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Research Article

Comparative Efficacy of Propofol, Alfaxalone, Midazolam-Ketamine-Butorphanol, And Dexmedetomidine-Ketamine-Butorphanol to Anesthetize Pekin Ducks

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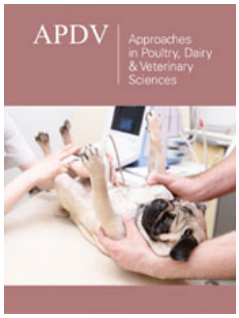

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Abstract

Gas anesthesia is the gold standard for producing general anesthesia in ducks; however, there are instances where it may not be appropriate. Injectable anesthesia is an alternative, but results can be variable, necessitating further research to determine proper dosing to achieve a surgical plane of anesthesia in this species. Our study investigated various doses of bolus versus Continuous Rate Infusion (CRI) of propofol or alfaxalone in Pekin ducks. Additionally, a one-time bolus of ketamine and butorphanol was compared with either dexmedetomidine or midazolam administered intravenously. Propofol was administered with an initial bolus of 10mg/kg, followed by additional boluses of 4mg/kg as needed, or alternatively, a 10mg/kg bolus followed by a CRI of 24-50mg/kg/hr. Eight ducks received propofol, with four additional ducks used to explore higher CRI doses. Alfaxalone was administered with an initial bolus of 4-6mg/kg, followed by additional boluses of 2mg/kg as needed, or a CRI of 25.5-40mg/kg/hr. The MKB protocol involved a single dose of ketamine (8-15mg/kg), midazolam (0.5-3mg/kg), and butorphanol (0.5-2mg/kg). The DKB protocol involved a single dose of ketamine (10-12mg/kg), dexmedetomidine (0.02-0.03mg/kg), and butorphanol (0.5-1mg/kg). Statistically, there were no significant differences among the groups compared. However, clinically, a CRI of at least 45 mg/kg/hr of propofol produced the most stable plane of surgical anesthesia. Our findings are critical because the typical dose of 10mg/kg of propofol was insufficient to produce a surgical plane of anesthesia in this study. Further research is needed to optimize dosing protocols for injectable anesthetics in ducks.

Keywords: Anesthesia; Duck; Analgesia; CRI; Adverse effects

Abbreviations: CRI: Constant Rate Infusion; TAS: Total Anesthesia Score; MKB: Midazolam-Ketamine-Butorphanol; DKB: Dexmedetomidine-Ketamine-Butorphanol; ASC: Air Sac Cannulation

Introduction

Injectable anesthesia in avian species has become an increasingly common practice in avian research, including ducks. Despite the associated risks, interest in this method has grown due to its advantages, such as rapid administration and minimal equipment requirements. However, ducks' unique physiology, including their high metabolic rate and susceptibility to the diving reflex, presents challenges for safe and effective anesthesia. While gas anesthesia is considered the gold standard for ducks, the equipment involved may not always be appropriate for the study being performed, including when performing stereotaxic procedures. The diving reflex, a physiological response observed in aquatic mammals and birds, poses a significant

risk during intubation. This reflex is characterized by apnea, bradycardia, and peripheral vasoconstriction, which help conserve oxygen for critical tissues [1]. Intubation can potentially interfere with the diving reflex, leading to apnea and other adverse effects. Therefore, careful consideration must be given to the potential risks and benefits of intubation before proceeding with stereotaxic procedures.

Several injectable anesthetic agents have been used in avian anesthesia, including ducks. These agents, including propofol, alfaxalone, midazolam-ketamine-butorphanol, and dexmedetomidine-ketamine-butorphanol possess general anesthetic properties such as inducing unconsciousness, muscle relaxation, and antinociception.

While these agents offer advantages, they also pose risks due to the unique physiology of ducks. Propofol is a non-barbiturate IV sedative with rapid onset and short duration of action. It offers excellent muscle relaxation and can produce smooth induction and recovery [2]. However, this drug requires careful monitoring and frequent redosing due to its short duration and may require large volumes of drug for a typical 30-minute procedure [3]. It may also cause dose dependent respiratory depression cardiopulmonary effects [4]. Alfaxalone, a synthetic neurosteroidal anesthetic, offers a longer duration of action than propofol. Its effects are on GABA receptors in the central nervous system, and provides effective anesthesia, especially when combined with other agents. While alfaxalone can be administered as a bolus or a constant rate of infusion, it may require higher doses when used alone and can have limited efficacy in certain cases. Its extended duration of action, however, reduces the need for frequent redosing. Midazolam-Ketamine-Butorphanol cocktail (MKB) is a balanced anesthetic combination often used for its reliable and longer-lasting effects. Ketamine can produce a dissociative anesthetic state, while midazolam and butorphanol provide muscle relaxation or sedation and analgesia.

However, this combination can also cause significant respiratory depression and muscle rigidity. Dexmedetomidine-Ketamine-Butorphanol (DKB) is another combination that can provide prolonged anesthesia. Dexmedetomidine, an alpha-2 adrenergic agonist, produces sedation, muscle relaxation, and analgesia. However, it can also cause adverse cardiorespiratory depression. This study aims to evaluate the effectiveness and safety of these four common anesthetic combinations in Pekin ducks via intravenous administration. By understanding the risks and benefits of each combination, veterinarians can make informed decisions about anesthesia for ducks.

