RESEARCH PAPER

Avian anaesthesia related mortality and the associated risk factors in a UK zoological collection

Phillipa Dobbs[a], **Sophie Moittié**[a,b] & **Matyas Liptovszky**[a]
[a]Veterinary Department, Twycross Zoo, East Midland Zoological Society, Atherstone, UK
[b]School of Veterinary Medicine and Science, University of Nottingham, Sutton Bonington, Loughborough, UK

Correspondence: Phillipa Dobbs, Veterinary Department, Twycross Zoo, Burton Road, Atherstone, Warwickshire, CV9 3PX, UK.
E-mail: Phillipa.dobbs@twycrosszoo.org

Abstract

Objective To analyse avian anaesthesia-related mortality in a UK zoological collection over a 5-year period and identify risk factors for mortality.

Study design Retrospective cohort study.

Animals A total of 135 individual birds across 37 species, anaesthetized during 206 events in a UK zoological collection between 1 January 2014 and 30 June 2019 (inclusive).

Methods Anaesthesia records were reviewed and variables such as age, body condition, weight, sex, duration of anaesthesia and health status were collated. Anaesthesia-related mortality was defined as those deaths occurring during anaesthesia and up to 7 days post anaesthesia. Outcome was analysed using multivariable conditional logistic regression. Overall mortality was defined and included birds euthanised during anaesthesia for non-anaesthesia related reasons. Data were summarised as median (range). A value of $p < 0.05$ was considered significant. Relative risks and 95% confidence intervals (95% CI) were calculated for the association between risk factors and anaesthetic death where a statistically significant difference was found.

Results The overall mortality rate was 10.19% [95% confidence interval (CI) = 6.06−14.3%), while anaesthesia-related mortality was 3.88% (95% CI = 1.69−7.51%). Birds with an abnormal health status had a 15.53-fold (95% CI = 1.95−123.63) increased risk of death compared with those with a normal health status. The duration of anaesthesia was also a statistically significant risk factor ($p = 0.021$) in the univariable analysis, but not when combined with health status. No other variables were associated with anaesthesia-related mortality.

Conclusions and clinical relevance Abnormal health status and longer anaesthetic procedures were associated with a significantly increased risk of anaesthesia-related death in this population of birds. It is recommended that anaesthetic duration is minimized, and pre-existing diseases are diagnosed where possible prior to general anaesthesia of birds. Anaesthetizing healthy birds was associated with a low risk of mortality.

Keywords Aves, birds, general anaesthesia, mortality, risk factors, zoo animals.

Introduction

General anaesthesia of birds is performed at many zoological collections and private practices worldwide. General anaesthesia is preferred over physical restraint of a conscious bird to reduce the stress associated with handling while allowing diagnostic procedures to be completed (Longley 2008). In zoological collections, many birds are not handled routinely, so even minimally invasive procedures can be stressful to them (Heard 2014; Balko & Chinnadurai 2017). Zoological collections perform avian anaesthesia for several reasons such as the investigation and diagnosis of a clinical disease or to perform preventative health examinations of elderly birds, or pre-exportation and post-importation. Small birds (<5 kg) are commonly anaesthetized with inhalant anaesthetics (isoflurane or sevoflurane) with or without a premedication (Longley 2008).

Every anaesthesia is associated with risk, but anaesthesia-related mortality varies between different species. A retrospective review of anaesthesia in birds in a referral hospital documented a 3.4% risk of anaesthesia-related deaths (Seamon et al. 2017). This is higher than in horses (Senior 2013; Dugdale et al. 2016), or dogs and cats (Brodbelt 2009), but similar to that of rabbits and other small pets, such as guinea pigs and hamsters (Brodbelt et al. 2008; Brodbelt 2009; Lee et al. 2018). The reasons for these differences are unknown.

The purpose of this study was to analyse anaesthesia-related mortality and identify risk factors in a zoological avian

Please cite this article as: Dobbs P, Moittié S, Liptovszky M Avian anaesthesia related mortality and the associated risk factors in a UK zoological collection, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.04.012

collection. Our hypothesis was that there would be a higher anaesthesia-related mortality rate in birds undergoing anaesthesia for a clinical problem compared with those undergoing anaesthesia for a preventative health check.

