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CASE REPORT

Novel use of a 3-way stopcock for ventilatory monitoring during anesthesia in small birds

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ABSTRACT. A novel system using a 3-way stopcock and intravenous catheter enabled effective ventilatory monitoring and controlled anesthesia in nine birds (70–260 g) undergoing fracture repair. End-expired carbon dioxide was generally maintained near 40 mmHg without complications. This simple method provides a practical alternative to avian anesthesia in general veterinary settings.

Keywords: Birds, dead space, end-expired carbon dioxide, intubation, ventilatory monitoring, 3-way stopcock.

The overall risk of anesthesia in birds exceeds 10%, which is comparable to the anesthetic risk in American Society of Anesthesiologists (ASA) grade 4–5 dogs and cats (Seamon *et al*., 2017; Dobbs *et al*., 2021; Bille *et al*., 2012). This elevated risk is attributed to the anatomical limitations of avian respiratory systems, including restricted functional residual lung volume (FRLV), which limits tolerance to apnea, and the technical difficulty in monitoring vital signs in smaller individuals (Zehnder *et al*., 2014; Seamon *et al*., 2017). Accordingly, effective ventilation and respiratory monitoring are critical during avian anesthesia. This study describes a novel and practical method for ensuring ventilatory stability and monitoring respiratory parameters using commonly available equipment during general anesthesia in small birds.

Nine birds from eight species, including cockatiel, conure, dollar bird, kestrel, magpie, nightjar, pigeon, and woodpecker, weighing between 70 and 260 g, were administered general anesthesia for the surgical repair of bone or beak fractures. Prior to anesthesia, each bird underwent a pre-anesthetic examination, including assessment of body condition score, body temperature (BT), respiratory pattern, general physical status, and potential injuries to the beak, claws, or wings beyond the surgical site. The level of consciousness and standing ability were also evaluated. Hematological assessment (packed cell volume and total protein) was performed, and all the results were within normal limits. However, one bird was in a cachectic state.