Materials and Methods

Animals

10 total juvenile Pekin ducks (*Anas platyrhynchos domesticus*) (mean weight 4.40±0.67kg) of both sexes were obtained from a local commercial producer (Maple Leaf Farm, Inc; Leesburg, IN USA). The ducks were healthy on initial exam and housed in a poultry barn under production standards [5]. They were housed indoors on pine shaving bedding and fed standard adult, breeder duck diet [5]. This study was approved by the Purdue Institutional Animal Care and Use Committee, protocol 2109002191 (09-24-2021).

Study design and treatment protocols

A total of eight ducks (mixed sex) were randomly assigned to one of four experimental groups: propofol (Propoflo 28, Zoetis, Parsippany, NJ), alfaxalone (Alfaxan, Zoetis, Parsippany, NJ), Midazolam-Ketamine-Butorphanol (MKB) (Midazolam, West-Ward, Eatontown, NJ; Ketamine, Covetrus, Dublin, OH; Dolorex, Merck, Rahway, NJ), and Dexmedetomidine-Ketamine-Butorphanol (DKB) (Dexmedesed, Dechra Vet Products, Overland Park, KS; Ketamine, Covetrus, Dublin, OH; Dolorex, Merck, Rahway, NJ). A crossover design was employed with a minimum one-week washout period between anesthetic events.

Ducks were briefly physically restrained for intravenous catheter placement in the medial metatarsal vein. The four injectable anesthetics were administered intravenously according to the following protocols:

A. Propofol:

i. Initial bolus of 10mg/kg, followed by additional boluses of 4mg/kg as needed.

ii. Alternatively, a 10mg/kg bolus could be followed by a Continuous Rate Infusion (CRI) of 24-50mg/kg/hr.

iii. Eight ducks received propofol, with four additional ducks used to explore higher CRI doses.

B. Alfaxalone:

i. Initial bolus of 4-6mg/kg, followed by additional boluses of 2mg/kg as needed.

ii. Alternatively, a CRI of 25.5-40 mg/kg/hr could be used.

iii. Eight ducks received alfaxalone, with 4 bolus only and 4 CRI.

C. MKB:

i. A single dose of midazolam (0.5-3mg/kg), ketamine (8-15mg/kg), and butorphanol (0.5-2mg/kg).

ii. Eight ducks received MKB.

D. DKB:

i. A single dose of dexmedetomidine (0.02-0.03mg/kg), ketamine (10-12mg/kg), and butorphanol (0.5-1mg/kg).

ii. Eight ducks received DKB, with one duck excluded from analysis from this group due to illness.

Initial dosing for each treatment was determined by referencing existing literature [3,6] and is shown in Table 1. However, dosages were individualized based on each duck's response, including righting reflex, respiratory rate, heart rate, muscle relaxation,

and nociception. To maintain a surgical plane of anesthesia, top-off doses of propofol were administered as needed. The dosing paradigm for this study involved a range of bolus and Continuous Rate Infusion (CRI) doses for each anesthetic agent. The doses were not standardized and varied across individual ducks. For instance, alfaxalone was administered in initial boluses ranging from 4 to 6mg/kg, with additional boluses of 1.5 to 2mg/kg as needed, or as a CRI ranging from 25.5 to 40mg/kg/hr. Similarly, the Ketamine-Dexmedetomidine-Butorphanol (DKB) And Ketamine-Midazolam-Butorphanol (MKB) protocols involved single doses with varying amounts of each component. Propofol was administered with an initial bolus of 10mg/kg, followed by additional boluses of 2 to 4mg/kg or a CRI ranging from 24 to 50mg/kg/hr. This approach allowed for flexibility in dosing to achieve the desired anesthetic effect, but it also introduced variability in the dosing regimen. Animals were monitored for up to 30 minutes of anesthesia.

Table 1: Dosing Paradigm.

ID	Anesthetic Agent (mg/kg) IV	CRI
1	Alfaxalone 4mg/kg bolus + 1.5-2mg/kg bolus	
2	Alfaxalone 6mg/kg+2mg/kg bolus	
3	Alfaxalone 6mg/kg+2mg/kg bolus	
4	Alfaxalone 6mg/kg+2mg/kg bolus	
5	Alfaxalone 4mg/kg bolus	30mg/kg/hr
6	Alfaxalone 4mg/kg bolus	40mg/kg/hr
7	Alfaxalone 6mg/kg bolus	25.5mg/kg/hr
8	Alfaxalone 6mg/kg bolus	30mg/kg/hr
9	Ket (10) +Dex (0.02) + But (0.7)	
10	Ket (12) +Dex (0.02) + But (0.5)	
11	Ket (12) +Dex (0.02) + But (0.5)	
12	Ket (10) +Dex (0.02) + But (0.5)	
13	Ket (10) +Dex (0.03) +But (0.5)	
14	Ket (10) +Dex (0.03) +But (0.5)	
15	Ket (10) +Dex (0.02) +But (1)	
16	Ket (10) +Mid (2) +But (2)	
17	Ket (8) +Mid (0.5) +But (0.5)	
18	Ket (10) +Mid (1) +But (1)	
19	Ket (10) +Mid (1) +But (1)	
20	Ket (10) +Mid (2) +But (1)	
21	Ket (12) +Mid (2) +But (0.7)	
22	Ket (15) +Mid (2) +But (0.5)	
23	Ket (15) +Mid (3) +But (0.5)	
24	Propofol 10mg/kg bolus + 2-4mg/kg bolus	
25	Propofol 10mg/kg+4mg/kg bolus	
26	Propofol 10mg/kg+4mg/kg bolus	
27	Propofol 10mg/kg+4mg/kg bolus	
28	Propofol 10mg/kg bolus	24mg/kg/hr
29	Propofol 10mg/kg bolus	28mg/kg/hr
30	Propofol 10mg/kg bolus	35mg/kg/hr IV
31	Propofol 10mg/kg bolus	40mg/kg/hr
32	Propofol 10mg/kg bolus	40mg/kg/hr
33	Propofol 10mg/kg bolus	45mg/kg/hr
34	Propofol 10mg/kg bolus	45mg/kg/hr
35	Propofol 10mg/kg bolus	50mg/kg/hr

