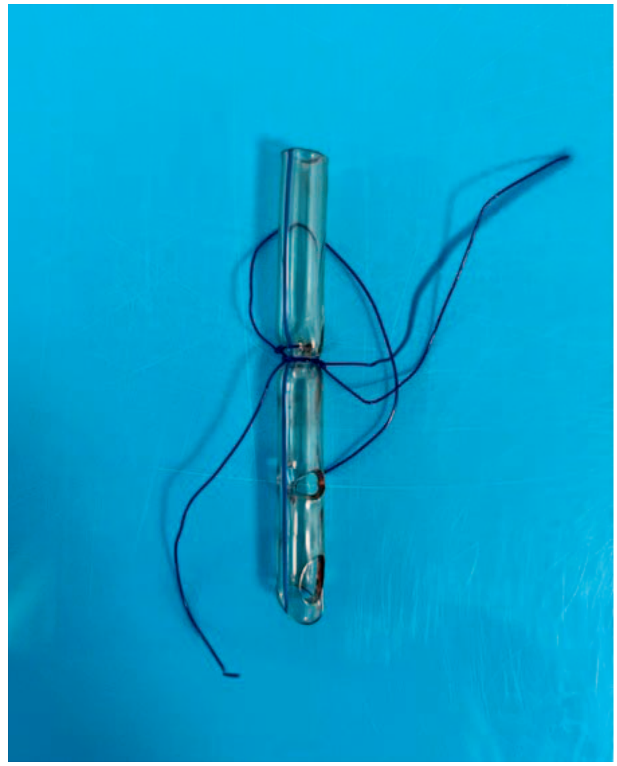

Figure 1. An air sac cannula made from a modified bevel-tipped polyvinyl chloride endotracheal tube, including two pre-placed circumferential monofilament nylon sutures and two additional fenestrations created above the Murphy eye at the terminal end of the cannula.

Each instance of air sac cannulation was considered an individual case, and when a patient had multiple ASCs placed, these were recorded as separate cases. Data for each variable were only recorded if explicitly stated in, or could be otherwise conclusively determined from, the patient's medical records. Patient signalment (species, age, and sex) and weight at the time of air sac cannulation were recorded. Other patient variables recorded for each case included the clinical disease signs reported at case presentation, the indication for ASC placement, duration and location of air sac cannulation, the total number of previous ASCs placed and the total number of days between any previous ASC placements, the presence of any known organomegaly or air sac disease (as determined by reviewing the imaging reports for any concurrent radiography, computed tomography, coelomic ultrasonography, or coelioscopy performed), details of other therapeutics provided, and the duration of hospitalization after ASC placement. Complication data recorded for each case included the category and clinical implications of any ASC complication encountered. Outcome data recorded included the overall survival time, survival to ASC removal, and 7- and 30-day survival after ASC placement.

Data assessment and statistical analyses were performed using a commercially available statistics software (SPSS® Statistics Version 28.0, IBM Statistics, Armonk, NY, USA). Data for patient age and weight, the total number of days ASCs were left in place, the total number of previous ASCs placed, and the number of days between ASC placements were each assessed for normality using the Shapiro-Wilk test. Descriptive statistics for patient characteristics, therapeutics, and patient outcomes were performed, and the results were reported as a median and range. Univariate analyses were performed using Fisher's exact test and binary logistic regression to compare all known patient variables against the recorded complication variables. All known patient and ASC complication variables were further compared against all known patient outcome variables. For patients that underwent more than one ASC placement, only the first instance of air sac cannulation was included, resulting in the exclusion of 19% (16/84) of the cases from the statistical testing. Results were presented as odds ratio (OR) and 95% confidence interval (CI), and $P \leq 0.05$ was considered significant.