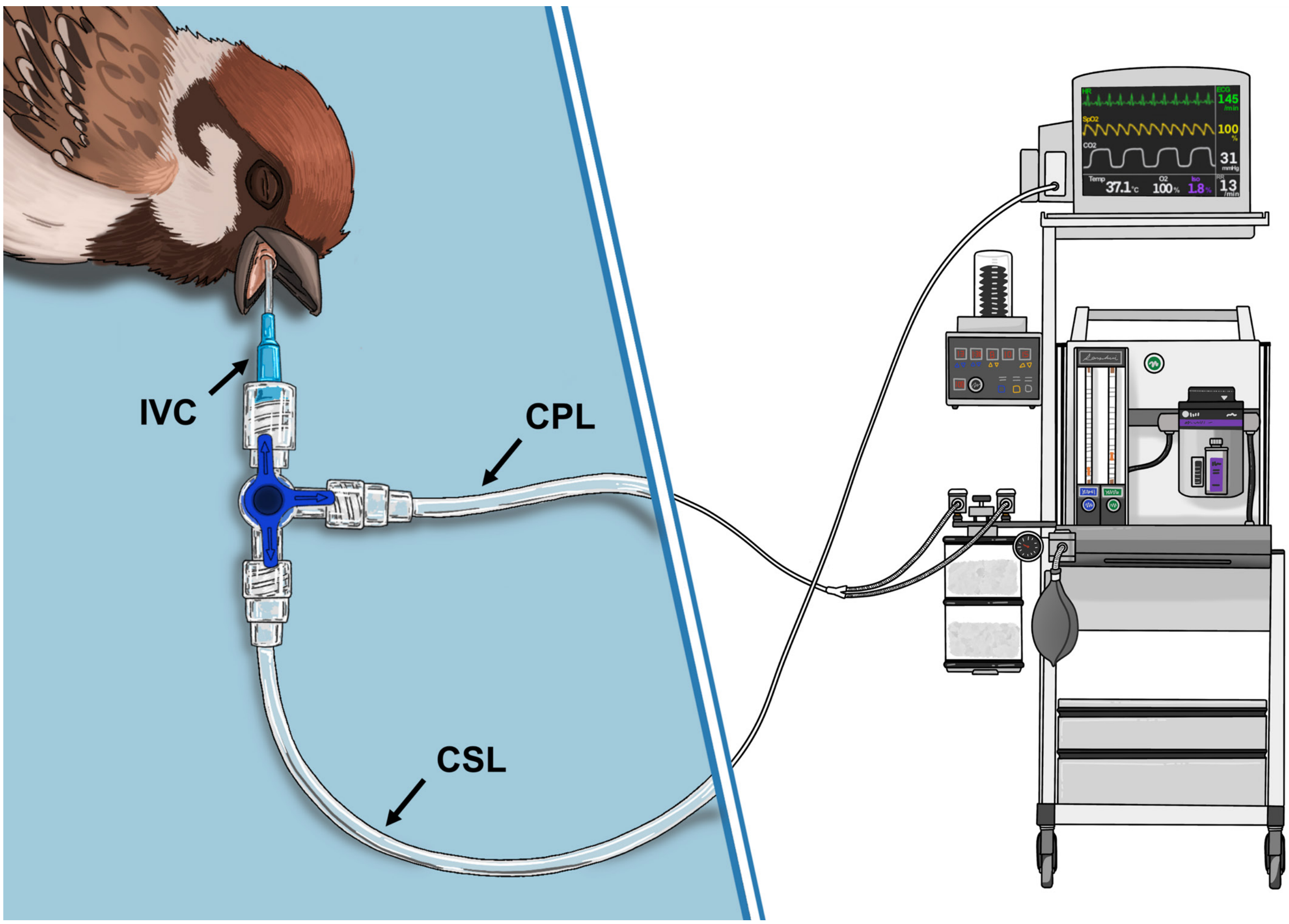
Premedication was administered intramuscularly (IM) with one or more of the following agents: meloxicam (0.5 mg/kg; Metacam; Boehringer Ingelheim Korea Ltd., Republic of Korea), medetomidine (40–80 μg/kg; Domitor; Orion Pharma, Finland), midazolam (0.2 mg/kg; Bukwang Midazolam Inj.; Bukwang Pharm Ltd., Republic of Korea), alfaxalone (2–10 mg/kg; Alfaxan; Jurox Pty Ltd., Australia), hydromorphone (0.1 mg/kg; Dilid injection; Hana Pharm Ltd., Republic of Korea), ketamine (10 mg/kg; Yuhan ketamine 50 injection; Yuhan, Republic of Korea), and tramadol (4–5 mg/kg; Trodon Injection, Ajupharm, Republic of Korea). Cefazolin (30 mg/kg; Cefazoline Injection 1 g Chongkundang; Chong Kun Dang Pharmaceutical Corp., Republic of Korea) or cefotaxime (75–100 mg/kg; Wooridul Cefotaxime Sodium Injection 500 mg; PharmGen Science Inc., Republic of Korea) was administered IM before surgery.