Anesthesia monitoring and assessment

Time to general anesthesia was determined by the absence of the righting reflex, a Muscle Relaxation Score (MRS) of 1 (assessed by jaw tone), a palpebral reflex score of 2 (assessed by saline stimulation), and a lack of response to a moderate toe pinch. Anesthesia was monitored every 5 minutes, including heart rate, respiratory rate, rectal body temperature, ECG, toe pinch, palpebral reflex, and muscle relaxation. A Total Anesthesia Score (TAS) was calculated by summing the scores for respiration pattern, muscle relaxation, palpebral reflex, and nociception (Tables 2 & 3) as in Darbyshire, et al [7]. A TAS of 3 was considered ideal.

Table 2: Anesthetic Scoring System.

Score	0	1	2	3	4
Respiration	Apnea>30s	Periodic	Spontaneous	n/a	n/a
Muscle Relaxation	n/a	Fully relaxed	Relaxed, some reflex present	Rigidity present	n/a
Palpebral Response	Absent	Slow, NM extending <50%	Slow, NM extending 100%	Fast	Spontaneous
Nociception	Absent	Slow	Immediate	Immediate & Violent	n/a

Table 3: Total Anesthesia Score.

TSA	1-Very Light	2- Light	3-Ideal	4-Deep	5-Very Deep
Score	12-Nov	10-Aug	7-May	4-Mar	2-Jan

Air sac cannulation and nociception assessment

If a TAS of 3-4 was maintained for at least 15 minutes during propofol CRI, an Air Sac Cannulation (ASC) procedure was attempted. Nociceptive reactions were assessed during the ASC. For ASC, a small incision was made over the abdominal air sac, and a 3-5mm endotracheal tube was inserted using a hemostat. Animals

undergoing ASC were euthanized via IV Euthasol (Virbac, Fort Worth, TX) following the procedure.

Recovery

Animals that survived were monitored for recovery time, defined as regaining the righting reflex and maintaining a sternal position after the last drug dose. Recovery time was recorded. Between anesthetic events, a wash-out period of at least one week was observed. Reversal drugs were used only in cases of suspected overdose. Humane endpoints included unresolving anesthetic complications such as severe apnea, hypotension, brady or tachycardia that was unable to be normalized with reversal agents and/or assisted ventilation, or ducks having prolonged or difficult recovery or other health concerns. Animals were monitored under anesthesia by trained veterinarians and veterinary technicians.

Statistical analysis

Repeat procedures were conducted using different anesthetic schemes, resulting in samples for Propofol with CRI, Propofol without CRI, Alfaxalone with CRI, Alfaxalone without CRI, KDB, and KMB. Since ducks underwent multiple anesthesia sessions, individual samples were considered at the session level rather than the animal level. Propofol with and without CRI was compared to Alfaxalone with and without CRI using a 2-way ANOVA. Post hoc analysis of ANOVAs was performed with Tukey's corrections for multiple comparisons where applicable. KMB was compared to KDB using an independent t-test. Results are reported for each anesthetic measure. Sessions where the animal did not reach a total anesthetic depth score of 3 or higher were excluded from the analysis of time to anesthesia. This exclusion resulted in one comparison group (Alfaxalone with bolus) containing only one session. Additionally, one animal from the DKB group was excluded from statistical analysis due to ascites, which affected the results.

Result and Discussion

Time to anesthesia

Time to anesthesia was not significantly influenced by anesthetic type (Propofol vs. Alfaxalone, F1,12=3.04, p=0.11) or route of administration (CRI vs. bolus, F1,12=0.0, p=0.97). Ducks receiving either Propofol or Alfaxalone achieved anesthesia in an average of 7.13minutes. No significant differences were found between DKB and MKB regimens (t12=1.17, p=0.27), with an overall mean of 2.93 minutes (Figure 1). Anesthetic dosing and time to anesthesia is shown in Table 4.

