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CASE REPORT

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Anaesthetic management and complications of a Humboldt penguin (*Spheniscus humboldti)* undergoing diagnostic imaging

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Abstract

Background The presence of a tracheal septum dividing the trachea into two makes intubation one of the main challenges of penguin anaesthesia. Differences in the length and location of the aforementioned tracheal septum have been described in some penguin species. However, to the best of the authors' knowledge, it has not been reported in Humboldt penguins (*Spheniscus humboldti)*. Therefore, one of the aims of this publication is to report the septal position in this Humboldt penguin. Furthermore, this publication describes the anaesthetic protocol and complications encountered and discusses some of the more important features of penguin anaesthesia. It is anticipated that this case report will aid in future procedures requiring anaesthesia of this penguin species.

Case presentation A 25-year-old female Humboldt penguin was anaesthetized at the University College Dublin Veterinary Hospital for radiographs and computed tomography (CT) following three weeks of inappetence. After assessing the health status of the penguin from the clinical history and performing a physical examination, an American Society of Anesthesiologists physical status score of II was assigned and a combination of butorphanol 1 mg/kg and midazolam 1 mg/kg was administered intramuscularly to sedate the penguin. Induction of anaesthesia was performed via a face mask using sevoflurane in oxygen. The airway was intubated with a 4.0 mm Cole tube and anaesthesia was maintained with sevoflurane in oxygen during the entire procedure. Anaesthetic monitoring consisted of an electrocardiogram, pulse oximetry, non-invasive blood pressure, capnography, and body temperature.

Conclusions Tracheal bifurcation was identified as the start of the tracheal septum 4.67 cm from the glottis using CT. Most of the anticipated complications of penguin anaesthesia, such as hyperthermia, hypothermia, regurgitation, hypoventilation, and difficulties in intubation were present in this case. However, no major sequalae occurred following the anaesthetic protocol described.

Keywords Anaesthesia, Diagnostic imaging, Humboldt penguin, *Spheniscus humboldti*, Tracheal bifurcation, Septum

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In addition, it is worth mentioning that unilateral tracheal intubation does not pose a significant risk to the penguin's ventilation as avian species have an efficient pul-monary-air sac system to achieve gas exchange [26, 30]. For this reason, and compared to other species such as mammals, unilateral ventilation does not lead to hypox-aemia even if the penguin hypoventilates.

In the present case, the measured distance from the glottis to the tracheal septum was approximately 3.60 cm when radiographs were used, whereas when the measure-ment was performed using the CT images, the distance was 4.67 cm. This discrepancy of almost 1 cm is due to the glottis being superimposed by the skull in the radio-graphs and is an important finding since it indicates that the ETT could still advance beyond the septum if radio-graphs alone were taken and used. It is important to note that the measurements performed in this case report cannot be extrapolated to other penguin species.

Previous literature reports that while in the Rockhopper penguin (*Eudyptes chrysocome*) the septum projects only 5 mm in length from the carina [12], in the Jackass penguin (*Spheniscus demersus)* the septum starts from only 1 to a few centimetres from the larynx [10, 11]. It has also been reported that in the Yellow-eyed penguin (*Megadyptes antipode*), the lower third of the trachea is also divided by a septum [20], and that in King penguins (*Aptenodytes patagonicus*), the septum extends over 80% of the tracheal length [31]. Therefore, these variations between species make these findings more relevant as it is the first time that the tracheal septum location has been measured in Humboldt penguins.

Similarly, to other bird species, the use of cuffed ETTs is not recommended in penguins as they can have partially ossified tracheal rings [31]. In addition, the use of Cole tubes has been reported as a safe method for endotra-cheal intubation when there is a risk of tracheal dam-age [32]. In this case, a first attempt with a 3.5 mm Cole endotracheal tube resulted in some air leakage during manual intermittent positive pressure ventilation (IPPV), so a 4 mm Cole endotracheal tube was replaced. This size of the ETT was comparable to a previous report in which a 4.5 kg Humboldt penguin was intubated with an uncuffed 4 mm ETT for endoscopic foreign body removal [7]. Despite this, a small leak was still present in this case when IPPV was performed so a slightly larger tube would have been a preferable option. Unfortunately, a larger size Cole tube was unavailable at the hospital. This presump-tion is supported by another report in which a smaller penguin: a 2.6 kg African Black-Footed penguin (*Spheniscus demersus*) was intubated with a 4 mm Cole endotracheal tube [33]. However, after measuring the ID of the trachea (see Fig. 4A and B) nothing larger than a 5 mm Cole tube [34] (with an outer diameter of 1.26 cm) would have been suitable for this penguin's trachea.

