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INTRAVENOUS ANESTHESIA IN POULTRY: A COMPREHENSIVE REVIEW OF DRUGS AND PROTOCOLS

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ABSTRACT

Anesthesia in poultry presents unique challenges due to its particular physiology. This study, a literature review, investigates intravenous anesthesia in poultry, addressing drugs, doses, efficacy and adverse effects, with the aim of optimizing anesthetic protocols and improving poultry welfare. The research considered articles published between 1990 and 2024, indexed in databases such as PubMed, BSV Veterinária, Google Scholar, Science Direct, and Springer Open. The review identified propofol and alfaxalone as the most studied intravenous drugs in avian anaesthesia. The interspecific variability in doses and protocols reinforces the need for anesthetic individualization. The combination of drugs, aiming at balanced anesthesia, demonstrated potential to optimize analgesia and minimize adverse effects. Total intravenous anesthesia appears as a promising alternative, especially when inhalational anesthesia is contraindicated. However, the heterogeneity of studies and the scarcity of research with certain species and drugs limit the generalization of the results. The findings of this review contribute to veterinary practice, guiding the choice of drugs and anesthetic protocols that are more appropriate for different avian species. Caution in the application of the results is recommended, consultation of multiple sources and individualization of anesthesia are crucial.

Keywords: Propofol. Alfaxalona. Midazolam. Acepromazine. Fentanyl.

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INTRODUCTION

Birds comprise approximately 10,000 species, distributed in 28 orders, many of which are kept as pets. The growing presence of birds in rehabilitation centers, veterinary offices and hospitals justifies the wide use of anesthesia in these animals. Physical restraint, in addition to being extremely stressful, can be fatal in some cases, making anesthesia a less stressful alternative and often necessary in simple outpatient procedures, such as nail and beak trimming, physical and imaging examination, and is indispensable in surgical procedures (Ludders, 2015).

Anesthesia in birds presents considerable challenges due to the anatomical and physiological diversity of these species, both wild and domesticated. Differences in the cardiovascular and respiratory systems require specific anesthetic approaches, based on the principles of avian anatomy, physiology, and pharmacology (Ludders, 2015). Despite advances in anesthetic agents and monitoring techniques that have contributed to increased safety (Ferrier et al., 2022), anesthetic risks in poultry remain relevant. Anesthetic agents can induce cardiorespiratory depression, which is potentially fatal, especially in critically ill patients (Ludders, 2015).

Total intravenous anesthesia (TIVA) consists of the exclusive administration of intravenous anesthetic drugs, both for induction and maintenance. Ideal drugs for TIVA should have rapid induction and recovery, without cumulative effects that prolong anesthetic awakening (Yan et al., 2023). Widely used in small animals in critical condition, TIVA offers advantages over inhalational anesthesia, constituting a safe and effective alternative in complex scenarios. By minimizing the cardiovascular impact, TIVA reduces the risks of myocardial depression, vasodilation, and hypotension, often associated with inhalational agents (Ferrier et al., 2022). In addition, it provides a gentle awakening, reducing the incidence of agitation, dysphoria, nausea, and vomiting in the postoperative period, particularly benefiting critically ill patients (Raffe, 2020). Administration by controlled continuous infusion (CRI) allows precise adjustment of doses, ensuring stable anesthesia adapted to individual needs. The absence of emissions of halogenated anesthetic gases, such as isoflurane and sevoflurane, minimizes the environmental impact and occupational risks for the veterinary team (Yan et al., 2023). The flexibility of TIVA makes it suitable for both short- and long-term procedures, being advantageous in settings with limited infrastructure for inhalational anesthesia (Raffe, 2020).

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A meta-analysis comparing TIVA and volatile anaesthesia (VA) in oncological surgery (10 studies, 14,036 patients) associated TIVA with better outcomes, including longer overall and recurrence-free survival, as well as a lower incidence of postoperative complications. The authors suggest that propofol, often used in TIVA, preserves immunity and inhibits pro-tumor factors, while volatile anesthetics may exacerbate immunosuppression and favor metastases (Yan et al., 2023).

In poultry, TIVA may be preferable to inhalational anesthesia in specific circumstances, such as respiratory tract diseases, surgical repair of pneumatic bones, respiratory or coelomatic tract surgeries with air sac invasion, and oral cavity procedures, where the endotracheal tube may be an obstacle, in addition to exposing staff to high concentrations of residual anesthetic gases (Santos et al., 2020).

The present study, through a narrative review of the literature, sought to compile information on the main intravenous drugs used in different avian species, highlighting doses, efficacy and potential adverse effects, with the objective of optimizing anesthetic protocols, minimizing risks and maximizing the success of procedures, emphasizing the importance of the theme for veterinary medicine and the conservation of species.

MATERIAL AND METHODS

Studies that addressed anesthesia in birds, with drugs administered intravenously, either for induction or maintenance of anesthetics, were included. Studies highlighting the pharmacodynamics and pharmacokinetics of the main drugs used in induction and maintenance by intravenous and adjuvant routes. In the absence of evidence on the use of certain drugs in the avian species, studies in other species were used as a comparative model. Studies that use intramuscular and intranasal anesthetic drugs were also included, when relevant in the anesthesia of birds. The inclusion criteria were studies published in English, Portuguese, and Spanish, journal articles, available in full format, published between 1990 and 2024. Studies that addressed only the use of inhalational anesthesia in birds were excluded. Pre-1990 publications, plus simple or expanded abstracts and newsletters.