RESULTS

Patient characteristics and presenting clinical signs

A total of 84 cases of air sac cannulation in 68 client-owned birds were included. The median age was 6.5 years (range 0.2–35.5 years), and median bodyweight was 420 g (range 48–3410 g). Patient age was unknown in 17.9% (15/84) of the cases, and bodyweight was not recorded in 16.7% (14/84) of the cases. The patient was male in 33.3% (28/84) and female in 40.5% (34/84) of the cases. The sex was unknown in 26.2% (22/84) of the cases. The study population comprised 28 species of bird from across 6 orders (Table 1); birds from the order Psittaciformes (72.6%, 61/84) were overrepresented, and the African grey parrot (*Psittacus erithacus*) was the most frequently encountered species (30.9%, 26/84). The most frequently reported presenting clinical signs were dyspnea (86.9%, 73/84) and a change of voice (26.2%, 22/84) (Table 2). Information available to classify the respiratory pattern further was insufficient for cases where dyspnea was reported.

Comorbidities

Coelomic imaging was performed in 67.9% (57/84) of the cases, and a complete imaging report was available for all 57 cases. Concurrent organomegaly or nonascitic or generalized abdominal distension, which was defined as a swollen or enlarged abdomen that could not be clearly attributed to a single enlarged organ in the absence of free fluid in any coelomic cavity, was described in 40.4% (23/57) of the cases (Table 3). Of the 23 cases where coelomic organomegaly or distension was reported, 34.8% (8/23) of the cases had more than 1 enlarged organ. Concurrent air sac disease was identified in 28.1% (16/57) of the cases. Details of other comorbidities were inconsistently available and, as such, were not assessed further.

Air sac cannulation

The study included ASCs placed by 17 clinicians who work solely with avian and exotic species. In 98.8% (83/84) of the cases, the patient required air sac cannulation for the management of airway disease (Table 4). The most frequently encountered primary indication for air sac cannulation was the presence of a tracheal or syringeal granuloma, or both, in 54.8% (46/84) of the cases; these lesions were confirmed by performing a tracheoscopy procedure in every case. In a single case (1.2%, 1/84), the patient presented with previously diagnosed bilateral cataract formation and underwent routine air sac perfusion anesthesia for cataract surgery. The indication for air sac cannulation was not reported in 2.4% (2/84) of the cases.

The median number of days an ASC was left in situ was 3 days (range 1–30 days). A previous ASC

Table 1. Total number of cases in which an air sac cannula was placed grouped by order, genus, and species.

Order	Genus species (common name)	n (%)
Psittaciformes	*Psittacus erithacus* (African grey parrot)	26 (31)
	Ara ararauna (blue-and-gold macaw)	6 (7.1)
	Cacatua sulphureous (lesser sulphur-crested cockatoo)	4 (4.8)
	Nymphicus hollandicus (cockatiel)	3 (3.6)
	Amazona autumnalis (red-lored Amazon)	2 (2.4)
	Aratinga jandaya (jenday conure)	2 (2.4)
	Eolophus roseicapilla (galah)	2 (2.4)
	Poicephalus senegalus (Senegal parrot)	2 (2.4)
	Psittacula eupatria (Alexandrine parakeet)	2 (2.4)
	Pyrrhura spp. (conure species)	2 (2.4)
	Amazona aestiva (blue-fronted Amazon)	1 (1.2)
	Anodorhynchus hyacinthinus (hyacinth macaw)	1 (1.2)
	Ara ararauna × *Ara chloroptera* (harlequin macaw)	1 (1.2)
	Ara chloropterus (green-winged macaw)	1 (1.2)
	Cacatua haematuropygia (red-vented cockatoo)	1 (1.2)
	Myiopsitta monachus (monk parakeet)	1 (1.2)
	Poicephalus robustus (Cape parrot)	1 (1.2)
	Cyanoramphus sp. (Kākāriki)	1 (1.2)
Total		61 (72.6)
Accipitriformes	*Parabuteo unicinctus* (Harris hawk)	8 (9.5)
	Accipiter gentilis (northern goshawk)	4 (4.8)
	Circus cyaneus (hen harrier)	1 (1.2)
	Haliaeetus albicilla (white-tailed eagle)	1 (1.2)
Total		14 (16.7)
Bucerotiformes	*Penelopides* spp. (hornbill species)	3 (3.6)
Total		3 (3.6)
Falconiformes	*Falco jugger* (laggar falcon)	1 (1.2)
	Falco peregrinus (peregrine falcon)	1 (1.2)
	Falco tinnunculus (common kestrel)	1 (1.2)
Total		3 (3.6)
Stringeiformes	*Tyto alba* (western barn owl)	1 (1.2)
	Tyto sp. (barn owl species)	1 (1.2)
Total		2 (2.4)
Galliformes	*Gallus gallus domesticus* (domestic chicken)	1 (1.2)
Total		1 (1.2)

Abbreviation: n, number of cases.