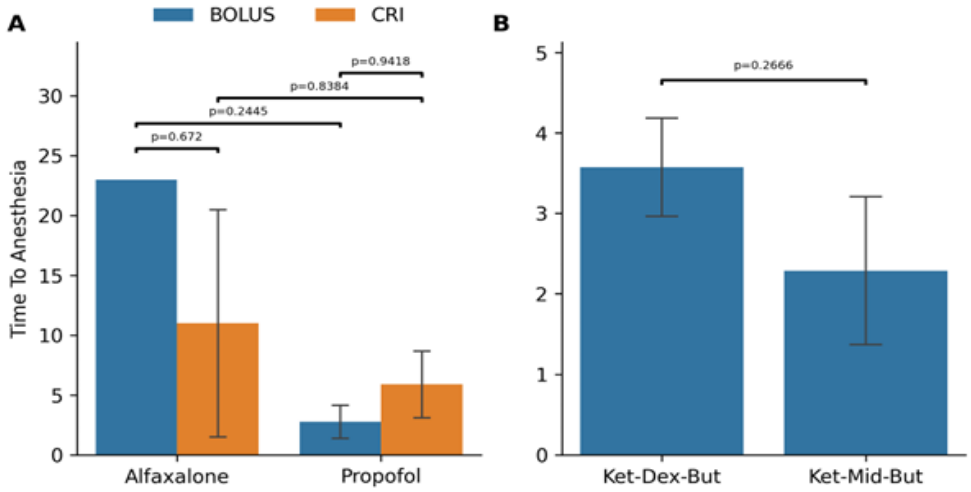

Figure 1: Time to anesthesia. (A) Time to anesthesia evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=1), alfaxalone-CRI(n=3), propofol-BOLUS(n=4) and propofol-CRI(n=8). (B) Time to anesthesia evaluated for ducks who underwent regimens of either DKB(n=7) or MKB(n=7).

Table 4: Dosing schedule and total drug administered.

ID	Anesthetic Agent (mg/kg) IV	CRI	Time To Anesthesia (min)	Time To Recovery (min)
1	Alfaxalone 4mg/kg bolus +1.5-2mg/kg bolus		Not reached	22
2	Alfaxalone 6mg/kg+2mg/kg bolus		Not reached	11
3	Alfaxalone 6mg/kg+2mg/kg bolus		23	7
4	Alfaxalone 6mg/kg+2mg/kg bolus		Not reached	20
5	Alfaxalone 4mg/kg bolus	30mg/kg/hr	30	14
6	Alfaxalone 4mg/kg bolus	40mg/kg/hr	Not reached	5

7	Alfaxalone 6mg/kg bolus	25.5mg/kg/hr	1	10
8	Alfaxalone 6mg/kg bolus	30mg/kg/hr	2	overdose
9	Ket (10) +Dex (0.02) +But (0.7)		4	19
10	Ket (12) +Dex (0.02) +But (0.5)		4	7
11	Ket (12) +Dex (0.02) +But (0.5)		2	13
12	Ket (10) +Dex (0.02) +But (0.5)		2	8
13	Ket (10) +Dex (0.03) +But (0.5)		2	5
14	Ket (10) +Dex (0.03) +But (0.5)		6	10
15	Ket (10) +Dex (0.02) +But (1)			Overdose after 1 min
16	Ket (10) +Mid (2) +But (2)		7	Overdose; naloxone unsuccessful
17	Ket (8) +Mid (0.5) +But (0.5)		Not reached	43
18	Ket (10) +Mid (1) + But (1)		3	50; Naloxone administered
19	Ket (10) +Mid (1) +But (1)		<1	25
20	Ket (10) +Mid (2) +But (1)		<1	37
21	Ket (12) +Mid (2) +But (0.7)		2	36; Naloxone and Flumazenil administered
22	Ket (15) +Mid (2) +But (0.5)		3	37
23	Ket (15) +Mid (3) +But (0.5)		1	34
24	Propofol 10mg/kg bolus + 2-4mg/kg bolus		<1	22
25	Propofol 10mg/kg+4mg/kg bolus		6	18
26	Propofol 10mg/kg+4mg/kg bolus		1	7
27	Propofol 10mg/kg+4mg/kg bolus		4	27
28	Propofol 10mg/kg bolus	24mg/kg/hr	3	1
29	Propofol 10mg/kg bolus	28mg/kg/hr	25	2
30	Propofol 10mg/kg bolus	35mg/kg/hr IV	3	4
31	Propofol 10mg/kg bolus	40mg/kg/hr	3	3
32	Propofol 10mg/kg bolus	40mg/kg/hr	6	ASC-responded
33	Propofol 10mg/kg bolus	45mg/kg/hr	2	ASC-no response
34	Propofol 10mg/kg bolus	45mg/kg/hr	3	euthanized
35	Propofol 10mg/kg bolus	50mg/kg/hr	2	ASC-no response

Time to recovery

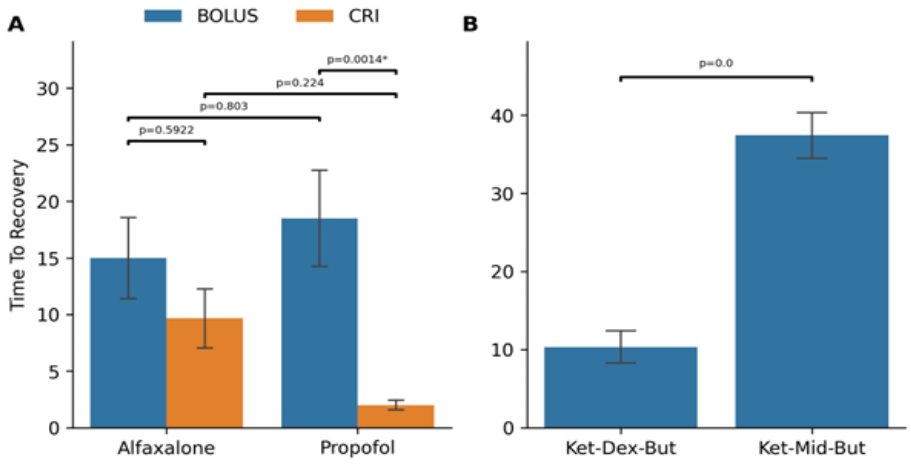

Figure 2: Time to recovery. (A) Time to recovery evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=4), alfaxalone-CRI(n=3), propofol-BOLUS(n=4) and propofol-CRI(n=7). (B) Time to recovery evaluated for ducks who underwent regimens of either DKB(n=6) or MKB(n=7).