The databases consulted for the search were: PubMed, BSV Veterinária, Google Scholar, Science Direct, Springer Open.

The keywords used to refine the search were: avian anesthesia; propofol in avian; Intravenous Propofol Avian Anaesthesia; total intravenous anesthesia; total intravenous

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anesthesia veterinary; Alfaxalone Avian; anesthetic adjuvant. These words were combined and adapted according to the requirements of each database, in order to ensure the comprehensiveness and relevance of the results.

RESULTS AND DISCUSSION

We found 21 publications that addressed anesthetic drugs used intravenously in birds. The studies included several avian species, focusing on the main intravenous drugs used, their doses, efficacy, and potential adverse effects (Tables 1).

The avian species studied were diverse in different clinical and research contexts. The studies ranged from small birds, such as pigeons and chickens, to larger birds, such as ostriches, swans, and emus (Tables 1).

Several drugs were used intravenously in these studies. Among them, propofol (ten studies) and alfaxalone (seven studies) stand out. Lidocaine, xylazine, ketamine, diazepam, midazolam, medetomidine and fentanyl make up the list of drugs evaluated, although with less representativeness. The doses administered varied considerably, influenced by factors such as species, route of administration, combination with other drugs, and objective of the procedure (Tables 1).

Only twelve studies investigated the isolated action of an anesthetic drug, providing accurate information about its unique effects. Most of the studies (16 out of 20) also used combinations of drugs, aiming to optimize the anesthetic procedure, minimize adverse effects, and promote a smooth recovery.

Propofol (2,6-diisopropylphenol) is a non-barbiturate general anesthetic widely used for both induction and maintenance of anesthesia. Its characteristics include rapid induction and recovery, as well as a comprehensive metabolism that occurs both in the liver and in other organs such as the kidneys, lungs, and intestines, which contributes to its rapid elimination from the body. In the last three decades, propofol has established itself as the most widely used intravenous anesthetic globally and is considered ideal for Total Intravenous Anesthesia (TIVA) (Raffe, 2020; Ferrier et al, 2022; Lopes et al., 2024). Although its efficacy and safety are well established in several mammalian species, based on its pharmacodynamic and pharmacokinetic properties, there is a paucity of studies documenting its application in birds (Hawkins et al., 2003) (Table 1).

A study conducted with twenty mute swans (*Cygnus olor*) investigated the efficacy of propofol in anesthetic induction using a dose of 8 mg/kg. The research compared two

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administration techniques: continuous infusion at 0.8 mg/kg/min and intermittent bolus doses of 1 mg/kg. Anesthetic induction, completed in 30 seconds, resulted in a smooth onset of anesthesia, with no occurrence of apnea or excitement. The physiological parameters evaluated — heart rate, respiratory rate, body temperature, and oxygen saturation — did not show significant differences between the groups. However, the group that received continuous infusion demonstrated a more stable and higher-quality anesthetic plan. In contrast, the bolus group required multiple doses at short intervals, leading to abrupt awakenings and complications in animal management. Both groups exhibited signs of mild arousal during awakening. These results suggest that continuous infusion of propofol offers a higher quality anesthetic for swans, being more effective in maintaining anesthetic stability (Müller et al., 2011).

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Table 1: Data on intravenous anesthetics in different avian species. The information was obtained from 16 original articles published between 1990 and 2024, identified in the PubMed, BSV Veterinária, Google Scholar, Science Direct, and Springer Open databases. The table gathers information on the drugs used, their doses, species studied, induction times, duration of anesthesia, and adverse effects observed.