Table 2. Presenting clinical signs in 84 cases in which an air sac cannula was placed.

Clinical sign	n (%)
Change of voice	22 (26.2)
Exercise intolerance	5 (6)
Abnormal respiratory sounds	4 (4.8)
Dyspnea	73 (86.9)
Nasal discharge/rhinolithiasis	3 (3.6)
Malaise/lethargy	3 (3.6)
Weight loss	3 (3.6)
Cyanosis	2 (2.4)
Regurgitation/vomiting	2 (2.4)
Cough	1 (1.2)
Diarrhea	1 (1.2)

Abbreviation: n, number of cases that presented with described clinical signs.

Table 3. Frequencies of organomegaly and abdominal distension identified by 1 or multiple modalities of diagnostic imaging in the 84 cases in which an air sac cannula was placed.

Organ system	n (%)
Liver	12 (14.3)
Spleen	6 (7.1)
Kidney(s)	5 (6)
Proventriculus	5 (6)
Reproductive tract (testes, ovary, oviduct)	2 (2.4)
Ventriculus	1 (1.2)
Heart	1 (1.2)
Nonascitic/generalized abdominal distension	2 (2.4)

Abbreviation: n, number of cases identified with organomegaly and abdominal distension by diagnostic imaging.

Table 4. Primary indication for air sac cannulation in the 84 cases included in the study.

Indication	n (%)
Tracheal and/or syringeal granuloma	46 (54.8)
Respiratory disease (other/unspecified)	10 (11.9)
Neoplasia	9 (10.7)
Oral cavity	*3 (3.6)*
Trachea (including syrinx)	*3 (3.6)*
Intrathoracic	*2 (2.4)*
Thoracic wall	*1 (1.2)*
Tracheitis	8 (9.5)
Tracheal collapse	4 (4.8)
Upper respiratory tract foreign body	2 (2.4)
Oropharyngeal disease	1 (1.2)
Parasitic airway disease	1 (1.2)
Air sac perfusion anesthesia (routine)	1 (1.2)

Indication not reported 2 (2.4). Abbreviation: n, number of cases with specific indications for air sac cannula placement.

had been placed in 20.2% (17/84) of the patients included in this study. The median number of prior ASCs placed was 0 (range 0–5), and the median interval between air sac cannula placement was 5 days (range 0–1185 days). The side (left or right) of the ASC placement could not be determined in 66.7% (56/84) of the cases, and the position (caudo-costal or intercostal) of the ASC placement could not be determined in 78.6% (66/84) of the cases. Of the 28 cases where the side of ASC placement was known, the ASC was placed on the left side in 67.9% (19/28) of patients (representing 22.6% of the 84 total cases) and on the right side in 32.1% (9/28) of patients (representing 10.7% of the 84 total cases). Of the 18 cases where the position of the ASC was known, the ASC was placed caudal to the last rib (caudo-costal) in 66.7% (12/18) of the cases (representing 14.3% of the 84 total cases) and between the last 2 ribs (intercostal) in 33.3% (6/18) of the cases (representing 7.1% of the 84 total cases).

Other therapeutics

Of the 80 cases that survived initial ASC placement, "peri-interventional antibiotic therapy" (defined as antibiotic therapy of any course administered at any time point from air sac cannulation to 7 days after ASC removal) was prescribed in 93.8% (75/80) of the cases; in 77.5% (62/80) of the cases the patient was already receiving systemic antibiotic therapy at the time of air sac cannulation, in 76.3% (61/80) of the cases the patient received at least 1 dose of a systemic antibiotic treatment while the ASC was in situ, and in 21.3% (17/80) of the cases the patient received at least 1 dose of a systemic antibiotic treatment within the 7 days after ASC removal. Hospitalization periods and discharge dates could be determined in 95% (76/80) of the cases that survived initial ASC placement. Of these 76 cases, 89.5% (68) were hospitalized for the duration of the ASC placement, and 10.5% (8) were discharged before ASC removal. Patient discharge before ASC removal was against recommended medical advice, and the decision to discharge the bird was based on client preference because of financial limitations in every case. An Elizabethan neck collar (Buster Bird Collar, Kruuse, Langeskov, Denmark) was placed on 2.5% (2/80) of patients (both African grey parrots) because of increasing interest or interference with the ASC by the patient after recovery from the initial ASC placement.