Materials and methods

All anaesthesia records of birds at a UK zoological collection were stored on a web-based Zoological Information Management Software (ZIMS, Species 360, MN, USA). Cases were included if the bird was anaesthetized between 1 January 2014 and 30 June 2019 (inclusive).

From these records the following information was extracted: species, individual animal identification number, age at time of anaesthesia, age category, sex, date of anaesthesia, body weight and body condition score (BCS) on day of anaesthesia, anaesthetic duration and health status/reason for anaesthesia. In addition, whether endotracheal intubation was used or not, if intravenous (IV) or intraosseous fluid therapy was administered, recovery status, outcome at 7 days post anaesthesia, time of death in relation to anaesthesia and cause of death as per gross and histopathological reports.

Owing to species-specific differences in aging, age category was classified as either elderly or not for the purpose of statistical analysis. The zoo identified birds as elderly when they reached 75% of their anticipated longevity had the species been living in the wild (Myers et al. 2020).

Body weight was recorded under anaesthesia in grams using Adams CBK bench scales (MK Scales, UK). Body condition was scored on a scale of 1 (emaciated) to 9 (obese) based on clinical experience and adapted from a 1 to 5 score from Pollock (2012). These were grouped into three categories: 1−3 (low), 4−6 (normal) and 7−9 (high) for statistical analysis.

The reason for anaesthesia was classified into two categories—for a preventative health check (normal health status) or to investigate a clinical problem (abnormal health status). Preventative health checks were defined as post-importation, pre-exportation, routine (anaesthetized every 2 years) or as an elderly health check (anaesthetized every year) if the bird had no known pre-existing clinical signs of any disease or injury. A preventative health check involved a full clinical examination, blood sampling and whole-body right lateral and ventro-dorsal radiographs. If the bird was anaesthetized for the investigation of a clinical problem, this included all of the same procedures as a preventative health check in addition to endoscopy and treatment of the presenting complaint if possible (e.g. surgical repair of a wound).

No birds were given a premedication and in all events anaesthesia was induced with 5% isoflurane (Isoflo 100% w/v inhalation vapour liquid, Zoetis, UK) with a minimum of 1 L minute^{-1} oxygen flow via a tight-fitting facemask (Burton's Veterinary, UK) whilst the bird was manually restrained. Once a light plane of anaesthesia was achieved birds were then intubated (if possible) and anaesthesia was maintained with isoflurane with a minimum of 1 L minute^{-1} oxygen flow via an Ayres T circuit with a 500 mL bag (Burton's Veterinary). Birds were continuously monitored by a dedicated qualified veterinary nurse using a multiparameter anaesthesia monitor (Surgivet; Smith Medical, UK) with at least heart rate, respiratory rate and body temperature recorded every 5 minutes. When possible, end-tidal carbon dioxide and haemoglobin oxygen saturation were also recorded.

The recovery period was recorded from the time the anaesthetic gas was turned off and was categorized as normal, abnormal (e.g. bird showing respiratory or neurological symptoms), prolonged (e.g. bird remaining recumbent or showing decreased responsiveness for longer than expected—more than 5 minutes post extubation) or dead. The time to extubation, head lift and standing were recorded. The individual was considered fully recovered when it showed normal, stable standing or perching behaviour.

The outcome of anaesthesia at 7 days post-anaesthetic event was categorized as—alive, dead (not euthanized) or euthanized. For the purpose of this study, 'anaesthesia-related mortality' was used for birds that died but were not euthanized and 'overall mortality' was used to describe all cases that died or were euthanized within 7 days of anaesthesia.

Statistical analysis

Continuous data were assessed graphically for normality and if the data were skewed they are summarized as median (range). All birds that were euthanized were excluded from statistical analysis.