Anesthetic type did not affect recovery time (F1,14=0.67, p=0.43), but route significantly influenced recovery (F1,14=20.48, p<0.05) for propofol and alfaxalone. This effect was more pronounced in Propofol-treated animals, with significant differences between bolus and CRI (p<0.005) within this group. Overall, animals in the Propofol group recovered in an average of 9.83minutes. DKB-treated animals recovered significantly faster than MKB-treated animals (t11=-7.33, p<0.05), despite reversal agent use in two MKB animals (Figure 2). The average recovery time for DKB and MKB groups was 24.92 minutes.

Physiological parameters

a. Heart rate: No significant differences were observed in heart rates between Propofol and Alfaxalone or between CRI and bolus. DKB regimens resulted in significantly lower heart rates compared to MKB (t13=-2.2, p<0.05), with average rates of 145.73bpm for DKB and 194.63bpm for MKB (Figure 3).

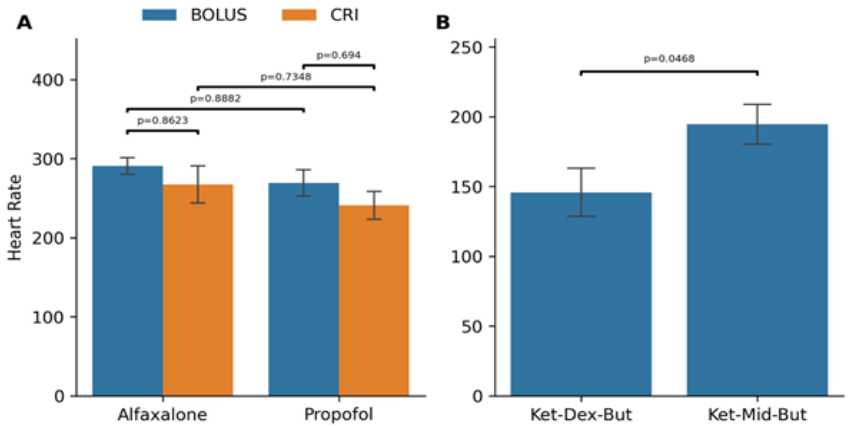

Figure 3: Heart Rate. (A) Heart rate evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=4), alfaxalone-CRI(n=4), propofol-BOLUS(n=4) and propofol-CRI(n=8). (B) Heart rate evaluated for ducks who underwent regimens of either DKB(n=7) or MKB(n=8).

b. Body temperature: Body temperature was not significantly affected by anesthetic type or route in either Propofol-Alfaxalone or DKB-MKB groups (Figure 4).

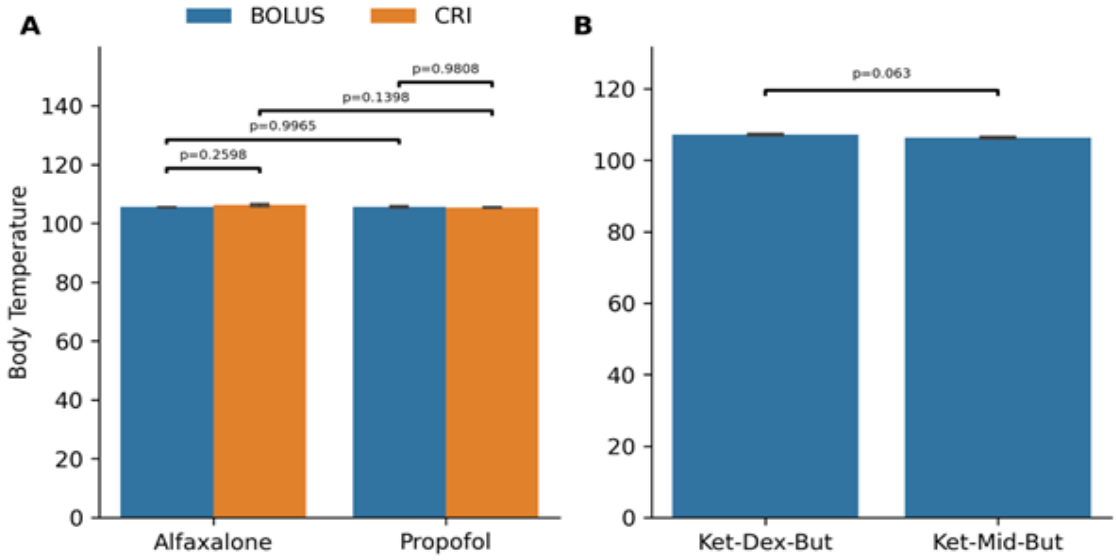

Figure 4: Body temperature. (A) Body temperature evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=4), alfaxalone-CRI(n=4), propofol-BOLUS(n=4) and propofol-CRI(n=7). (B) Body temperature evaluated for ducks who underwent regimens of either DKB(n=7) or MKB(n=8).

c. Respiration: No significant differences were observed in respiration rates between Propofol and Alfaxalone or between CRI and bolus. Similarly, DKB and MKB groups showed no differences in respiration rates (Figure 5).