Table 5. Frequency and types of air sac cannulation complications for 80 cases that survived initial air sac cannulation within the study group.

Complication	n (%)
Loss of patency (any)	19 (23.8)
Loss of patency (obstruction)	*14 (17.5)*
Loss of patency (dislodged)	*2 (2.5)*
Loss of patency (insufficient diameter)	*2 (2.5)*
Loss of patency (positionally variable patency)	*1 (1.3)*
Subcutaneous emphysema	3 (3.8)
Acquired ASC placement site infection	3 (3.8)
Minor hemorrhage	2 (2.5)
Gross ASC contamination	2 (2.5)
Patient interference	2 (2.5)
Secondary coelomic wall disease	2 (2.5)
Secondary coelomitis	1 (1.3)

Abbreviations: n, number of air sac cannulation complications; ASC, air sac cannula.

Outcomes and complications

In 4.8% (4/84) of the cases, the bird died either during or on recovery from anesthesia for ASC placement. The cause of death in each of these cases was determined to be anesthetic related (ie, attributed to complications encountered because of the patient's underlying disease process); as such, they were excluded from analysis of acquired ASC complications. Of the remaining 80 cases that survived ASC placement, 32.5% (26/80) of cases encountered an acquired ASC complication (Table 5). The most frequently encountered ASC complication was loss of patency 23.8% (19/80). The cases where ASC patency was lost were further categorized as ASC obstruction (17.5%, 14/80), ASC dislodged (2.5%, 2/80), insufficient ASC diameter

Table 6. Summary of the 3 air sac cannulation complication–related deaths out of 84 birds included in the study.

Species	Age, y	Sex	Weight, g	Indication for ASC
Blue-and-gold macaw (*Ara ararauna*)[a]	5	M	1014	Bronchopneumonia
Hyacinth macaw (*Ara hyacinthinus*)[b]	19	U	1240	Tracheitis
Kākāriki (*Cyanoramphus* spp.)[c]	U	U	54	Tracheitis

Abbreviations: M, male; U, unknown; ASC, air sac cannula.

[a] Patient died the same day as the ASC was placed: acute respiratory decompensation after ASC became nonpatent (ASC displaced).

[b] Patient died the same day as the ASC was placed: acute respiratory decompensation after ASC became nonpatent (obstruction of ASC with fluid from air sac).

[c] Patient died day 3 after the ASC was placed. The kākāriki was euthanatized (client decision) following acute respiratory decompensation after loss of ASC patency (ASC obstruction was related to gross contamination with debris and dried exudate).

(ie, lack of functional patency in an otherwise correctly placed cannula that resolved after subsequent replacement by a larger diameter cannula via the original stoma site) (2.5%, 2/80), and positionally variable ASC patency 1.3% (1/80). Other reported acquired ASC complications included subcutaneous emphysema (3.8%, 3/80), acquired ASC placement site infection (3.8%, 3/80), minor hemorrhage (ie, defined as nonfatal hemorrhage with an estimated blood loss of <10% of circulating blood volume) (3.8%, 3/80), gross ASC contamination (2.5%, 2/80), patient interference (2.5%, 2/80), secondary coelomic wall disease (ie, inflammation, fibrosis, or scarring of the coelomic wall) (2.5%, 2/80), and secondary coelomitis (1.3%, 1/80). In 97.5% (78/80) of cases, it was possible to confirm whether a bacterial culture was obtained after the removal of the ASC. Of these 78 cases, inhouse ASC cultures were performed in 5.1% (4/78) of the cases. Moderate or heavy bacterial monoculture was identified in 75% (3/4) of these patients. These 3 birds were subsequently recorded as having an acquired ASC placement site infection. No details pertaining to bacterial culture identification or antimicrobial sensitivity profiles were available. No further complication types were encountered in any of the cases included in this study.