Anaesthetic duration and body weight were analysed as continuous variables. The following putative risk factors were analysed using conditional binary logistic regression: sex, age, weight, BCS, health status, duration of anaesthesia, if the animal was intubated and whether IV fluid therapy (IVFT) was provided. Risk factors which were significant at $p < 0.2$ were taken forward into a multivariable model with forwards stepwise entry.

A value of $p < 0.05$ was considered significant. Relative risks and 95% confidence intervals (95% CI) were calculated for the association between risk factors and anaesthetic death where a statistically significant difference was found. Statistical analysis was performed using jamovi 1.2 (The jamovi project, NSW, Australia) and Epi Info for Windows 7.2 (Centers for Disease Control and Prevention, GA, USA).

Results

A total of 135 individual birds (68 females, 66 males, one unknown sex) across 37 species (Table 1), with a median age of 9 years (range 0.25−31.5 years), and a body weight of 0.55

Please cite this article as: Dobbs P, Moittié S, Liptovszky M Avian anaesthesia related mortality and the associated risk factors in a UK zoological collection, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.04.012

Table 1 Summary of the avian species included in the study detailing the number of individual birds within a species, the age range of birds within each species, the number of birds identified as elderly (defined as 75% of anticipated maximum age in the wild) at the time of anaesthesia, the total number of anaesthetic events, anaesthesia-related deaths and anaesthetic events where birds were intubated. Data are shown as number or age range per species

Common name/scientific name:	Individual birds	Age range of individuals	Elderly at time of anaesthetic	Anaesthetic events	Anaesthesia-related deaths	Anaesthetic events where intubated
African Grey Hornbill *Tockus nasutus*	4	5 months–8 years	0	4	0	3
Black-Cheeked Lovebird *Agapornis nigrigenis*	5	9 months–4 years 4 months	0	6	0	0
Black-Crowned Night Heron *Nycticorax nycticorax*	2	1 year 11 months–10 years	0	3	0	1
Chilean Flamingo *Phoenicopterus chilensis*	2	12 years 9 months–31 years 6 months	0	2	0	1
Chilean Lapwing *Vanellus chilensis*	3	8 months–13 years 7 months	1	5	0	5
Common Pochard *Aythya ferina*	1	16 years 3 months	0	1	0	1
Demoiselle Crane *Grus virgo*	3	1 year 3 months–31 years 2 months	2	9	0	9
Glossy Ibis Plegadis falcinellus	6	5 months–15 years 8 months	0	7	1	6
Great Grey Owl *Strix nebulosa*	3	9 years 1 month–2 years 2 months	3	13	0	13
Green-Winged Macaw *Ara chloropterus*	1	16 years 2 months	0	1	0	1
Grey Peacock Pheasant *Polyplectron bicalcaratum*	2	8 years–13 years 1 month	1	3	0	2
Hammerkop *Scopus umbretta*	2	1 year–4 years 6 months	0	2	1 (not intubated)	1
Humboldt Penguin *Spheniscus humboldti*	21	4 months–28 years 5 months	8	38	1	36
Little Egret *Egretta garzetta*	3	11 months–15 years 9 months	1	7	0	0
Little Pied Cormorant *Microcarbo melanoleucos*	1	3 years 10 months	0	1	1	1
Manchurian Crane *Grus japonensis*	1	7 years 11 months	0	1	0	1
Orange-Winged Amazon *Amazona amazonica*	9	1 year 3 months–26 years 9 months	0	9	0	5
Pied Imperial Pigeon *Ducula bicolor*	1	6 years 11 months	0	1	0	1
Pink-Backed Pelican *Pelecanus rufescens*	3	12 years 3 months–15 years 10 months	1	4	1	4
Rainbow Lorikeet *Trichoglossus moluccanus*	7	4 months–3 years 11 months	0	13	1 (not intubated)	1
Red-Crested Turaco *Tauraco erythrolophus*	2	10 months–9 years 8 months	1	5	0	4
Red-fronted macaw *Ara rubrogenys*	6	2 months–2 years 9 months	0	12	0	11
Red-Legged Seriema *Cariama cristata*	2	1 year–7 years 1 month	0	2	0	2
Ringed Teal *Callonetta leucophrys*	1	8 years 7 months	0	1	0	1
Scarlet Ibis *Eudocimus ruber*	1	11 year 11 months–13 years	1	2	0	1