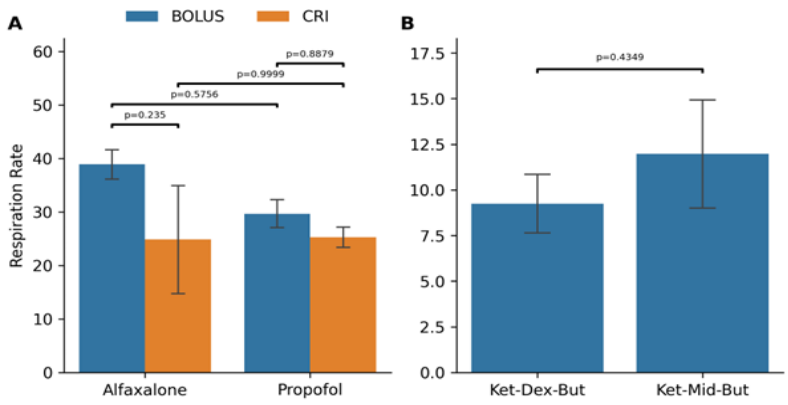

Figure 5: Respiration rate. (A) Respiration rate evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=4), alfaxalone-CRI(n=4), propofol-BOLUS(n=4) and propofol-CRI(n=8). (B) Respiration rate evaluated for ducks who underwent regimens of either DKB(n=7) or MKB(n=7).

d. Muscle relaxation: Anesthetic type and route did not significantly affect muscle relaxation scores in either Propofol-Alfaxalone or DKB-MKB groups (Figure 6).

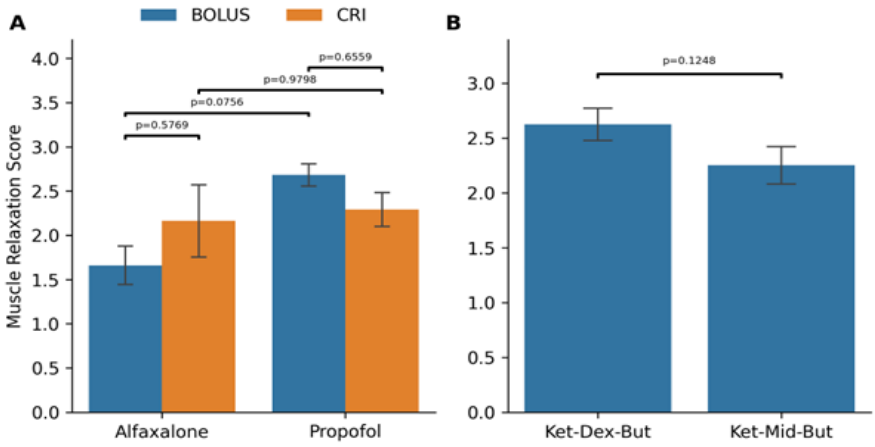

Figure 6: Muscle relaxation score. (A) Muscle relaxation score evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=4), alfaxalone-CRI(n=4), propofol-BOLUS(n=4) and propofol-CRI(n=8). (B) Muscle relaxation score evaluated for ducks who underwent regimens of either DKB(n=7) or MKB(n=8).

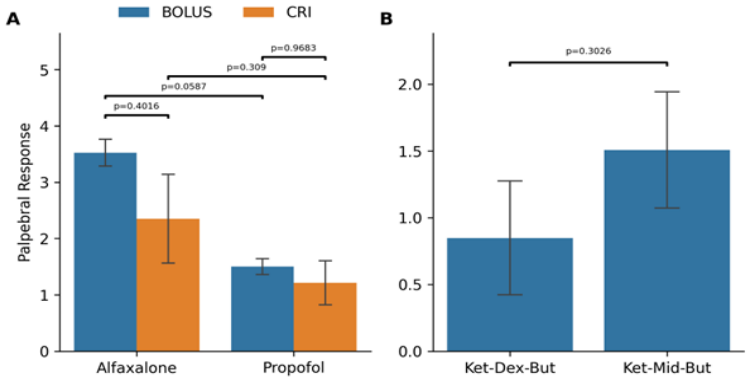

Figure 7: Palpebral response. (A) Palpebral response evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=4), alfaxalone-CRI(n=4), propofol-BOLUS(n=4) and propofol-CRI(n=8). (B) Palpebral response evaluated for ducks who underwent regimens of either DKB(n=7) or MKB(n=8).

e. Palpebral reflex: Propofol treatment resulted in a lower palpebral response compared to Alfaxalone ($F_{1,16}=10.1$, $p<0.05$), while route had no effect (Figure 7).

f. Nociception: No significant differences were found in nociception scores between Propofol and Alfaxalone or between CRI and bolus (Figure 8).