In 67.9% (57/84) of the cases, the patient was recorded as deceased at the time of data collection, with a median survival after ASC placement of 4 days (range 0–1454 days). In 8.8% (7/80) of the birds that survived initial ASC placement, it could not be determined from their records whether the patient survived to ASC removal. Of the remaining 73 cases, 58.9% (43/73) survived to ASC removal. Complete 30-day survival data were not available for 4.7% (2/43) of the patients and, as such, they were excluded from further survival analysis. Of the remaining 41 cases, 80.5% (33/41) were alive at day 7, and 61% (25/41) were alive at day 30 after ASC placement; the cause of death could not be determined in 1 case but was determined to be non–ASC related in all remaining cases.

Of the 73 cases for which outcome was confirmed, 41.1% (30/73) of the birds did not survive to ASC removal. The cause of death could not be determined in 16.7% (5/30) of the cases because of incomplete medical records. Of the 25 cases where a cause of death could be determined, 12% (3/25) (representing 11.5% of the 26 cases that encountered an ASC complication) died as a direct result of an ASC complication; the loss of ASC patency was the cause of death in all 3 cases (Table 6). The remaining 88% (22/25) of the deaths were the result of the patient's underlying disease process and were non–ASC related. Of the 8 cases that were discharged from hospital with the ASC in place, 50% (4/8) encountered at least 1 complication and 25% (2/8) died at home. Both out-of-hospital deaths appeared to be a consequence of the patient's underlying disease process and did not appear to be ASC-related on the basis of a gross postmortem examination or client communication records.

Risk factors

An increased likelihood for a patient to encounter an ASC complication was seen in cases where exercise intolerance (OR = 3 [95% CI 2.1–4.2]; $P =$ 0.04) or abnormal respiratory sounds (OR = 3 [95% CI 2.1–4.2]; $P = 0.04$) were reported at presentation. No variables were found to impact the likelihood for a patient to encounter any specific category of complication. An increased likelihood of survival to ASC removal was seen with intercostal ASC placement (OR = 3 [95% CI 1.2–7.6]; $P = 0.049$); the side (left vs. right) of placement did not appear to significantly impact patient survival to ASC removal. Patients that survived to ASC removal were significantly more likely to have received peri-interventional antibiotic therapy (OR = 2.1 [95% CI 1.6–2.8]; $P =$ 0.005). Decreased likelihoods of patient survival to

ASC removal were seen in cases where a voice change was reported at presentation (OR = 0.2 [95% CI 0.05–0.8]; $P = 0.02$). No other variables were found to significantly alter the risk of ASC complication or to impact patient outcomes.

DISCUSSION

This study identified a relatively high incidence of complications after air sac cannulation in a range of avian species, with approximately one-third of cases encountering at least 1 complication. Although not directly comparable, the complication rate in this study appeared to be lower than that reported in dogs and cats with temporary tracheostomy tubes, where overall complication rates of >85% have been reported.[15,16] The most frequently encountered complication in this study was a loss of ASC patency, with ASC obstruction being the most common subcategory of this complication seen. This result is comparable to complications seen with tracheostomy tubes in dogs and cats where tube obstruction was reported as the most frequently encountered complication in dogs and the fourth most frequently encountered complication in cats, and an incidence rate of 26% reported in both species.[15,16] Bacterial airsacculitis has been associated with exudate-related loss of cannula patency by day 10 after experimental air sac cannulation in bob-white quail (*Colinus virginianus*).[14] Movement of a patient around their cage may also contribute to a loss of ASC patency by increasing soft tissue contact with the cannula, occasionally requiring repositioning or replacement.[17]

