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ARTICLE

Avian anaesthesia and analgesia

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Abstract

Wildlife rehabilitators are often presented with injured birds. We recognize that birds are not dogs and cats and, therefore, require specialized protocols for anaesthesia and analgesia. This paper discusses recent research on anaesthesia and analgesia in birds, with a focus on a multimodal approach to treatment. Rehabilitators will need to work closely with veterinarians to provide the best care for wild bird patients.

Keywords

Avian; anaesthesia; analgesia; physiology

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Introduction

Those who have federal rehabilitation permits for avian species often need to treat birds that are in pain, or that need anaesthesia, for a variety of reasons. Procedures requiring excessive restraint, surgery, wound care, physical therapy, bandage changes and, in some cases, the initial exam may require anaesthesia in order to decrease stress to the bird. Rehabilitators must work closely with veterinarians to develop protocols for pain control (analgesia) in wild patients and to provide safe and effective anaesthesia when procedures are needed. Being familiar with wild birds and their safe capture and restraint, rehabilitators may be asked to help monitor anaesthesia for their veterinarians. Anaesthesia requires close attention to the bird and proper communication with the veterinarian performing the procedure.

Unique avian anatomy and physiology

When considering anaesthetic procedures for avian patients, it is critical to be aware of the unique physiology of birds compared to mammals. The upper airway has the nares (nostrils), which continue into the choana, which is the opening seen in the top of the mouth. When the bird's mouth is closed, the choana sits opposite to the glottis, the opening into the trachea, located at the base of the tongue, creating a direct airway from the nares through to the trachea. Birds do not have an epiglottis like mammals, and in most species, the opening of the glottis is actually larger than the diameter of the mid to lower trachea (which is important when considering an endotracheal tube for gas anaesthesia). Birds have complete tracheal rings, which means that endotracheal tubes with cuffs can cause mucosal damage when inflated. Non-cuffed tubes are recommended (Sinn 1994; Lawtown & Howlett 2000; Tully 2009; Lierz & Korbel 2012).

There is a myriad of species variation in anatomy, and some species are obligate mouth-breathers with no external nares. This includes gannets, cormorants, anhingas, frigate birds, pelicans and many diving birds; the mouths of these species need to be kept open during restraint. Many waterfowl species have a syringeal bulla, an enlargement of the trachea at the syrinx that is important in vocalization. Cranes, swans and birds of paradise have extremely complex, elongated tracheas for the same reason. Pelicans, gulls and hornbills have a crista ventralis, a cartilaginous projection at the glottis, whilst pelicans have a vestigial tongue (glottal mass). Emus and male ruddy ducks (*Oxyura jamaicensis*) have a tracheal sac-like diverticulum that may be mistaken for a ruptured trachea.

The avian respiratory system separates ventilatory and gas exchange compartments, making it highly efficient. More efficient gas exchange leads to rapid induction of gas anaesthesia and recovery from gas anaesthesia. The ventilatory compartment includes the major airways, the air sacs and the thoracic skeleton (pneumatic bones, which are hollow). Most species have nine air sacs: the paired cervical, cranial thoracic, caudal thoracic and abdominal, and the single intraclavicular. Some species have subcutaneous air sacs, such as pelicans, boobies, tropic birds and gannets. Pneumatic bones include the vertebral ribs, sternum, humerus, pelvis, femur and cervical, and some thoracic vertebrae. In pelicans and

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California condors (*Gymnogyps californianus*), the ulna is also a pneumatic bone.

Rigid lungs and lack of a diaphragm require external body wall movement (excursions) for breathing. The overall lung capacity in birds is much smaller than that of mammals, but the total respiratory volume (with air sacs) is two to four times that of dogs. This smaller functional reserve means that brief apnoea (lack of breathing) leads to marked hypoxia (lack of oxygen in the tissues). In some birds, dorsal recumbency (lying on the back) can cause the weight of the abdominal organs to compress the abdominal and caudal thoracic air sacs (Rupley 1997; Lierz & Korbel 2012; Raftery 2013; Ludders 2015; Heard 2016; Zehnder et al. 2017).

Intermittent positive pressure ventilation (IPPV) may be needed under anaesthesia to ensure adequate ventilation. Studies of red-tailed hawks (*Buteo jamaicensis*) under gas anaesthesia showed the greatest lung and air sac volumes in sternal (compared to lateral or dorsal) recumbency, with no changes in ventilatory rate as a function of position (Ludders 2015).

There is a dive response in many species of waterfowl. Episodes of apnoea and bradycardia (low heart rate) can occur during induction of anaesthesia. This is a stress response initiated by the stimulation of receptors in the beak and nares and can be triggered simply by placing a mask snugly over a bird's bill. When this occurs, turn off anaesthetic gas, remove the mask from the head and provide flow-by oxygen until the bird has recovered.