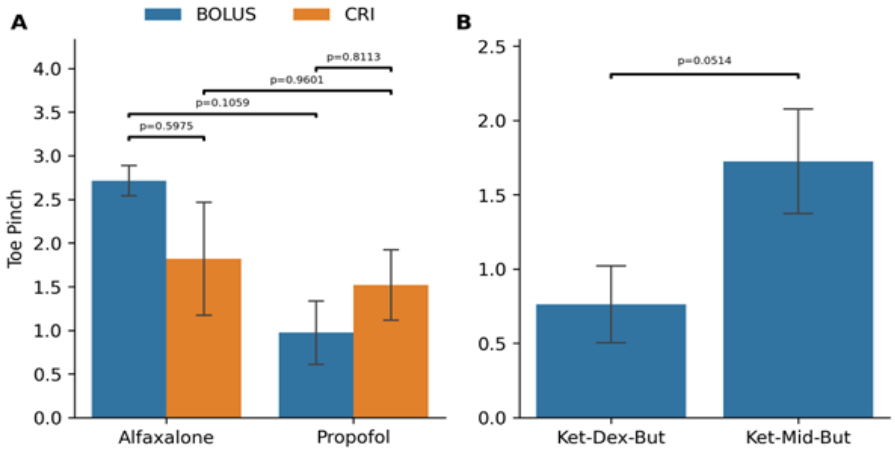

Figure 8: Toe pinch response. (A) Toe pinch evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=4), alfaxalone-CRI(n=4), propofol-BOLUS(n=4) and propofol-CRI(n=8). (B) Toe pinch evaluated for ducks who underwent regimens of either DKB(n=7) or MKB(n=8).

Total Anesthesia Score (TAS)

Total anesthesia score was not affected by anesthetic type when administered Propofol or Alfaxalone and averaged 2.68. DKB and MKB also did not significantly differ and had an average score of 3.30 (Figure 9).

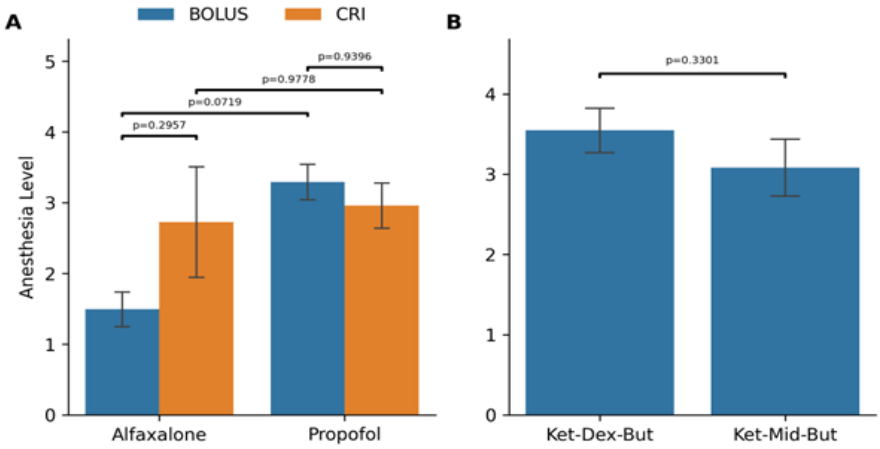

Figure 9: Total anesthesia score. (A) Anesthesia level evaluated for ducks who underwent regimens of alfaxalone-BOLUS(n=4), alfaxalone-CRI(n=4), propofol-BOLUS(n=4) and propofol-CRI(n=8). (B) Anesthesia level evaluated for ducks who underwent regimens of either DKB(n=7) or MKB(n=8).

Discussion

The present study highlights the individual variability in anesthetic responses among ducks. Despite standardized dosing regimens, achieving a consistent and ideal anesthetic plane (TAS 3) was challenging. Many animals exhibited movement, such as head, jaw, or wing twitching, even when toe pinch was absent. Additionally, some ducks did not lose the toe pinch response, suggesting that the stimulus might have been insufficient. One possible explanation is that the toe pinch may not have been applied with enough force to elicit a response, resulting in a false negative where the duck appears unresponsive despite not being fully anesthetized. Ducks, like other animals, have spinal reflexes that can respond to painful stimuli independently of the brain. Thus, if the toe pinch is a spinal reflex, the absence of a response might indicate that the spinal reflex arc was not activated, possibly due to the depth of anesthesia affecting spinal cord function. Individual ducks may have different sensitivities to anesthetic agents, leading to variability in their

responses, with some ducks requiring higher doses to achieve the same level of anesthesia. This fact could explain the movements observed despite the absence of a toe pinch response.

The movements observed could also indicate that the ducks were in a state of partial (or light plane of) anesthesia, where the central nervous system was sufficiently depressed to prevent a toe pinch response, but some motor functions were still active. Anesthetic depth can also fluctuate due to putative high drug metabolism rate during the procedure, leading to periods where the duck is not fully anesthetized, that led to intermittent movements even if the toe pinch response is absent at other times. Ducks may have physiological differences that affect how they metabolize and respond to anesthetic agents, leading to variability in achieving a consistent anesthetic plane across individuals. Finally, the dosing regimen might not have been optimal for all individuals, with some ducks requiring higher doses to achieve a stable anesthetic plane, leading to movements in those that received insufficient anesthesia. We recognize a limitation that since the dosing was not exactly the same for each animal, the statistics performed are not ideal, however, we still feel that the results are clinically relevant.