While the side of ASC placement did not appear to impact patient survival, placing an ASC in an intercostal location was associated with an increased likelihood for patient survival to ASC removal compared with caudo-dorsal ASC placement. It could be cautiously assumed that ASC placement in an intercostal location would predominantly enter the caudal thoracic air sac and those placed in a caudo-costal location would predominantly enter the abdominal air sac; however, the definitive location of the ASC would require confirmation through concurrent imaging (eg, endoscopy, computed tomography).[5] It has been suggested that the site of air sac cannulation is a matter of clinician preference; however, the results from this study appear to support other sources that recommend the caudal thoracic air sac as the preferred site of air sac cannulation.[5,18,19] Clinicians were encouraged at this center to place ASCs on the left side, preferably in an intercostal location; however, data regarding the side or location of placement were only included in this study if this was explicitly stated in the medical records. As such, it is likely that more ASCs were placed in these locations than were stated in the results. It should also be considered that the unequal distribution and relatively limited number of cases where the side and location of cannula placement could be determined may have affected the results. It is regrettable that there was insufficient complete data to assess the effect of side and location combined (ie, left intercostal, left caudo-costal, right intercostal, and right caudo-costal), because this information would have allowed a more detailed assessment of the preferred location for routine air sac cannulation.

Incorrectly placing or securing ASCs may result in a reduction or loss of function. Techniques described for securing ASCs after placement include using cuffed endotracheal tubes that are inflated, placing purse-string or Roman-sandal sutures, or directly suturing the cannula to the skin with butterflied tape.[17,20–23] Some authors also suggest securing the ASC to the tail feathers.[17] Placing at least 1 securing ligature around the caudal rib after placement of an ASC is recommended to minimize the risk of cannula displacement, regardless of location.[19] Descriptions of the exact suture techniques used in these cases were rarely included in the clinical records, and variability in the suturing techniques used between cases is expected on the basis of patient factors and clinician preferences. It was therefore not possible in this study to determine what, if any, effect variations in techniques to secure ASCs might have had on the risk of ASC complication, particularly the loss of patency from ASC dislodgement. It was also not possible to determine if, or how, each clinician confirmed successful placement and patency of each ASC; it is possible that some complications might have arisen from improperly placed ASCs. Techniques used to confirm ASC placement include demonstrating condensation on a glass microscope slide or movement of a down feather (exercising caution not to allow aspiration) held close to the external aperture of the cannula, radiography, and demonstration of a capnography waveform when the monitor is attached to the ASC.[6]

Although some studies have suggested that small dogs and cats are at higher risk of developing tracheostomy tube complication or tube-related mortality, patient size did not appear to affect patient outcome or the likelihood of complication in this study.[16,24] This result is comparable to the findings in a separate study looking at temporary tracheostomy tubes in dogs, in which the internal and external diameter of temporary tracheostomy was shown to have no effect on the incidence of tracheostomy tube obstruction.[15] Another study assessing a modified tracheostomy tube placement technique in dogs noted that, in 1 case where tube obstruction was encountered, it occurred in a dog that had a relatively large diameter tube placed.[25] Only 4 patients included in this study were known to weigh less than 100 g, which may alter the apparent risk of air sac cannulation in very small birds. Current recommendations suggest that ASCs be 1–1.3 times the diameter of the tracheal lumen, with a length not exceeding two-thirds of the coelomic width.[19] Smaller diameter ASCs are usually needed for intercostal placements compared with caudo-costal placements because of anatomical restrictions on the available space for placement. An increased ASC length would permit more fenestrations in the tube, which possibly could reduce the likelihood of ASC obstruction by reducing the effect of soft tissue contact with the ASC in the air sac. It was not possible in this study to determine whether the diameter or length of ASC used affected the likelihood for complication because of a lack of information in the clinical records.