(*continued on next page*)

Please cite this article as: Dobbs P, Moittié S, Liptovszky M Avian anaesthesia related mortality and the associated risk factors in a UK zoological collection, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.04.012

Table 1 (*continued*)

Common name/scientific name:	Individual birds	Age range of individuals	Elderly at time of anaesthetic	Anaesthetic events	Anaesthesia-related deaths	Anaesthetic events where intubated
Silvery-Cheeked Hornbill *Bycanistes brevis*	3	6 years 10 months—11 years	0	3	0	0
Southern Boobook Owl *Ninox boobook*	1	23 years 5 months	0	1	0	1
Speckled Pigeon *Columba guinea*	2	6 years 10 months—9 years 3 months	0	3	0	0
Spectacled Owl *Pulsatrix perspicillata*	5	3 months—18 years 7months	0	7	0	4
Ural owl *Strix uralensis*	2	13years—15 years 3 months	0	3	1	3
Vasa Parrot *Coracopsis vasa*	6	6 years 11 months—24 years 3 months	0	8	1	8
Verreaux's Eagle Owl *Bubo lacteus*	2	8 years 10 months—20 years 2 months	1	4	0	3
Victoria Crowned Pigeon *Goura victoria*	1	5 months	0	1	0	1
Waldrapp Ibis *Geronticus eremita*	1	15years 10months	1	1	0	1
Western Cattle Egret *Bubulcus ibis*	13	2 years 11 months—11 year 3 months	0	14	0	2
White Stork *Ciconia ciconia*	2	12 years 3 months—15 years 10 months	0	2	0	2
Yellow-Shouldered Amazon *Amazona barbadensis*	5	1 year 1 month—19 years 4 months	0	7	0	4
Total number	135		21	206	8	140

kg (range 0.04—5.89 kg), were anaesthetized during 207 anaesthetic events. Median anaesthesia duration was 24.5 minutes (range 3—133 minutes). The majority (69%, 142/206) of anaesthetic events were to facilitate preventative health checks of 104 individual birds; the remaining anaesthetic events (31%, 64/206) were to examine 46 individual birds with an abnormal health status. A total of 21 individual birds were anaesthetized for investigation of a clinical problem in year 1 and then anaesthetized in subsequent years for their preventative health check or vice versa. An individual bird was anaesthetized twice in the same day and died the following day; it is counted as a single anaesthetic event for the purposes of statistical analysis and thus, we report 206 anaesthetic events. A total of 42 individual birds were anaesthetized more than once during the study period (accounting for 114 anaesthetic events); only one of these birds died during anaesthesia (Table 2).

Birds were intubated in 68% (140/206) of the anaesthetic events; IVFT was used during three of 206 (1.45%) anaesthetic events. Intraosseous fluid therapy was not used during anaesthesia.

Of 206 anaesthetic events (135 birds), 190 events (118 birds) ended in full recovery (92.2%), but nine events (seven birds—species involved: African Grey Hornbill, Great Grey Owl, Rainbow Lorikeet, Red Crested Turaco, Red Fronted Macaw, Spectacled Owl and Ural Owl) had a prolonged recovery owing to respiratory distress after extubation. An abnormal recovery was seen in two events (two birds) as a result of apnoea prior to extubation requiring manual ventilation.

Duration of anaesthesia had a statistically significant effect on anaesthesia-related mortality ($p = 0.021$). Duration of anaesthesia was between 3 and 133 minutes and longer duration resulted in an increased risk of anaesthesia-related mortality.

At 7 days post-anaesthesia, eight birds had died—four of these birds died during anaesthesia: one during induction, one during maintenance of anaesthesia and two during recovery. An additional four birds recovered from anaesthesia but died within 1—7 days of the anaesthetic event. Of these eight birds, six (75%) were diagnosed at post-mortem with one or more chronic systemic diseases, while two birds (25%; both of abnormal health status prior to anaesthetic) had no obvious cause of death confirmed at post-mortem. Prior to their anaesthetic death, seven of the eight birds that died had not been anaesthetized for any other reason during the study period. The remaining bird was anaesthetized 14 days prior to death to investigate a swollen digit.