Fonte da Informação	Fármaco, Dose e Via de Administração	Tipo de Administração	Espécie Estudada	Efeitos do Fármaco (Eficácia)	Efeitos Adversos Observados
Fitzgerald e Cooper (1990)	Grupo I: Propofol - 14 mg/kg - IV Grupo II: Cetamina (20 mg/kg, IM) + (4,1 a 8,6 mg/kg, IV) Grupo III: Propofol (14 mg/kg, IV) + halotano (1,5%) em mistura de nitrous oxide/oxigênio (1:1)	Bolus	Pombos-domésticos (*Columba livia*)	Indução rápida e relaxamento muscular, duração curta (2-7 min); recuperação suave sem excitação.	Depressão respiratória severa em alguns casos; apneia transitória em 62% das doses incrementais; margem de segurança estreita.
Machin & Caulkett (1998)	Grupo I - Medetomidina (50 µg), Midazolam (2 mg), Cetamina (10 mg) – Intravenosa (bolus) Grupo II - Propofol - 10 mg (bolus) seguido de 1-4 mg a cada 5 min – Intravenosa	Bolus	Patos-reais (*Anas platyrhynchos*)	GI - Sedação profunda e analgesia por 20 minutos; reversão com atipamezole (250 µg) e flumazenil (25 µg). GII - Indução rápida e manutenção de um plano leve de anestesia por 30 minutos.	GI -Bradicardia severa, hipoxemia significativa, acidose respiratória, e óbito em 4 de 12 patos anestesiados. GII - Apneia após o bolus inicial; depressão respiratória significativa; necessidade de suporte ventilatório.
Machin & Caulkett (2000)	Grupo I - Propofol: 10 mg/kg IV para indução; 1–2 mg/kg IV bolus para manutenção Grupo II – Isoflurano; Indução: de 1% a 5%; Manutenção: de 1,5 a 3,5%.	Bolus e Infusão Contínua	Patos-fêmeas (*Aythya valisineria*)	Indução suave e rápida, boa recuperação; menor taxa de abandono do ninho comparado ao isoflurano (Grupo I).	GI - Depressão respiratória dose-dependente; excitação transitória. GII - Indução prolongada comparada ao propofol. Recuperação frequentemente marcada por lutas e estresse. Alta taxa de apneia durante a anestesia, exigindo ventilação artificial.
Hawkins et al. (2003)	Propofol - 4.48 ± 1.09 mg/kg (hawks), 3.36 ± 0.71 mg/kg (owls) IV para indução; 0.48 ± 0.06 mg/kg/min (hawks), 0.56 ± 0.15 mg/kg/min (owls) IV para manutenção	Bolus e Infusão Contínua (CRI)	Gavião-de-cauda-vermelha (hawks) (*Buteo jamaicensis*) e Coruja-grande-americana (Owls) (*Bubo virginianus)*	Indução suave e manutenção estável do plano anestésico leve; reflexos abolidos progressivamente; ventilação necessária para hipoventilação.	Hipoventilação com aumento de PaCO2 (30-45%), hipercapnia e acidose; sinais de excitação do SNC na recuperação (opistótonos e tremores musculares).
Ciboto et al. (2006)	Grupo I: MPA - Acepromazina (0,25 mg/kg IM); Indução: Propofol (4,0 mg/kg IV) Grupo II: MPA - Acepromazina (0,25 mg/kg IM); Indução: Cetamina (5,0 mg/kg IV) + Diazepam (0,25 mg/kg IV) Grupo III: MPA - Acepromazina (0,25 mg/kg IM); Indução - Tiletamina-zolazepam (3,0 mg/kg IV) Grupo IV: MPA - Xilazina (1,0 mg/kg IM); Indução: Cetamina (5,0 mg/kg IV) + Diazepam (0,25 mg/kg IV) Grupo V: MPA- Xilazina (1,0 mg/kg IM); Indução: Tiletamina-zolazepam (3,0 mg/kg IV)	Bolus	Avestruz (*Struthio camelus*)	Todos os protocolos resultaram em imobilização completa e relaxamento muscular; protocolos variaram no tempo de manutenção e recuperação.	G IV e V: Sedação moderada com Xilazina; efeitos adversos mínimos; qualidade da recuperação variou entre os grupos.
Müller et al. (2011)	Propofol (indução): 8 mg/kg IV; Manutenção em bolus: 2.9 mg/kg a cada 4 (1–8) minutos Propofol (manutenção CRI): 0,85 mg/kg/min IV	Bolus Infusão Contínua (CRI)	Cisnes-mudos (*Cygnus olor*)	Indução rápida e suave; fácil intubação; manutenção por bolus resultou em períodos curtos de anestesia profunda. (Bolus) Anestesia estável e adequada para procedimentos diagnósticos sem apneia; recuperação em 30 (18–50) minutos. (CRI)	Recuperação abrupta; apneia transitória em 2 aves; sinais de excitação no SNC durante recuperação em 55% dos casos. (Bolus) Sinais transitórios de excitação no SNC (55% das aves). (CRI)
Araújo et al. (2013)	Propofol - 5 mg/kg - Intravenosa	Bolus	Emas (*Rhea americana americana*)	Indução anestésica em 2,48±0,6 minutos; Período hábil de anestesia de 2,98±0,8 minutos	Aumento na frequência cardíaca após administração;