Secondary coelomic wall disease and coelomitis were uncommonly encountered complications in this study. Although none of these complications were fatal, scarring of the coelomic wall was diagnosed in 1 case and resulted in difficulties with a subsequent successful ASC placement in that patient. Air sac cannula culture after removal was only performed in 4 cases; however, positive bacterial growth was demonstrated in 75% (3) of these patients. In the 3 cases that had a positive bacterial culture, the cannulas likely were cultured in response to a clinical concern, because each of these 3 cases were documented to have had either airsacculitis, a loss of ASC patency from obstruction, or gross contamination of the cannula site. As such, these results are likely to have been influenced by potential selection bias. The use of antibiotic agents did not appear to affect the likelihood of acquired ASC infections or positive ASC cultures in this study; however, the small number of cases where ASC cultures were performed may have affected this result. The use of antibiotic therapy was associated with improved patient outcomes, in that patients that survived to ASC removal were more likely to have received peri-interventional antibiotic therapy than those that did not survive to ASC removal. It is worth noting that the majority (93.8%) of cases in this study received peri-interventional antibiosis, and that when the timing of the antibiotic therapy was assessed separately (ie, antibiosis started either prior to air sac cannulation, during the ASC maintenance period, or in the 7 days following ASC removal), no statistically significant impacts on patient survival were noted. The large number of cases in which antibiotic therapy was administered, compared to the very small number of cases that received no antibiotic treatment, likely impacted this finding. Air sac cannulation has been shown to facilitate contamination and colonization of air sacs with both Gram-positive and Gram-negative organisms, and the routine microbial culture of the terminal end of an ASC after removal is generally considered good practice.[6,15] A more rigorous prospective study would be needed to make clear recommendations regarding the empirical use of antibiotic treatment as part of a standardized ASC placement protocol.

Other infrequent complications encountered in this study were subcutaneous emphysema and minor hemorrhage. When encountered, subcutaneous emphysema was self-limiting and was restricted to the area surrounding the ASC placement site. Subcutaneous emphysema did not appear to be associated with altered patient outcomes in any of the 3 cases in which it occurred, and in all cases it was the only complication encountered. Emphysema has been associated with dislodgement of ASCs in situ as well as ASC removal.[6,22] In the 66.7% (2/3) of cases in which subcutaneous emphysema was diagnosed, the complication occurred before ASC removal, and none of the 3 cases showed evidence of ASC dislodgement. These observations suggest that subcutaneous emphysema after air sac cannulation might have other explanations, such as air leakage from the air sac or through fenestrations in the cannula during the period of ASC maintenance. Hemorrhage was rarely encountered in this study and was considered minor or nonfatal in every case. Conversely, accidental organ puncture during air sac cannulation may result in severe or life-threatening hemorrhage.[6] This complication was not encountered in this study despite the relative frequency with which concurrent coelomic organomegaly was reported in the patient population.

The majority of patient variables assessed in this study did not appear to affect outcomes significantly. The only patient factor shown to affect the likelihood of a patient to survive to ASC removal was where a voice change was reported at presentation, resulting in a reduced likelihood of survival to ASC removal. The predominant reason for air sac cannulation in birds with a voice change was a tracheal or syringeal granuloma, and the main cause of death reported in this group was from complications arising from the underlying disease. Granulomas of any type were grouped together because of a paucity in appropriate diagnostic investigations confirming the etiology in these cases; however, the authors suspect that a fungal disease (eg, aspergillosis) was most likely associated with the granulomatous disease noted in these avian patients. This finding demonstrates that, even with successful air sac cannulation, the prognosis for severe tracheal or syringeal granulomas resulting in upper respiratory compromise can remain guarded. Clinicians should consider the decision to pursue placement of an ASC in the wider context of the underlying disease processes in each case, and clients should be prepared for potentially significant long-term clinical and financial commitments beyond initial air sac cannulation.

The only patient variables shown to impact the likelihood of encountering an ASC complication were when exercise intolerance or abnormal respiratory sounds were reported at presentation, both resulting in an increased likelihood for an ASC complication. While no clear explanation for these observations could be determined, it is worth considering that these clinical signs may indicate the presence of other nondefined patient or disease factors which may have impacted ASC placement and maintenance. Interpretation of results pertaining to the presenting clinical signs in this study is challenging, as many of the presenting clinical signs evaluated in this study are subjective in nature, and data acquisition for this study was dependent on the clinician making detailed medical records following comprehensive anamnesis and examination.

No association between coelomic organomegaly and either patient outcome or complication rates was found. Many cases had a reported organomegaly; however, the presence of organomegaly could be considered debatable because the inclusion criteria relied solely on the clinician's description of the diagnostic imaging findings, and it was not possible to review the images to confirm the presence or absence of organomegaly. Therefore, cases in which organomegaly was described might have been falsely included; conversely, some cases in which organomegaly was present might have been overlooked and omitted from the statistical analysis. One patient factor that was not assessed in this study was the effect of body condition score. Unfortunately, this risk factor was rarely recorded in the patient records and could not be accurately estimated from recorded details such as patient body weight. An increased body condition score would be expected to be associated with an increased volume of body fat, which in the authors' anecdotal experiences can make placing and maintaining ASCs more challenging. Future studies should evaluate this risk factor.