Please cite this article as: Dobbs P, Moittié S, Liptovszky M Avian anaesthesia related mortality and the associated risk factors in a UK zoological collection, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.04.012

Table 2 Details of individual birds that had multiple anaesthetic events during the study period. The identification number (ID) of each bird and their species are listed with the number of anaesthetic events they underwent, the time interval between these events and the anaesthesia-related death. No., number

Species and ID	No. of anaesthetic events	Interval between each anaesthetic event in months unless indicated as days	Anaesthetic-related death
Black-Cheeked Lovebird 7224	2	14	No
Black-Crowned Night Heron 5785	2	24	No
Chilean Lapwing 5198	3	11, 12	No
Demoiselle Crane B204	4	7, 26, 17	No
Demoiselle Crane B205	4	14, 19, 7	No but euthanized owing to fractured leg
Glossy Ibis 5832	2	23	No
Great Grey Owl 5832	2	23	No
Great Grey Owl 3051	4	7, 12, 9	No but euthanized owing to neoplasia
Great Grey Owl 3052	6	7, 12, 11, 12, 11	No
Great Grey Owl 7336	3	12, 11	No
Grey Peacock Pheasant 5022	2	12	No
Humboldt Penguin 3545	7	7, 6, 6, 6, 12, 12	No
Humboldt Penguin 5112	2	12	No
Humboldt Penguin 5231	2	19	No
Humboldt penguin 6793	3	32, 5	No
Humboldt Penguin 6852	2	15	No
Humboldt Penguin 6872	2	32	No
Humboldt Penguin 7103	2	13	No
Humboldt Penguin 7104	5	6, 13, 12, 11	No
Little Egret 5587	2	23	No
Little Egret 5590	3	1, 23	No
Little Egret 7320	2	11	No
Pink-Backed Pelican 4904	2	11	No but euthanized owing to severe wing tip oedema
Rainbow Lorikeet 6891	2	30	No
Rainbow Lorikeet 6908	3	1, 2	No
Rainbow Lorikeet 6920	2	19 days	No
Rainbow Lorikeet 6927	3	2, 1	No
Red-Crested Turaco 4478	4	7 days, 14 days, 14 days	No
Red-Fronted Macaw 3054	4	1, 17 days, 61	No
Red-Fronted Macaw 7536	4	15 days, 25 days, 7 days	No
Scarlet Ibis 4940	2	23	No
Speckled Pigeon 6106	2	23	No
Spectacled Owl 3657	2	23	No
Spectacled Owl 3670	2	23	No
Ural Owl 4113	2	25	No
Vasa Parrot 5093	2	3	No
Vasa Parrot 5984	2	14 days	Yes
Verreaux's Eagle Owl 7392	2	1	No
Verreaux's Eagle Owl 7393	2	1	No
Western Cattle Egret 6555	2	46	No
Yellow-Shouldered Amazon 3855	2	9	No
Yellow-Shouldered Amazon 7326	2	3	No

An additional 13 birds were euthanized for non-anaesthesia-related reasons, therefore they were not included in statistical analysis. The reasons for euthanasia included severe ulcerative pododermatitis (bumblefoot), osteoarthritis, fractured limbs or severe systemic disease identified radiographically (e.g. chronic egg yolk coelomitis and renal gout). Prior to their euthanasia, 11 of these 13 birds had not been anaesthetized for any other reason during the study period.

Overall mortality in this study was 10.19% (21/206; 95% CI = 6.06−14.3%), while anaesthesia-related mortality was 3.88% (eight out of 206; 95% CI = 1.69−7.51%). Anaesthesia-related mortality was different between animals

Please cite this article as: Dobbs P, Moittié S, Liptovszky M Avian anaesthesia related mortality and the associated risk factors in a UK zoological collection, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.04.012

with a normal health status (0.7%, one out of 142; 95% CI = 0−2.08%) *versus* those with an abnormal health status (10.9%, seven out of 64; 95% CI = 3.29−18.58%) (p = 0.008). Birds with an abnormal health status had a 15.53-fold (95% CI = 1.95−123.63%) increased risk of death compared with those with a normal health status.