During anesthesia, heart rate, peripheral oxygen saturation (SpO_2), BT, partial pressure of end-expired carbon dioxide ($PECO_2$), and respiratory rate (f_R) were monitored using a multiparameter monitor (CARESCAPE Monitor B650; GE HealthCare, IL, USA) with sidestream capnography (sampling flow rate: 50 mL/min). A breathing circuit compatible with a circle system was designed using a readily available 3-way stopcock (3-way stopcock; HYUPSUNG MEDICAL Co., Ltd., Republic of Korea) to facilitate $PECO_2$ and f_R monitoring (Figure 1). After induction with 2.5–3% end-tidal isoflurane (FE′Iso) (Ifran Solution; Hana Pharm Ltd., Republic of Korea) in 97–98% oxygen (2 L/min) delivered via an oxygen mask (veterinary mask; Provet, Republic of Korea), intubation was performed using a 14–22 gauge intravenous (IV) catheter (3S-Cath; Dukwoo Medical Co., Ltd., Republic of Korea), selected according to the bird's size. Anesthesia was maintained with 1.2–2.5% of FE′Iso in 98% oxygen (1 L/min). The catheter was connected in the opposite direction to the CO_2 sidestream sampling line via a 3-way stopcock to enable effective sampling of a small volume of exhaled gas. The other port of the stopcock was connected to the rebreathing system (Multiplus-MEVD; Royal Medical Co., Ltd., Republic of Korea) via a corrugated breathing tube, which was extended using a control pressure line (HYUPSUNG MEDICAL Co., Ltd., Republic of Korea). The birds were mechanically ventilated to maintain a $PECO_2$ below 40 mmHg (Hawkins *et al.*, 2014) using the following ventilator settings: initial inspiratory pressures of 8–10 cmH_2O, f_R of 5–10 breaths/min, and an inspiratory time of at least 1 s. The normality of the monitored variables was assessed using the Shapiro–Wilk test. Non-parametric data are presented as medians (ranges).

presumed to have died of hypoperfusion and hypovolemic shock. No complications related to intubation or ventilation were observed during the peri-anesthetic period.

Birds have a high metabolic rate and corresponding high oxygen demand, supported by a unique anatomical and physiological gas exchange system (Zehnder *et al.*, 2014; Seamon *et al.* 2017). Although they have a relatively large tidal volume (V_T), their f_R, minute ventilation, and FRLV

Figure 1.
Application of 3-way stopcock and intravenous catheter (IVC) to intubate birds. The carbon dioxide sidestream sampling line (CSL) was connected opposite the IVC, and the corrugated breathing tube was extended to the control pressure line (CPL) and connected to the side of the stopcock. The model of the 3-way stopcock illustrated here is a non-standard type, in which all three ports are open simultaneously when the lever with the arrow is aligned appropriately.



The total duration of anesthesia was 50 min (25–103 min), HR was 210 beats/min (100–450 beats/min), SpO_2 was 96% (85–100%), BT was 37.1 °C (33.7–40.2 °C), f_R was 12 breaths/min (5–40), and $PECO_2$ was 35 mmHg (11–44 mmHg). Several vital parameters, except for BT and $PECO_2$, could not be monitored because of the small size of the patients (Table 1). Extubation was performed after surgery, and all patients recovered except for one case. One bird with cachexia was

values were low. Cardiac arrest can occur within 1–2 min of apnea; therefore, if apnea persists beyond 10–20 s, artificial ventilation is recommended (Hawkins *et al.*, 2014). As every breath is critical, ventilatory monitoring is essential. It may provide the earliest indication of anesthetic complications and guide timely interventions (Hawkins *et al.*, 2014; Crawford *et al.*, 2022).

Minimizing dead space is essential for successful venti-

Table 1.
Vital parameters during anesthesia were observed in nine patients. The vital parameters of smaller individuals could not be monitored; however, with the novel device configuration, respiratory parameters such as end-expired carbon dioxide ($PECO_2$) and respiratory rate (f_R) were successfully monitored in all cases. Some values were found to be outside the normal range; however, these deviations were transient and likely caused by artifacts, with most parameters remaining within the normal limits.

Breeds	Pigeon	Kestrel	Pigeon	Magpie	Dollar bird	Woodpecker	Nightjar	Cockatiel	Conure
WT (g)	260	194	160	146	114	84	81	78	70
HR (/min)	100–300	209–225	104–265	128–450	180–300	162–252	191–300	-	-
SpO_2 (%)	94–97	86–97	85–100		86–98	-	-	-	-
BT (℃)	36.0–39.0	37.2–38.0	33.7–37.1	39.4–39.8	34.4–37.2	35.7–37.3	35.5–37.9	-	38.4–40.2
$PECO_2$ (mmHg)	11–34	34–39	21–43	32–43	25–38	30–37	29–44	30–44	24–41
f_R (/min)	6–22	6–20	5–18	6–20	19–40	10–22	10–31	11–12	20–28