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Bigby et al. (2016)	MPA -Medetomidina (25 µg/kg) + Diazepam (0,38 mg/kg) IM Indução - Propofol - 3,7 mg/kg – IV Manutenção - Propofol - 0,1–0,3 mg/kg/min - Intravenosa (CRI)	Bolus; Infusão Contínua (CRI)	Pinguim-rei (*Aptenodytes patagonicus*)	Indução e recuperação rápidas, manutenção estável da anestesia sem efeitos cardiovasculares significativos.	Depressão respiratória prevenida por ventilação mecânica.
Santos et al. (2020)	Grupo I – Propofol (9 mg/kg IV) Grupo II – Propofol + Metadona (9 mg/kg IV + 6 mg/kg IM) Grupo III – Propofol + Nalbufina (9 mg/kg IV + 12.5 mg/kg IM) Grupo IV – Propofol + Fentanil (9 mg/kg IV + 30 µg/kg IV)	Bolus; Infusão Contínua (CRI)	Galinhas (Gallus gallus domesticus)	todos os protocolos proporcionaram anestesia adequada para osteotomia da ulna. A combinação de propofol com metadona ou nalbufina reduziu a dose de propofol necessária para manutenção anestésica.	Hipercapnia (PE'CO2 > 60 mmHg) foi observada em todos os grupos, independentemente do protocolo anestésico utilizado. Não foram relatados outros efeitos adversos significativos.
Zendehboudi & Vesal (2024)	Grupo I - Propofol - 10 mg/kg/min (indução), seguido de 1.1 mg/kg/min (manutenção) – Intravenosa Grupo II - Cetamina - 5 mg/mL + Propofol - 5 mg/mL (combinados); 10 mg/kg/min (indução), seguido de 1.1 mg/kg/min (manutenção) – Intravenosa GIII - Isoflurano - 5% (indução), seguido de 2% (manutenção) - Inalatória	Infusão contínua	Galos Leghorn (Gallus gallus domesticus)	GI - Anestesia mantida por 65 minutos; Variáveis cardiopulmonares clinicamente aceitáveis. GII - Anestesia mantida por 65 minutos; Dose de indução e manutenção de propofol reduzida significativamente (p=0.0001); Variáveis cardiopulmonares clinicamente aceitáveis. GIII - Anestesia mantida por 65 minutos; Variáveis cardiopulmonares clinicamente aceitáveis.	GII - Frequência cardíaca significativamente maior (p=0.0001); Frequência respiratória significativamente menor (p=0.0001).
Cullen et al. (1995)	MPA - Xilazina: 1,13–1,85 mg/kg IV; indução - Alfaxalona-Alfadolona: 2,15 mg/kg IV	Bolus	Avestruzes (*Struthio camelus*)	Indução rápida e suave; plano anestésico adequado para intubação e manutenção com isoflurano.	Bradicardia leve no início da anestesia; apneia ocasional.
Bailey et al. (1999)	Alfaxalona-Alfadolona: 6,5–7,0 mg/kg IV	Bolus	*Grous Demoiselle, Grous-comuns* e *Grous-coroa-oriental*	Indução rápida (13–26 segundos); sedação adequada para endoscopia; relaxamento muscular completo.	Apneia transitória; recuperação agitada em alguns casos.
Villaverde-Morcillo et al. (2014)	Grupo I – Isoflurano; Indução - 4–5%; Manutenção - 1,5–2%. Grupo II – Alfaxalona; Indução: 2 mg/kg, (IV); Manutenção: isoflurano concentrações menores que 1,5–2%	Bolus	Flamingos (*Phoenicopterus roseus*)	Indução mais rápida (1,7 ± 0,4 min) e suave; reduzida necessidade de isoflurano para manutenção (1,5–2%); recuperação mais tranquila.	Hipotermia leve e 19% com excitação leve.
Kruse et al. (2019)	Alfaxalona - 10 mg/kg IM e IV	Bolus	Patos (*Anas platyrhynchos*)	Sedação leve a moderada; duração curta (IV: 5 min); estabilidade cardiovascular e respiratória. A via IM resultou em efeitos sedativos mais duradouros. A via IV ofereceu indução rápida,	Recuperação hiperexcitável; tremores musculares e hipersensibilidade ao toque; sem efeitos hematológicos. A via IM não proporcionou profundidade anestésica adequada. A via IV proporcionou tempo anestésico mais curto e respostas adversas como movimentos espásticos.
Ono et al., 2023	Grupo I -Alfaxalona - 5 mg/kg – Bolus Grupo II - Alfaxalona - 10 mg/kg - Infusão contínua	Bolus Infusão contínua	Pinguins Gentoo (*Pygoscelis papua*)	GI - Indução anestésica eficaz; Manutenção estável da anestesia durante o procedimento GII- Indução rápida e manutenção prolongada da anestesia; Recuperação rápida	GI - Hipotensão leve observada em alguns indivíduos. GII- Bradicardia transitória em alguns indivíduos.