Alfaxalone: While Alfaxalone maintained good respiration in most ducks, some ducks required intubation for respiratory support, usually for the first few minutes after induction. Heart and respiratory rates were higher with Alfaxalone compared to Propofol. Alfaxalone alone was insufficient to induce general anesthesia in most ducks, with frequent wing and jaw twitching and persistent toe pinch. Repeated boluses were necessary, generally every 2-3 minutes, ultimately leading to sedation but not a deep anesthetic plane. Recovery from Alfaxalone was slower than with Propofol CRI. These findings align with previous studies that reported the ineffectiveness of Alfaxalone as a standalone anesthetic in ducks [8].

Ketamine, butorphanol, and midazolam/dexmedetomidine combinations: Our study investigated the potential of Ketamine, Butorphanol, and either Midazolam or Dexmedetomidine for providing reliable, long-term anesthesia in ducks. While these drug combinations have not been extensively studied in avian species, they offer the advantage of a single IV administration and the possibility of reversing their effects. Ketamine, as an NMDA receptor agonist, can induce an anesthetic plane but is often associated with muscle rigidity, laryngeal reflexes, and rough recoveries [9,10]. Combining it with benzodiazepines or alpha-2 adrenergic agonists can improve relaxation and depth of anesthesia. Butorphanol, an opioid analgesic, has sedative effects and can cause respiratory depression [4,11].

Midazolam, a benzodiazepine, provides sedation, muscle relaxation, and minimal cardiorespiratory depression. Dexmedetomidine, an alpha-2 adrenergic agonist, offers sedation, muscle relaxation, and moderate analgesia but can also cause adverse cardiorespiratory effects. Prior studies have found that that combination of medetomidine, midazolam and ketamine was unsafe for use, as it caused significant cardiorespiratory depression and death in some ducks [3,12]. Our study also found that the combination of Ketamine, Midazolam, and Butorphanol (MKB) had a narrow safety margin and was not suitable for most ducks due to significant cardiorespiratory depression. While both MKB and DKB (Dexmedetomidine, Ketamine, Butorphanol) resulted in depressed heart rates, MKB had higher rates and produced more muscle relaxation. DKB, however, required respiratory support during the initial minutes and did not consistently achieve a general anesthetic plane.

Propofol: Propofol, administered as a bolus followed by CRI, provided faster time to anesthesia compared to Alfaxalone. However, maintaining a consistent anesthetic plane with Propofol was challenging, requiring frequent boluses and higher CRI rates. Propofol administration resulted in initial apnea, which was minimized with a slow bolus, however after a couple of minutes respiration improved and was generally well-maintained. Boluses needed to be repeated every 4-5 minutes, with a light plane of anesthesia achieved. This is a concern since 10mg/kg propofol is generally used as a standard injectable anesthesia protocol in ducks, however this was not sufficient to produce a surgical plane in the Pekin ducks from our study. Despite the need for higher doses, Propofol was generally well-tolerated by the ducks.

Conclusion

The findings of our study highlight the challenges associated with achieving a reliable and consistent anesthetic plane in ducks using injectable anesthetics. While individual variations and the complex physiology of ducks play a significant role, the choice of anesthetic agents and dosing regimens also influences anesthetic outcomes. Clinically, we saw promising results with the higher CRI rates of propofol. Our recommendation for injectable anesthesia in Pekin ducks is to use a 10mg/kg IV bolus, followed by CRI of at least 45mg/kg/hr to achieve a steady surgical plane of anesthesia. Further research is necessary to identify optimal anesthetic protocols that can provide effective and safe anesthesia for various procedures in ducks.

References

1. Coluccy J, Shaw H (2009) Diving ducks: Into the deep.
2. Molter C, Escobar A, Schroeder C (2022) Backyard poultry and waterfowl sedation and anesthesia. Veterinary Clinics of North America: Exotic Animal Practice 25(1): 163-180.
3. Machin KL, Caulkett NA (1998) Cardiopulmonary effects of propofol and a medetomidine-midazolam-ketamine combination in mallard ducks. Am J Vet Res 59(5): 598-602.
4. Paul MJ, Fialkowski J (2001) Injectable anesthesia and analgesia of birds. Recent Advances in Veterinary Anesthesia and Analgesia: Companion Animals.
5. Chen X, Shafer D, Sifri M, Lilburn M, Karcher D, et al. (2021) Centennial review: History and husbandry recommendations for raising pekin ducks in research or commercial production. Poultry Science 100(8): 101241.
6. (2024) Sedation/immobilization protocols. BSAVA.
7. Darbyshire AK, Fraley GS, Horvath A, Ko JC (2023) Assessment of urethane as an anesthetic in pekin ducks. Appro Poult Dairy & Vet Sci 9(4): 925-930.

8. Kruse TN, Messenger KM, Bowman AS, Aarnes TK, Wittum TE, et al. (2019) Pharmacokinetics and pharmacodynamics of alfaxalone after a single intramuscular or intravascular injection in mallard ducks (Anas platyrhynchos). J Vet Pharmacol Ther 42(6): 713-721.

9. Rosenbaum SB, Gupta V, Patel P, Palacios JL (2017) Ketamine. StatPearls Publishing LLC.

10. Machin K (2004) Waterfowl anesthesia. Seminars in Avian and Exotic Pet Medicine 13(4):206-212.

11. Mans C (2017) Sedation and Analgesia in Birds.

12. Faris GAM, Abd AZT, Abass BT (2007) Comparative injectable anesthetic protocols in ducks. Iraqi Journal of Veterinary Sciences 21(1):105-115.