This study did not find any significant association between the length of time an ASC was in place and the likelihood of either developing a complication or a patient dying before the ASC was removed. As a result, it was not possible to make definitive recommendations for the maximum length of time an ASC can be left in place. Published recommendations suggest a maximum duration of 7 days, whereas other sources suggest no more than 5 days to reduce the risk of complications such as exudate-related ASC obstruction, airsacculitis, and bacterial infection.[6,14] In this study, 12 ASCs were placed for a duration of >7 days, including 1 ASC that was in place for 30 days. Of the ASCs placed for >7 days, 41.7% (5/12) encountered a complication, which was higher than the rate seen in the overall study population, and higher rates of infection were also seen in cases where the ASC was in place for >7 days. Neither of these observations were statistically significant, but these findings do support the published recommendation to remove an ASC on or by day 7 to reduce the risk of complications.

The majority of birds in this study were hospitalized for the duration of air sac cannulation; however, a reasonable number of birds were discharged before ASC removal. No statically significant risks for complication or death before ASC removal between hospitalized patients and those that were discharged were identified, although a higher overall rate of complication was seen in patients discharged from hospital before ASC removal. This study has demonstrated that ASCs can potentially be managed on an outpatient basis in certain cases; however, the decision to discharge a patient before ASC removal is not without risk and should be determined on a case-by-case basis following careful client education.

The use of neck collars has been suggested as a method to reduce patient interference with an ASC; however, the routine placement of a neck collar at the time of ASC placement was not performed at this center, and no patients had a neck collar placed before recovery from the initial ASC placement in this study.[20] Patient interference was only observed in 2 birds, both African grey parrots. This complication did not result in the loss or reduction of ASC function in either case. Neck collars were successfully used in both cases to prevent further patient interference, which likely limited the potential for further ASC damage. The observations in this study illustrate that birds are unlikely to interfere with an ASC and, although still occasionally necessary, the routine use of neck collars after air sac cannulation is generally not indicated. This consideration is important because neck collar placement can be stressful in avian patients, and patients undergoing air sac cannulation for management of respiratory disease are potentially susceptible to stress-related respiratory decompensation.

The retrospective nature of this study introduced a fundamental risk of bias into the study design. Examples of other weaknesses in the study design included the wide range of patient signalments, errors in patient record-keeping (or interpretation of patient records), and potential variations in the techniques used to place and maintain the ASCs between each case. The study included ASCs placed by many different clinicians, which will have led to inevitable variations in the techniques and approaches used, some of which are likely to be unappreciated because of incomplete medical records. The overall study population was small, and incomplete record-keeping resulted in further reductions of data acquisition for patient variables and outcomes, highlighting the importance of detailed reporting systems to improve patient record-keeping and benefit future retrospective studies. The side of cannula placement was only reported for one-third of the cases, and the location of cannula placement in just over one-fifth of the study population. Furthermore, the distribution of cannula placement locations was unequal across cases when the location could be determined. These factors may have affected the significance of the reported findings in this study. Because of lack of consistency with the use and recording of postoperative interventions, further recommendations for optimal postoperative ASC care could not be made.

This study describes air sac cannulation in a wide distribution of species, with a predominant requirement for their use as part of a therapeutic plan for the management of obstructive upper respiratory granulomas. In this study, a moderate risk of complication with a guarded overall prognosis for survival to ASC removal was found. Although infrequently seen, the cases of complication-related mortality described in this study illustrate the potential significance of lost ASC patency and reinforces the need for vigilant ASC monitoring (in particular for signs of ASC discharge or dislodgement). The routine use of neck collars at the time of ASC placement does not appear to be necessary in the majority of patients, although it can be a useful tool in the management of patient interference. Further studies are needed to develop clearer recommendations for air sac cannulation techniques and postoperative cannula care in avian species.

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