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White e Martinez-Taboada, (2019)	Caso 1: Midazolam - 2 mg - IM Butorfanol - 4 mg - IM; Alfaxalona - 10 mg/kg - IV; Isoflurano – IN Caso 2: Midazolam - 3.8 mg - Intramuscular; Butorfanol - 1.9 mg - Intramuscular; Alfaxalona - 15	Bolus	Galinha *(Gallus gallus domesticus)*	Indução anestésica permitindo intubação endotraqueal; Anestesia mantida com isoflurano.	Caso 1 - Excitação após dose inicial de 5 mg/kg de alfaxalona (rigidez de membros e dorsiflexão da cabeça e pescoço). Caso 2:Excitação após dose inicial de 5 mg/kg de alfaxalona (rigidez, bater de asas e dorsiflexão da cabeça e pescoço).
Mastakov et al. (2021)	Grupo I - Alfaxalona - 7.5 mg/kg - Intravenosa Grupo II - Butorfanol - 2 mg/kg - Intramuscular; Midazolam - 0.5 mg/kg - Intramuscular; Alfaxalona - 4	Bolus	Galinhas (*Gallus gallus domesticus*)	G I - Indução anestésica permitindo intubação endotraqueal em 15 segundos (dose mínima eficaz); Duração da anestesia entre 51 segundos e 4 minutos e 45 segundos. G II - Indução anestésica permitindo intubação endotraqueal em 15 segundos (dose mínima eficaz com pré-medicação); Melhora na qualidade da indução e recuperação com pré-medicação; Duração da	G I -Hiperatividade durante indução e recuperação (frequência não especificada). G II - Hiperatividade durante indução e recuperação (frequência não especificada); Aumento significativo do tempo para ficar em pé e retornar a comportamentos normais após anestesia (P < .001).
Da Cunha et al. (2011)	Lidocaína - 2.5 mg/kg – Intravenosa Isoflurano 1,4 e 1,7%	Bolus	Galinhas (*Gallus gallus domesticus*)	Estabilidade anestésica; Metabolismo rápido da lidocaína;	Não foram relatadas complicações anestésicas graves ou mortes durante o estudo, sugerindo que o protocolo foi bem tolerado pelas aves
Brandão et al. (2015)	Lidocaína - 6 mg/kg – Intravenosa Isoflurano 1,4 e 1,7%	Infusão em 2 minutos	Frangos de corte (*Gallus gallus domesticus*)	Não houve efeitos cardiovasculares clinicamente relevantes; estudo sugere segurança em doses superiores a 4 mg/kg.	Nenhum efeito adverso observado.
Pavez et al. (2011)	Fentanil – 20 µg/kg (IV) Isoflurano	Infusão contínua	Gaviões-de-cauda-vermelha (*Buteo jamaicensis*)	Redução da CAM do isoflurano em 31%, 44% e 55% para as concentrações plasmáticas de fentanil de 8, 16 e 32 ng/mL, respectivamente.	Sem alterações significativas na frequência cardíaca, pressão arterial sistólica, diastólica ou média. Redução significativa nos níveis de lactato plasmático com o aumento das concentrações plasmáticas de fentanil.
Hawkins et al. (2018)	Fentanil - Infusão IV para atingir concentrações plasmáticas de 8, 16 e 32 ng/mL Isoflurano	Infusão contínua	Papagaios-da-amazônia (*Amazona ventralis*)	Fentanil reduziu a necessidade de isoflurano em papagaios	Fentanil causou queda na pressão arterial e frequência cardíaca.

Studies show a wide variation in the doses of propofol used for anesthetic induction in different species of birds (Tables 1). In pigeons, the average dose is 14.49 ± 2.91 mg/kg (Fitzgerald & Cooper, 1990), while in mute swans it is 8 mg/kg (Müller et al., 2011). For red-tailed hawks, the dose is 4.48 ± 1.09 mg/kg, and for great horned owls, it is 3.36 ± 0.71 mg/kg (Hawkins et al., 2003). In king penguins, the dose used is 3.7 mg/kg (Bigby et al., 2016), and in mallards, it is 10 mg/kg (Machin & Caulkett, 1998; Machin & Caulkett, 2000). In the case of ostriches, the dose is 4 mg/kg (Ciboto et al., 2006), in emus, 5 ± 0.8 mg/kg (Araújo et al., 2013), and in domestic chickens, 9 mg/kg (Santos et al., 2020). These doses were effective in inducing unconsciousness, facilitating orotracheal intubation after loss of the swallowing reflex, and minimizing noxious stimuli. Propofol also provides rapid, safe, and gentle induction, as well as optimal muscle relaxation (Fitzgerald & Cooper, 1990; Machin & Caulkett, 2000; Ciboto et al., 2006; Araújo et al., 2013).

Respiratory depression is considered to be the most significant side effect of propofol use in clinical settings. This anesthetic acts on the central nervous system through neuronal hyperpolarization mediated by the GABA A receptor complex. This complex is a

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ligand-activated ion channel, which is instrumental in mediating the effects of gamma-aminobutyric acid (GABA), the main inhibitory neurotransmitter of the central nervous system, especially present in the brainstem (Jiang et al., 2021). In the study conducted by Araújo et al. (2013), which investigated anesthetic induction in rheas (*Rhea americana americana*) with a dose of 5 mg/kg of propofol, no cases of apnea were observed. This result contrasts with other studies (Fitzgerald & Cooper, 1990; Machin & Caulkett, 1998; Müller et al., 2011; Santos et al., 2020), who reported episodes of apnea in birds anesthetized with propofol. This discrepancy can be attributed to different methodologies, variations between species, different experimental models and doses used. For example, the work of Guimarães et al. (2006) showed that the increase in the rate of intrabony propofol infusion in pigeons resulted in apnea.

Santos et al. (2020) observed that the administration of high doses of propofol at the beginning of anesthesia of domestic broilers, through continuous infusion, resulted in an increase in carbon dioxide concentration at the end of expiration. However, the reduction in the infusion rate associated with oxygen supplementation prevented desaturation of the birds. This finding contrasts with the results of Müller et al. (2011), who investigated the anesthesia of mute swans and observed significant hypoxemia. In that study, oxygen saturation (SpO2) dropped dramatically to values between 81% and 71% in both groups, regardless of whether they received propofol by bolus or continuous infusion.

Studies indicate that the use of propofol in anesthetized birds results in a significant increase in the partial pressure of carbon dioxide (PaCO2) in arterial blood, which causes a drop in blood pH and leads to respiratory acidosis (Machin & Caulkett, 1998). Despite these alterations in acid-base balance, propofol has not been shown to significantly impact the respiratory rate of birds. To mitigate respiratory depression associated with propofol use, the authors recommend oxygen supplementation. In situations of apnea, it is advisable to implement controlled ventilation (Fitzgerald & Cooper, 1990; Machin & Caulkett, 1998; Ciboto et al., 2006; Müller et al., 2011; Araújo et al., 2013; Santos et al., 2020).