Health status and duration of anaesthesia were offered into a multivariable model based on the findings of the univariable analysis, but only health status was statistically significant (p = 0.019).

There was no statistically significant difference in body weight between birds that died during anaesthesia (median = 0.55 kg; range 0.14−5.88 kg) and those which recovered (median = 0.55 kg; range 0.04−5.42 kg). Sex, body condition, intubation and IVFT had no significant effect on anaesthesia-related mortality. None of the birds that died during anaesthesia were classed as elderly (Table 3).

Discussion

This study identified two risk factors for anaesthetic-related mortality: duration of anaesthesia and an individual bird's health status. The majority (87.5%) of anaesthesia-related deaths occurred in individuals that had an abnormal health status prior to the anaesthetic event.

Risk factors for anaesthesia-related mortality have not been identified in many species, but in cats they include poor health status, increasing age, extremes of body weight, increasing urgency and complexity of the procedure, endotracheal intubation and fluid therapy (Brodbelt et al. 2007). Over a broader range of mammalian species, including dogs, cats, great apes and horses, an association between animal health status and anaesthetic-related death has been demonstrated (Brodbelt et al., 2006; Brodbelt, 2009; Masters et al. 2007; Bille et al., 2012; Senior, 2013). In horses, anaesthesia of increased duration has been reported as a risk factor for anaesthesia-related death (Dugdale & Taylor 2016).

In a previous study, the anaesthesia-related mortality rate in 352 birds was found to be 3.4%, however this only included birds that died during the anaesthetic event (Seamon et al. 2017). A further 4.3% of birds died in the intensive care unit following anaesthesia (total 7.7% mortality). This is markedly higher than the 7-day anaesthesia-related mortality rate of 3.88% that we report in our study. The reason for this higher reported figure may be because the study in 2017 was conducted at a referral hospital, and therefore those birds probably underwent anaesthesia for further diagnostic investigation or surgery. However, the mortality rate found in our study is higher when compared with the rate in dogs, cats and horses

Table 3 Risk factors for anaesthesia-related death in 135 individual birds across 37 species, anaesthetized during 206 events in a UK zoological collection between 1 January 2014 and 30 June 2019. Age was classified as elderly when animals reached 75% of their anticipated longevity had the species been living in the wild. Animals with a normal health status had no known underlying clinical problem and were anaesthetized for a preventative health check, while birds with an abnormal health status were anaesthetized to investigate a clinical problem. Risk of anaesthesia-related death was calculated as the percentage of anaesthetic events which resulted in the animal dying within 7 days of anaesthesia, excluding euthanasia. The p-value refers to the results of conditional univariable binary logistic regression of putative risk factors. A value of $p < 0.05$ was considered significant. BCS, body condition score; CI, confidence interval; IVFT, intravenous fluid therapy; min, minimum; max, maximum N/A, not applicable; No., number. *Significant difference. Abnormal health status (*versus* normal) and increased anaesthesia duration both result in an increase in anaesthesia related mortality

Risk factor		No. of anaesthesia-related deaths	No. of anaesthetic events	Risk of anaesthesia-related death (%)	95% CI min (%)	95% CI max (%)	p-value
Sex	Male	4	93	4.3	0.18	8.42	0.528
	Female	3	112	2.68	0.56	7.63	
Age	Elderly	0	56	0	0	0	0.991
	Non-elderly	8	150	5.33	1.74	8.93	
Weight	Gram	N/A	N/A	N/A	N/A	N/A	0.723
Health status	Abnormal	7	64	10.94	3.29	18.58	0.008*
	Normal	1	142	0.7	0	2.08	
Duration of anaesthesia	Minutes	N/A	N/A	N/A	N/A	N/A	0.021*
Intubation	Yes	6	140	4.3	0.93	7.64	0.665
	No	2	66	3	0	7.17	
IVFT	Yes	1	3	33.33	0	86.68	0.996
	No	7	203	3.45	0.94	5.96	
BCS	Low	5	79	6.3	0.96	11.7	0.995
	Medium	3	124	2.4	0	5.12	
	High	0	3	0	0	0	

reported in the literature and it is more similar to those reported for rabbits and exotic companion mammals (Brodbelt 2009; Senior 2013; Dugdale et al. 2016).