Data are presented as range.
BT, body temperature; HR, heart rate; SpO_2, peripheral oxygen saturation; WT, weight.

latory monitoring in small birds. Although commercial devices are available for this purpose, their high cost and size variability often limit their use in general practice, especially when unexpected avian patients present. The device described in this report consists of an IV catheter and a 3-way stopcock, utilizing common and readily accessible equipment in most primary care practices. This system enables controlled ventilation and ventilatory monitoring during anesthesia using a rebreathing circuit. The dead space within the expiratory line for CO_2 monitoring, consisting of the internal volume of the 3-way stopcock and the CO_2 sidestream sampling line, was approximately 0.4 mL each, totaling approximately 0.8 mL. The V_T of the bird is estimated to be 20–30 mL/kg (Zehnder *et al*., 2014), which theoretically allows monitoring in individuals weighing as little as 27–40 g.

Given their sensitivity to posture and movement, intubated devices must be securely fixed, and sudden movements of the patient or breathing circuits should be avoided during the procedure. To enhance stability, a control pressure line with a diameter of 1.5 mm and length of 25 cm, contributing approximately 0.4 mL to the internal volume, was added to the breathing circuit. Although this addition increased the dead space within the inspiratory line, it did not affect the CO_2 monitoring segment and was used successfully without any anesthesia-related complications in our patients. When added to the volume of the 3-way stopcock, the total dead space was approximately 0.8 mL. This volume, combined with the estimated V_T of 20–30 mL/kg in birds (Zehnder *et al*., 2014), suggests that both CO_2 monitoring and delivery of oxygen and anesthetic gas are feasible in individuals weighing as little as 27–40 g. The smallest bird monitored for ventilation in this study was a conure weighing 70 g. Further discussion is needed on how to reduce the dead space in the breathing circuit for efficient gas delivery, including oxygen, while maintaining the stability.

Although efforts were made to maintain $PECO_2$ below 40 mmHg, the elevated values presented in Table 1 were transient and not sustained. The absence of time-resolved data is a limitation of this study. The $PECO_2$ values may have been diluted by the inspired gases owing to the sampling characteristics of the monitoring device; however, the multiparameter monitor used in this study employed sidestream CO_2 monitoring at a flow rate of 50 mL/min, which is one of the lowest rates available. Additionally, contamination from room air through non-cuffed endotracheal catheters may have contributed to the underestimation of the $PECO_2$ values. The SpO_2 readings may have been affected by motion artifacts or small patient size, resulting in sporadic decreases, although most values were maintained at approximately 100%. Unfortunately, arterial blood gas analysis was not performed, which limits the ability to confirm the accuracy of the $PECO_2$ values or to determine whether they were underestimated. Another limitation was the absence of detailed records of the pre-anesthetic evaluations. Incorporating such information in future studies would provide a more comprehensive assessment of the anesthetic outcomes. An additional potential limitation of this technique is that prolonged anesthesia may promote the accumulation of viscous secretions within the tracheal catheter, which could interfere with accurate $PECO_2$ measurements. Although no catheter obstruction was observed in the present cases, this possibility should be considered in future applications, particularly during prolonged procedures. This study estimated the dead space based on the internal volume of the components but did not include direct experimental measurements or comparisons with commercially available low-dead-space adapters. Such data would further substantiate the clinical relevance of this technique.

In conclusion, despite certain limitations, such as the absence of arterial blood gas validation and transient monitoring variability, this system allowed effective respiratory monitoring and controlled ventilation in small avian patients. The smallest bird monitored in this case series was a 70 g conure, indicating the system's applicability even in very small individuals. This approach may help reduce the anesthetic risk in birds, particularly in general practice settings, by offering a simple and practical alternative to specialized equipment.

DECLARATIONS

Competing Interests

The authors declare no competing interests.

Author Contributions

Shin, D.: design, execution of the study, acquisition of data, and preparation of manuscript; Lee, I.: supervision of the report; Son, W.: study design, revision of the manuscript.

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