A study involving red-tailed hawks (*Buteo jamaicensis*) and horned owls (*Bubo virginianus*) investigated the anesthetic, cardiopulmonary, and pharmacokinetic effects of propofol administered by continuous infusion. During the 30-minute anesthesia period, no clinically significant changes in heart rate or systolic, mean, and diastolic blood pressures were observed, indicating hemodynamic stability with this protocol (Hawkins et al., 2003).

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Although other studies have also not reported changes in heart rate or blood pressure (Ciboto et al., 2006; Santos et al., 2020), some studies have highlighted adverse effects such as hypotension, bradycardia, tachycardia, and arrhythmias, including premature ventricular contractions and T-wave elevation on the electrocardiogram of propofol-anesthetized birds (Fitzgerald & Cooper, 1990; Machin & Caulkett, 1998; Guimarães et al., 2006; Müller et al., 2011; Araújo et al., 2013; Bigby et al., 2016).

The tachycardia observed may be a compensatory response to the drug-induced reduction in blood pressure. In this scenario, baroreceptors activate mechanisms that increase heart rate to maintain adequate cardiac output. On the other hand, arrhythmias can arise as a reaction to hypoxemia, hypercarbia, and the release of catecholamines, which directly affect the myocardium. It is important to note that some of these changes may vary in a nonspecific way depending on the species studied (Müller et al., 2011; Araújo et al., 2013; Bigby et al., 2016).

Body temperature during anesthetic procedures is a crucial factor that demands attention. Although studies have shown that propofol anesthesia has no significant impact on the temperature of birds (Hawkins et al., 2003; Ciboto et al., 2006; Araújo et al., 2013), the relationship between dose, anesthetic time and depth, body mass, losses due to surgical incision, respiratory tract and fluid therapy, influence thermoregulation, especially in continuous infusions. General anesthesia, in turn, interrupts thermoregulation, resulting in changes in body temperature that affect physiological functions such as coagulation, diapedesis, tissue oxygenation, and risk of surgical wound infection (Fitzgerald & Cooper, 1990; Machin & Caulkett, 1998; Guimarães et al., 2006; Silva & Peniche, 2014; Santos et al., 2020). Therefore, the maintenance of normothermia during the anesthetic procedure is essential.

The anesthetic recovery time in birds using propofol varies according to the species, methodology, dose, route of administration and pharmacological associations. A study with emus reported recovery in 7.85 ± 2.2 minutes (Araújo et al., 2013), while in ostriches it was 17.6 ± 6.05 minutes (Ciboto et al., 2006). In king penguins, recovery occurred in 15 minutes (Bigby et al., 2016), in mute swans in 30 minutes (Müller et al., 2011), and in red-tailed hawks and great horned owls, respectively, in 49.7 ± 19.7 and 42.0 ± 10.3 minutes (Hawkins et al., 2003). Although smooth recoveries without central excitation are often described (Fitzgerald & Cooper, 1990; Machin & Caulkett, 1998; Machin & Caulkett, 2000; Araújo et al., 2013; Bigby et al., 2016), the literature also records turbulent recoveries, with

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opisthotonus, transient CNS excitation, and myoclonus (Hawkins et al., 2003; Müller et al., 2011; Santos et al., 2020).

Accurate determination of the optimal dose for each patient is crucial to minimize adverse effects and optimize total intravenous anesthesia. The difficulty in maintaining the optimal plasma concentration of propofol in birds presents a significant challenge for the expansion of TIVA with this drug. The interspecies variability in the response to anesthetics, added to the pharmacokinetic and pharmacodynamic complexity inherent to birds, reinforces the need for accurate monitoring methods. Ferrier et al. (2022) reviewed the techniques available for detecting propofol blood concentration, ranging from complex and time-consuming methods, such as High Performance Liquid Chromatography (HPLC) and mass spectrometry, to faster alternatives, such as optical and electrochemical techniques. Despite the promise of greater speed, the latter still face challenges in terms of sensitivity and specificity. The development of molecularly imprinted polymers (MIPs) emerges as a possibility to improve specificity in the detection of propofol. The search for a real-time, automated and reliable monitoring system is essential for the safe and effective implementation of TIVA with propofol in different avian species. The absence of such a system limits the widespread application of TIVA with propofol, restricting its use to specific protocols and requiring greater attention from the anesthesiologist for the clinical monitoring of the patient.

Alfaxalone, formulated with 2-hydroxypropyl-β-cyclodextrin, a synthetic carbohydrate derivative with no history of allergic reactions, acts as a positive allosteric modulator of GABAA receptors. This action potentiates the inhibitory effect of endogenous GABA, increasing chloride ion conductance, hyperpolarizing the postsynaptic membrane, and inhibiting the propagation of the neuronal action potential (Warne et al., 2015; Bellido & Vettorato, 2022).