Although the ideal weight range is species-specific, when analysing body weight across all species, this study found no statistically significant difference in weight between those birds that died and those that survived. This might be a result of the dataset being skewed towards larger species, since only six anaesthetics were performed on birds with a body weight <0.1 kg. The BCS of the birds that survived the anaesthetic event, and those that did not, showed no statistically significant difference, which was also found in an earlier study in birds (Seamon et al. 2017). This was in contrast with another study, which found that small domestic animals at the extremes of weight are more at risk of an anaesthetic death (Brodbelt 2009). This disparity may reflect the skewed body weight data of the different species in our study.

No association between endotracheal intubation and anaesthetic outcome was found, which differs from the results in domestic cats (Brodbelt 2009). However, the two abnormal recoveries we report in our study showed apnoea or respiratory distress, which highlights the importance of securing an airway during avian anaesthesia.

No association was found between the number of anaesthetic events performed on individual birds or anaesthetic interval and anaesthetic outcome. Of the 42 individual birds that had multiple anaesthetic events (total of 114) over the study period, only one individual bird died during an anaesthetic.

Abnormal or prolonged recoveries occurred in nine individual birds during 11 anaesthetic events. An individual bird had prolonged recovery following three anaesthetic events between 2014 and 2016; with the exception of that individual bird, abnormal or prolonged recoveries were not associated with a particular age or species of bird. Only two birds died during the recovery stage of anaesthesia; however this is greater than during any other anaesthetic stage, highlighting the importance of continual monitoring of all species throughout the whole anaesthetic event (Brodbelt et al. 2008; Gil & Redondo 2013).

Anaesthesia in birds was thought to be associated with a higher mortality rate compared with domestic animals. This has been attributed to differences in physiology between mammals and avian species, the nature of procedures and the difficulties in performing a thorough assessment of the bird prior to anaesthesia (Seamon et al. 2017). Our study highlights some of these problems. Of the eight birds that died within 7 days of an anaesthetic event, 75% (six out of eight) were found at post-mortem to have a chronic disease. Only one out of the eight was suspected of being diseased, which highlights the difficulty in identifying disease prior to anaesthesia, and emphasizes the importance of performing a full post-mortem examination of any bird that dies during anaesthesia. A retrospective study of post-mortem lesions in nonavian species showed that pre-existing disease contributed to perianaesthetic mortality (DeLay 2016). Without the completion of a post-mortem, it is difficult to understand if the actual anaesthetic event was the cause of death or was a contributing factor in an already compromised and systemically ill bird.

Studies involving zoological collections encounter inherent constraints, such as the large numbers of species in the collection but few animals in each species. Indeed, the limitations of this study include the high number of avian species *versus* the low number of individual birds in each species, and the total number of anaesthetic events in the study period. These limitations may have affected the number of identifiable risk factors in this study. The addition of data from other zoological institutions could increase the total number of birds and anaesthetic events and possibly identify more risk factors. But this could also increase the variability in anaesthetic protocols used and thereby confound rather than clarify potential risk factors. The individual zoological collection in this study recorded and maintained extensive notes with no important information omitted during the data collection and analysis.

In conclusion, this study indicates that a bird's health status and the duration of anaesthesia are risk factors for perianaesthetic death. A thorough history and preanaesthetic physical examination focusing on detecting pre-existing disease conditions is warranted if possible and limiting anaesthetic duration may minimize anaesthesia-related death.

Acknowledgements

We would like to thank all staff members and volunteers assisting with avian anaesthesia and data input at Twycross Zoo, East Midland Zoological Society. We are especially thankful to Samantha Ashfield RVN and Isobel Howe for their assistance. This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors. Q4

Authors' contributions

PD: data input. ML: statistical analysis. All authors: design, data interpretation and preparation of manuscript.