The avian renal (kidney) system represents another difference between birds and mammals. An arrangement of smooth muscle forms a valve within the external iliac vein, which can cause blood flow from the back half of the body to pass through the kidneys before reaching the front half of the body (and heart/brain). This is called the renal portal system. Though its true significance is still unknown, it is recommended that drugs that could potentially harm the kidneys, or drugs with high renal excretion, be administered in the front half of the body (Fowler 1995; Heard 2016; Zehnder et al. 2017; Scott 2021).

Pain and multimodal analgesia

Analgesia, or the relief of pain, is critical in the care of wildlife, not only ethically but also to prevent physiological changes, such as changes in blood pressure, altered endocrine function, tachycardia (high heart rate), dysrhythmias (abnormal heart rhythm), hyperglycaemia (excess glucose in the blood), decreased immunity and decreased wound healing. Wild animals typically hide pain as much as possible, as an injured or hurt animal is likely to become food for another animal. Therefore, close observation of patients is key to determining and evaluating pain.

Some things to look for to help recognize pain in birds include (Malik & Valentine 2018):

- Changes in posture and appearance, including a hunched appearance, drooping demeanour with fluffed up feathers, closing eyes, poor feather quality, tucked-up abdomen and standing on one leg;
- Changes in locomotion, including lameness, decreased weight bearing on a limb, slower speed, difficulty perching/climbing, falling, stumbling and decreased confidence in mobility;
- Changes in temperament/personality, including aggression/passivity depending on normal behaviour; lethargy; apathy; decreased interest in surroundings; anxiety, fear or restlessness; escape reactions; passive immobility and sleep deprivation;
- Guarding behaviour, including protecting/hiding the affected area;
- Changes in grooming behaviour, including destroying feathers, overgrooming and self-mutilation;
- Changes in normal eating, drinking or toileting, including inappetence or constipation;
- Changes in vocalization, including increased or decreased vocalization and vocalizing on physical manipulation of the affected area;
- Changes in physiological parameters, including tachypnea, tachycardia and hypertension (acute pain);
- Changes in weight, including weight loss or loss of muscle mass (chronic pain).

The pain pathway, from pain stimulus to the brain, goes through a number of stages. Transduction occurs when the pain receptors sense the pain stimulus and start the electrical signals that will travel through the nerves to the spinal cord. Transmission conducts the stimulus from that first nerve to the second nerve within the spinal cord. Modulation occurs via neurotransmitters or other substances either amplifying or suppressing that signal from the first nerve at the point of transmission. Perception is the actual signal detection by the brain (Tseng 2007). Multimodal analgesia uses multiple types of pain medications to work at different points along the pain pathway. For instance, transduction of pain stimuli can be decreased with non-steroidal anti-inflammatory drugs (NSAIDs), local anaesthetics and opioids. Transmission can be decreased by alpha-2 agonists. Modulation to decrease pain can occur through epidurals and *N*-methyl-d-aspirate (NMDA) antagonists. Pain perception may be decreased with opioids. Each of these types of drugs is discussed in further detail below.

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Whenever possible, pre-emptive analgesia is important to prevent "wind-up", a response where once pain has already started, it is increasingly difficult to stop the pain due to increased numbers of nerves sensing the pain. Analgesic medications should be administered before the pain has started, for example, before a surgery, rather than waiting until after the event. Proper analgesia is key to maintenance of anaesthesia because, with appropriate analgesics used as pre-medications, the doses of anaesthetics can be decreased, which can, in turn, decrease the risks of anaesthesia. One key point to remember is that drug response is highly variable by species, so what works well in one species may have no effect on another species.

Types of analgesics

Opioids

Opioids are powerful analgesics that are controlled substances and can only be used under the direct supervision of a veterinarian. Different opioids work as agonists or antagonists at different types of receptors in the brain, called Mu, Kappa and Delta receptors. In birds, opioid receptors are detectable as early as 10 days in embryonic chicks. In mammals, the distribution of Mu, Kappa and Delta receptors is consistent across different parts of the brain, whilst in pigeons, 75% of the receptors in the fore- and mid-brain are Kappa (>Delta > Mu). In day-old chicks, there are more Mu receptors (>Kappa > Delta), and in adult peregrines, there are also more Mu receptors (>Detla > Kappa). Opioids are most commonly used in birds for moderate to severe pain such as from fractures, trauma or surgery.

There is a significant first-pass effect when opioids are given orally, which means that the concentration of drug is greatly decreased by absorption in the liver before it can reach the rest of the body. The most common opioids used in wildlife are buprenorphine and butorphanol.