The dose of alfaxalone required for anesthetic induction in birds varies between species. Flamingos require 2mg/kg (Villaverde-Morcillo et al., 2014), ostriches 2.15mg/kg (Cullen et al., 1995), cranes 6.5 – 7mg/kg (Bailey et al., 1999), mallards 10mg/kg (Kruse et al., 2019), and gentoo penguins 9 ± 1.9 mg/kg (Ono et al., 2023). In chickens, the dose varies between 4 and 15mg/kg (White and Martinez-Taboada, 2019; Mastakov et al., 2021). Generally, alfaxalone provides mild and effective anesthetic induction without neuronal excitation. However, in brown hens (*Gallus gallus domesticus*), the intravenous dose of 5mg/kg resulted in low-quality induction, with excitement, limb stiffness, and

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dorsiflexion of the neck and head, requiring dosage adjustment (White and Martinez-Taboada, 2019).

In a comparative study with flamingos (*Phoenicopterus roseus*) submitted to orthopedic surgery, intravenous anesthetic induction with alfaxalone demonstrated greater speed, gentleness, and muscle relaxation compared to inhalational induction. In addition to reducing the need for intraoperative isoflurane, alfaxalone minimized cardiorespiratory effects, maintaining heart and respiratory rates close to baseline values (Villaverde-Morcillo et al., 2014).

Villaverde-Morcillo et al. (2014) observed a lower incidence of excitation during anesthetic recovery with intravenous alfaxalone. This result contrasts with the study by Kruse et al. (2019), which evaluated the pharmacodynamics and pharmacokinetics of alfaxalone in mallards (*Anas platyrhynchos*). In the latter, excitation was observed, especially after intravenous administration.

Kruse et al. (2019) evaluated the pharmacodynamics and pharmacokinetics of alfaxalone, administered as a single dose, intramuscularly or intravenously, in mallards (*Anas platyrhynchos*). The results indicated similar elimination half-lives (15-16 minutes) for both routes, with shorter sedation in the intravenous route. Cardiorespiratory parameters remained stable. However, the short sedation time, observed in both routes, limits the use of alfaxalone to short, minimally invasive procedures in waterfowl, suggesting the need for dosage adjustments, pharmacological associations, or different anesthetic modalities to optimize its efficacy (Kruse et al., 2019).

Mastakov et al. (2021) demonstrated that the anesthetic efficacy of alfaxalone in domestic chickens is related to dose and premedication. Chickens premedicated with butorphanol and midazolam required lower doses (4 mg/kg) for anesthetic induction, compared to those not premedicated (7 mg/kg). Premedication, although it reduced the dose and improved the quality of induction and recovery, prolonged the time to full recovery. In gentoo penguins (Pygoscelis papua), continuous infusion of alfaxalone at 0.3 ± 0.08 mg/kg/min maintained stable plasma concentrations, with no significant changes in heart rate or blood pressure, demonstrating the safety of the drug for intravenous anesthesia in this species (Ono et al., 2023).

Alfalfalaxone has potential as an anesthetic agent in poultry, but its clinical application requires specific considerations regarding the species, dose and route of administration. Although effective in anesthetic induction with cardiorespiratory stability

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and smooth recovery in flamingos and gentoo penguins (Villaverde-Morcillo et al., 2014; Ono et al., 2023), limitations are observed in mallards and brown hens, particularly with low doses or administration alone (Kruse et al., 2019; Mastakov et al., 2021). The interspecies variability highlights the need for additional studies to optimize anesthetic protocols with alfaxalone.

Optimisation of anaesthesia with alfaxalone in poultry requires dosage adjustments and consideration of pharmacological associations. Alfalfaxone also offers advantages over inhalational agents in some situations, such as faster anesthetic induction and reduced isoflurane consumption. However, differences between species, prolonged recovery times in some cases, and variations in excitatory effects during induction and recovery show that their use should be carefully planned (Villaverde-Morcillo et al., 2014; White and Martinez-Taboada, 2019; Mastakov et al., 2021). Future studies should investigate pharmacological combinations and adjustments in anesthetic modalities to improve the efficacy and clinical safety of alfaxalone.

Balanced anesthesia techniques, such as the combination of opioids in continuous infusion, aim to reduce cardiovascular depression and the required concentrations of general anesthetics. In Amazon parrots (*Amazona ventralis*), the infusion of fentanyl, a synthetic μ-opioid agonist, reduced the CAM of isoflurane dose-independently (2.09 ± 0.17%, 1.45 ± 0.32%, 1.34 ± 0.31%, and 0.95 ± 0.14% for plasma fentanyl concentrations of 0, 8, 16, and 32 ng/mL, respectively), but with hemodynamic impact, reducing heart rate and blood pressure (Hawkins et al., 2018). In contrast, a similar study with fentanyl in red-tailed hawks demonstrated a significant reduction in the MAC of halogenate without hemodynamic impact (Pavez et al., 2011). The interspecies variability in the hemodynamic response to fentanyl infusion highlights the importance of species-specific studies.

Lidocaine, with analgesic, anesthetic, antiarrhythmic and anti-inflammatory properties, has limited use in poultry due to its toxic potential. Pharmacokinetic studies demonstrate that the half-life of intravenous lidocaine in poultry is shorter than in humans, pigs, dogs, cats, and rabbits (Da Cunha et al., 2012; Brandão et al., 2015). The maximum dose traditionally recommended in poultry 4mg/kg was reevaluated by Brandão et al. (2015), who showed safety of intravenous doses of up to 6mg/kg in chickens. This study expands the therapeutic possibilities of lidocaine in poultry, with the potential to improve analgesia and anesthetic quality.