IV access

Catheterization for IV access can be performed in different locations such as the flipper vein (brachial or medial) [2, 35] or in the medial metatarsal vein [25] (Fig. 5). In the present case, both metatarsal veins were catheterized due to dislodgement of one catheter. Metatarsal vein catheters have been used in previous reports in penguins; [7, 25] however, there is a risk of faecal contamination due its proximity to the cloaca [6]. Despite this, no complications were experienced other than the dislodgement following the first catheter placement.

Anaesthetic monitoring

Careful monitoring of anaesthesia is recommended when anaesthetizing penguins and specific considerations must be taken. Pulse oximetry has shown to be a deceptive method of measuring oxygen saturation in avian species owing to differences in the uptake features of oxygenated and deoxygenated haemoglobin. Despite this, pulse oximetry has some advantages when used to monitor avian patients, as it has a high accuracy in monitoring pulse rates up to 500 bpm with satisfactory recording of trends in oxygen saturation and HR [36].

The use of oscillometry to measure NIBP is unreliable when compared to direct blood pressure measurement in some bird species [37]. In the present case, NIBP was measured using a number 2 cuff placed around the tarsus (see Table 1 for measured values during anaesthesia).

Fig. 5 Humboldt penguin during general anaesthesia. Monitoring equipment, IV access and cold packs preventing hyperthermia

Although the measured values lack reference ranges for comparison, the pulse rate recorded by the oscillometer consistently matched the HRs given by the ECG and pulse oximeter readings throughout the procedure. Consequently, the oscillometer was employed to monitor trends and ensure the maintenance of an appropriate plane of anaesthesia during the procedure.

RRs and capnography values should be closely monitored to assess ventilation of anaesthetized patient. A previous study in anaesthetized African grey parrots using inhalant anaesthetics, indicated an adequate ventilation of the birds when Pe'CO_2 values were between 30 to 45 mmHg [14]. Based on that study, ventilation was manually controlled to treat hypoventilation and ensure oxygenation of the patient.

Regarding HR monitoring, an earlier study described normal HRs in Humboldt penguins when they were resting, floating inactively in the water and when running, ranging from 121 to 245 bpm (Table 1). They also rated the frequencies under submersion (from 119–125 bpm) and after 60 s under the water (decreasing by 78 bpm) [15]. Based on the reported HRs, the penguin was maintained within normal limits during all the procedure, oscillating between 120 and 200 bpm (Table 1).

Body temperature and thermoregulation

Normal body temperature in a penguin is reportedly between 37.8–38.9 °C [3]. They have been shown to develop both hypothermia and hyperthermia in the peri anaesthetic period [3, 4, 6, 38]. Core body temperature can be monitored in avian species via oesophageal or cloacal temperature probes. The oesophageal probe is inserted through the mouth and measures temperature at the level of the thoracic oesophagus [39]. If this probe is not available, or the procedure does not allow its use, alternatively a cloacal temperature probe can be used. However, cloacal temperature probes can be easily dislodged if they are not appropriately secured, with the consequence that measured temperatures appear to be lower [40]. But both measurement techniques can be correlated with one another and are non-invasive techniques [39]. In the present case, cloacal temperature was intermittently monitored via a digital thermometer since the presence of the ETT in the mouth impeded the use of an oesophageal probe.