Fentanyl is a Mu receptor agonist that has been used intramuscularly (IM), intravenously (IV) and in transdermal forms. It can cause apnoea, so the rehabilitator needs to be prepared to breathe for the bird if necessary whilst it is under anaesthesia. Common doses in rehabilitation start at a loading dose of 20 ug/kg IM then 0.15–0.5 ug/kg/min IV in a constant rate infusion (Hawkins et al. 2016; Barron & Hawkins 2017; Hawkins et al. 2018). Fentanyl can be very harmful to humans so use with caution and care.

Hydromorphone is another Mu receptor agonist used IV, IM or subcutaneously (SQ), with common doses of 0.1–0.6 mg/kg every 3–6 hr, studied in American kestrels (*Falco sparverius*). These same dosages had no effect on pain in cockatiels, using a thermal foot withdrawal test (Ceulemans et al. 2014; Hawkins et al. 2016; Barron & Hawkins 2017; Hawkins et al. 2018).

Buprenorphine is a partial Mu receptor agonist, as well as a Kappa receptor agonist and antagonist, commonly used at 0.1–0.6 mg/kg every 8 hr (Tseng 2007; Lierz & Korbel 2012; Ceulemans et al. 2014; Hawkins et al. 2016; Hawkins et al. 2018). When studied at 0.6, 1.2 and 1.8 mg/kg in cockatiels, it did not seem to provide analgesia (Guzman et al. 2018).

Butorphanol is a mixed agonist/antagonist that is often used at 1–4 mg/kg every 1–4 hr (Hawkins et al. 2016, Hawkins et al. 2018). It has poor oral availability, so IM injection is recommended, and it can cause sedation at higher doses.

Tramadol is a synthetic Mu opioid agonist that also inhibits reuptake of norepinephrine and serotonin and has NMDA antagonist effects. As in many of the drugs, the effects vary greatly by species, and in mammals, there is currently evidence that it is ineffective for osteoarthritis. In birds, doses range from 5 to 30 mg/kg PO every 6–12 hr (Souza et al. 2012, Hawkins et al. 2016, Hawkins et al. 2018), and it is recommended that it is not to be used as the sole analgesic. Larger birds require lower doses at decreased frequency compared to smaller birds. Tramadol is now a controlled substance and must be used under the direct supervision of a veterinarian.

Non-steroidal anti-inflammatory drugs

Cyclooxygenase enzymes COX-1 and COX-2 are widely distributed in birds and can be modulated with NSAIDs. NSAIDs work to decrease the production of prostaglandins, which promote inflammation, pain and fever. They also work locally to decrease nerve ending sensitization. COX-1 produces prostaglandins that protect the gastrointestinal (GI) system, so over the years, medicine has promoted the use of COX-2 specific drugs to prevent any adverse GI effects caused by inhibiting COX-1. NSAIDs should not be used if there is any sign of kidney disease, heart disease and GI disease (do not use after GI surgery). Adverse effects are often dose dependent and associated with chronic administration (Hawkins et al. 2016). Response is very species-specific, even amongst birds. For example, diclofenac has been used in some species but kills Old World vultures. Meloxicam is likely the most widely used NSAID in wildlife.

Flunixin meglumine (Banamine®; Merck Animal Health, Madison, New Jersey) is not COX-selective and causes muscle damage with IM injections. It has been shown to cause kidney lesions in quail, cranes and

budgies, and administration is not recommended in birds (Paul-Murphy & Fialkowski 2001; Hawkins et al. 2016; Barron & Hawkins 2017).

Meloxicam (Metacam®; Boehringer Ingelheim Animal Health USA Inc., Duluth, Georgia) is COX-2 preferential (not COX-2 specific, as at higher doses, its COX-2 specificity is diminished) and has been used in a wide variety of species. It is available as an injectable and as an oral formulation. It has been used at 0.25–2.0 mg/kg PO (orally) every 12–24 hr; ensuring adequate hydration is essential (Hawkins et al. 2016; Barron & Hawkins 2017; Hawkins et al. 2018). In a study of African Grey Parrots, 1 mg/kg/day for 12 days was not associated with adverse effects (Montesinos et al. 2019).

Carprofen (Rimadyl®; Zoetis, Kalamazoo, Michigan) has been researched in some species, at 5–10 mg/kg (Lawtown & Howlett 2000). It showed no effect in Broiler chickens (25 mg/kg), only a short-term effect in Hispanolan Amazon parrots (*Amazona ventralis*) (3 mg/kg), and caused renal, hepatic and muscle damages in pigeons (Columbidae) (2, 5 and 10 mg/kg) (Barron & Hawkins 2017).