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Dissociative anesthetics, such as ketamine and tiletamine, are characterized by their ability to induce a state of dissociation of consciousness, accompanied by analgesia and amnesia, and can be used both as a main anesthetic and as anesthetic adjuvants. However, these agents can cause muscle stiffness as a side effect. Zendehboudi and Vesal (2024) evaluated the combination of ketamine and propofol (1:1) for anesthetic induction in Leghorn hens (*Gallus gallus domesticus*). The results showed a reduction in the doses of propofol necessary for induction and maintenance of anesthesia. The combination also resulted in increased heart rate and reduced respiratory rate, although both variables remained within acceptable physiological parameters. This study suggests that the ketamine-propofol combination may be an effective alternative for anesthetic induction in chickens, minimizing the dose of propofol and its potential cardiorespiratory depressant effects. However, more studies are needed to evaluate the long-term safety and efficacy of this combination.

Benzodiazepines are extremely useful medications in bird anesthesia, helping to keep patients calm and safe during procedures and minimizing undesirable effects by reducing the need for general anesthetics. A study with chickens demonstrated that the use of midazolam and butorphanol before anesthesia facilitates the process and reduces stress in birds (White and Martinez-Taboada, 2019). Researchers found that diazepam and medetomidine contributed to smooth anesthesia and recovery in penguins (Bigby et al., 2016). In ostriches, the use of diazepam and ketamine has been shown to be effective for good anesthesia (Ciboto et al., 2006). Machin and Caulkett (1998) demonstrated that midazolam helps maintain cardiac and pulmonary stability during anesthesia in ducks. Despite these promising results, the diversity of species and protocols makes it difficult to generalize the conclusions, and more studies are needed to better understand the role of benzodiazepines in different bird species and types of anesthesia.

Evidence indicates the potential of opioids to improve anesthesia and recovery in poultry. In chickens, meperidine and nalbuphine demonstrated a propofol-sparing effect, optimizing TIVA and minimizing side effects (Santos et al., 2020). Butorphanol has been shown to be effective in anesthetic premedication, reducing stress and facilitating management (White and Martinez-Taboada, 2019). Its combination with midazolam provided safe chemical containment in domestic chickens (Mastakov et al., 2021). Fentanyl reduced isoflurane CAM in red-tailed hawks (Pavez et al., 2011) and Hispaniolan parrots (Hawkins et al., 2018), minimizing the risk of cardiopulmonary depression. However,

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depressive effects on heart rate and blood pressure have been observed in fentanyl parrots (Hawkins et al., 2018), requiring caution and cardiovascular monitoring. These findings corroborate previous studies, demonstrating interspecific variability in response.

Phenothiazines, especially acepromazine, are often used as anesthetic premedication in birds. This drug exhibits sedative, anxiolytic and antiemetic properties, facilitating management and anesthetic induction, in addition to allowing the reduction of doses of other anesthetic agents, minimizing their adverse effects (Gunkel and Lafortune, 2005). However, its hypotensive potential requires caution in patients with cardiovascular instability, with emphasis on hemodynamic monitoring and precise dose adjustment (Gunkel & Lafortune, 2005; Ludders, 2015; Hawkins & Griffenhagen, 2022). Similarly, alpha-2 adrenergic agonists, such as xylazine and medetomidine, play a key role in avian anesthesia. Xylazine, despite its efficacy as a sedative and analgesic, presents a risk of bradycardia and hypotension, requiring continuous and careful cardiovascular monitoring (Gunkel & Lafortune, 2005). Medetomidine, a more potent alpha-2 agonist, offers the advantage of reversibility with atipamezole, a feature shared with other alpha-2 agonists such as dexmedetomidine. This reversibility allows for more precise control of sedation and favors a faster and smoother recovery (Ludders, 2015). The efficacy and safety of medetomidine, especially in combined anesthetic protocols, are corroborated by Hawkins and Griffenhagen (2022), who highlight its relevance in perioperative analgesia.

CONCLUSION AND FINAL CONSIDERATIONS

Total intravenous anesthesia (TIVA) in poultry is still a nascent field, with most studies focusing on the drugs propofol and alfaxalone. The wide diversity of avian species makes it difficult to standardize anesthetic doses and protocols, reinforcing the need for therapeutic individualization. The combination of drugs, aiming at balanced anesthesia, demonstrates potential to optimize analgesia, reduce individual doses and minimize adverse effects. TIVA emerges as a promising alternative, especially when inhalational anesthesia is contraindicated. However, the limited number of studies with certain species and drugs restricts the generalization of results.

The heterogeneity of the available studies limits direct comparisons and extrapolation of findings. The scarcity of research with certain species and pharmacological classes limits the scope of the conclusions. To deepen knowledge in this area, more comprehensive studies are needed, with a larger number of animals, standardized

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protocols, and evaluation of new drug combinations. Pharmacokinetic and pharmacodynamic investigations specific to the different avian species are crucial for the advancement of the field.

In clinical practice, the results of this review should be applied with caution, considering methodological limitations and interspecific variability. It is recommended to consult multiple sources of information and to individualize anesthesia for each patient. Strict monitoring of physiological parameters is essential to ensure the safety and well-being of the birds. This review contributes as a foundation for the development of safer and more effective anesthetic protocols, stimulating research and innovation in anesthetic techniques in birds.

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