The presence of the humeral arterial plexus in the flippers works as a heat exchanger system that limits heat loss through the flippers and enables the penguin to maintain and regulate their body temperature. In addition, the insulation provided by their feathers and the presence of a subcutaneous fat layer, also help them to maintain their body temperature [3, 6]. These protective mechanisms make them prone to hyperthermia during stressful conditions or during anaesthesia, and they can develop some cardiac arrhythmias and increase oxygen demand [26]. To reduce the risk of hyperthermia, some authors recommend the use of ice blocks (Fig. 5) on their feet and flippers [4, 6]. Another prophylactic alternative to prevent hyperthermia is to keep them in an air-conditioned environment to prevent fluctuations in temperatures [6]. In this case, the penguin experienced a period of hyperthermia (up to 39.6 °C) at the beginning of the procedure that was treated by placing cold packs next to the flippers and the body of the patient.

However, there is also a risk of hypothermia during anaesthesia secondary to the inhalation of dry cold oxygen, [35] so constant temperature monitoring during anaesthesia is required. This patient experienced some periods of hypothermia (around 35.5 °C) that were monitored and treated with the removal of the ice packs and passive warming techniques (blankets and towels) to decrease the heat loss.

Positioning and recovery period

Some body positions of the penguin during anaesthesia negatively affect ventilatory function. A study in King penguins (*Aptenodytes patagonicus*) showed that they tend to develop tracheal obstruction because of the saliva accumulation while in dorsal recumbency, whereas when in ventral recumbency, there was less frequency of apnoeic episodes and "head lifting" to try to swallow accumulated saliva [38]. In this case, no complications were experienced related to the patient's positioning despite most of the procedure being performed in dorsal recumbency.

An animal's position during recovery is also an important anaesthetic consideration. Some authors recommend a standing position to prevent regurgitation and aspiration pneumonia when the patient has not fully recovered all the laryngeal reflexes [6]. In this case, the maintenance of an upright position while still intubated was decided until the penguin started to move the head and extubation was possible (see Fig. 2). This position also prevented trauma of the flippers in case of excitation or excessive movement during the recovery period.

To hasten the recovery, flumazenil can be administered at the end of the procedure if benzodiazepines are given. This allows a faster recovery and the reversal of side effects if they are still present [4]. In this case, the penguin was extubated 6 min after the administration of flumazenil IV and recovery was considered uneventful and fast.

Conclusions

Humboldt penguin anaesthesia can be a challenging procedure. Hyperthermia, hypothermia, regurgitation, hypoventilation, and difficult intubation are some of the anticipated complications of penguin anaesthesia and they were all present in this case. The anaesthetic protocol used, based on a premedication of butorphanol and midazolam IM and induction and maintenance with sevoflurane, showed no major complications and enabled smooth induction and recovery periods. Tracheal septum position in this Humboldt penguin is described, being approximately 3.60 cm from the glottis using radiographs and 4.67 cm from the glottis using CT images. Tracheal diameter was also measured, being 1.13 cm.

Abbreviations

CT	Computed tomography
IM	Intramuscularly
HR	Heart rate
Bpm	Beats per minute
RR	Respiratory rate
ID	Internal diameter
ETT	Endotracheal tube
SpO_2	Oxygen haemoglobin saturation
$Pe'CO_2$	End-tidal carbon dioxide partial pressure
ECG	Electrocardiogram
NIBP	Non-invasive blood pressure
IV	Intravenous
FiO_2	Inspired fraction of oxygen
IPPV	Intermittent positive pressure ventilation
UCDVH	University College Dublin Veterinary Hospital
ASA	American Society of Anaesthesiologists
ALT	Alanine transaminase

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Authors' contributions

PR: carried out the anaesthetic and drafted the manuscript. FR: helped to plan the anaesthetic protocol, supervised the anaesthetic, and drafted and revised the manuscript. NM: revised the manuscript and provided all the information about the history and progress of the penguin. SH: reported the diagnostic imaging reports and revised the manuscript. RCB: planned the anaesthetic protocol, supervised the anaesthetic, and revised the manuscript. All authors read and revised the manuscript. The author(s) read and approved the final manuscript.

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Availability of data and materials

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Competing interests

The authors declare that they have no competing interests.

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