Conflict of interest statement

The authors declare no conflict of interest.

Uncited reference Q6

Lierz and Korbel, 2012

References

Balko JA, Chinnadurai SK (2017) Advancements in evidence-based anesthesia of exotic animals. Vet Clin North Am Exot Anim Pract 20, 917–928.

Bille C, Auvigne V, Libermann S et al. (2012) Risk of anaesthetic mortality in dogs and cats: An observational cohort study of 3546 cases. Vet Anaesth Analg 39, 59–68.

Brodbelt D (2009) Perioperative mortality in small animal anaesthesia. Vet J 182, 152–161.

Brodbelt DC, Hammond R, Tuminaro D et al. (2006) Risk factors for anaesthetic-related death in referred dogs. Vet Rec 158, 563–564.

Brodbelt DC, Pfeiffer DU, Young LE et al. (2007) Risk factors for anaesthetic-related death in cats: Results from the confidential enquiry into perioperative small animal fatalities (CEPSAF). Br J Anaesth 99, 617–623.

Brodbelt DC, Blissitt KJ, Hammond RA et al. (2008) The risk of death: The confidential enquiry into perioperative small animal fatalities. Vet Anaesth Analg 35, 365–373.

DeLay J (2016) Perianesthetic mortality in domestic animals: A retrospective study of postmortem lesions and review of autopsy procedures. Vet Path 53, 1078–1086.

Dugdale AHA, Taylor PM (2016) Equine anaesthesia-associated mortality: Where are we now? Vet Anaesth Analg 43, 242–255.

Dugdale AH, Obhrai J, Cripps PJ (2016) Twenty years later: A single-centre, repeat retrospective analysis of equine perioperative mortality and investigation of recovery quality. Vet Anaesth Analg 43, 171–178.

Gil L, Redondo JI (2013) Canine anaesthetic death in Spain: A multicentre prospective cohort study of 2012 cases. Vet Anaesth Analg 40, 57–67.

Heard D (2014) Galliformes and Columbiformes. In: Zoo Animal and Wildlife Immobilization and Anesthesia (2nd edn). West G, Heard D, Caulkett N (eds). Wiley Blackwell, UK. pp. 473–480.

Lee HW, Machin H, Adami C (2018) Peri-anaesthetic mortality and nonfatal gastrointestinal complications in pet rabbits: a retrospective study on 210 cases. Vet Anaesth Analg 45, 520–528.

Lierz M, Korbel R (2012) Anaesthesia and analgesia in birds. J Exotic Pet Med 21, 44–58.

Longley L (2008) Anaesthesia of Exotic Pets. Elsevier Ltd, UK. pp. 129–166.

Masters NJ, Burns FM, Lewis JCM (2007) Peri-anaesthetic and anaesthetic-related mortality risks in great apes (Hominidae) in zoological collections in the UK and Ireland. Vet Anaesth Analg 34, 431–442.

Myers PR, Espinosa CS, Parr T et al. (2020) The animal diversity web. University of Michigan. https://animaldiversity.org/. (Accessed 13 July 2020).

Pollock C (2012) Body condition scoring in birds. Lafeber Vet. https://lafeber.com/vet/body-condition-scoring/. (Accessed 12 July 2020).

Seamon AB, Hofmeister EH, Divers SJ (2017) Outcome following inhalation anesthesia in birds at a veterinary referral hospital: 352 cases (2004-2014). J Am Vet Med Assoc 251, 814–817.

Senior JM (2013) Morbidity, mortality, and risk of general anesthesia in horses. Vet Clin North Am Equine Pract 29, 1–18.

Received 3 May 2020; accepted 20 April 2021.

Available online xxx

Please cite this article as: Dobbs P, Moittié S, Liptovszky M Avian anaesthesia related mortality and the associated risk factors in a UK zoological collection, Veterinary Anaesthesia and Analgesia, https://doi.org/10.1016/j.vaa.2021.04.012