Ketoprofen (Ketofen®; Zoetis, Kalamazoo, Michigan) has been shown to have low bioavailability and a short half-life in quail, caused high mortality in eiders (2–5 mg/kg) and Cape Griffon vultures (*Gyps coprotheres)* (5 mg/kg), and renal tubular necrosis in budgies (2.5 mg/kg). Administration in birds is generally not recommended (Hawkins et al. 2016; Barron & Hawkins 2017).

Piroxicam (Feldene®; Pfizer Inc., New York, NY) is a COX-1 specific drug with good oral absorption and a long half-life, though in cats and dogs, it is used primarily for its antitumor activity. Used in cranes, there was mild to moderate improvement of chronic degenerative joint disease at 0.5–1 mg/kg. In chickens, there was no effects at 0.15 mg/kg and gut ulceration at 0.6 mg/kg (Hawkins et al. 2016; Barron & Hawkins 2017).

Aspirin is a COX-1 inhibitor that is broken down by the body to its active state as salicylic acid. It has been used at 150 mg/kg (Lawtown & Howlett 2000).

Local analgesics

Local analgesics work to block sodium ion channels, decreasing local nerve transmission. Anecdotally, the toxic doses are lower in birds than in mammals, but there is little research to back this claim. They can be used to provide "local blocks" via injection into the tissue surrounding the incision site, "regional blocks" through injection around the nerves leading to that area or for epidurals in some species (though use of epidurals is limited in birds due to fusion of the lumbosacral spine).

EMLA® (AstraZeneca, Wilmington, Delaware) cream has a 2.5% lidocaine and 2.5% percent prilocaine that is used topically. It can be useful for things like catheter placement; however, it requires 30–45 min of contact time to work, and toxicity can occur with uptake after prolonged occlusion. Depth of penetration of effect correlates directly with contact time (Tseng 2007).

Ophthalmic topicals such as tetracaine and proparacaine are widely used for eye procedures.

Long-acting drugs such as bupivacaine, levobupivacaine and ropivacaine can be very useful for brachial plexus blocks before wing fracture repair, though use of a nerve locator/stimulator is advised. Common dosages are 1–2 mg/kg (Tseng 2007; Hawkins 2016). Intra-articular bupivacaine was studied in chicks with artificially induced arthritis, and they were able to feed and stand like normal birds (Paul-Murphy 2006).

Lidocaine has been used in a variety of species but has often had no effect (mallards [*Anas platyrhynchos*] ineffective at 15 mg/kg, chickens at 20 mg/kg), and dosages often used are 1–4 mg/kg (Paul-Murphy & Fialkowski 2001; Hawkins et al. 2016). It is usually diluted 1:10 for use in birds (Tseng 2007).

Other

Gabapentin has analgesic effects and can prevent allodynia (sensation of pain resulting from a normally non-noxious stimulus) or hyperalgesia (exaggerated response to painful stimuli). It also has antiseizure activity. The mechanism of action is not fully understood, but it appears to bind to voltage-gated calcium channels to decrease calcium influx, which inhibits the release of excitatory neurotransmitters such as substance P, glutamate and norepinephrine. It appears to work synergistically with NSAIDs and/or opioids. Research in great horned owls (*Bubo virginianus*) started with 11 mg/kg dose, and common dosages start at 10 mg/kg and have gone up as high as 80 mg/kg (Yaw et al. 2015). Gabapentin is considered a controlled substance in some states and must be used under direct supervision of a veterinarian.

Acetaminophen is the generic name for Tylenol® (Johnson & Johnson, New Brunswick, New Jersey). The exact mechanism of action of acetaminophen is not completely understood. It produces analgesia and inhibits fever via a weak, reversible inhibition of COX-3 and COX-1. It is not anti-inflammatory. It has been used in broiler chickens with no nephrotoxicity but has low bioavailability. There are anecdotal reports that doses proven toxic in other species may be well tolerated in many parrots, but there is little research behind its use in many bird species.

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Types of anaesthetics

Pre-anaesthetics

A veterinarian may recommend pre-anaesthetic medications, usually including a sedative, tranquilizer and/or an analgesic, to prevent the "wind-up" response. In many cases, it may also be beneficial to pre-oxygenate the patient by holding oxygen to the nares of the bird before it is completely sedated. Many of the drugs used as pre-anaesthetics are controlled substances that must be used under direct supervision of a veterinarian.

Anti-cholinergics such as atropine and glycopyrrolate are not commonly used in birds due to the already high resting heart rate.

Tranquilizers/sedatives

Benzodiazepines are tranquilizers. Diazepam and midazolam are commonly used and can be reversed with flumazenil. They provide muscle relaxation and sedation, have anticonvulsant properties and are mild analgesics.

Alpha-2 adrenergic agonists provide analgesia, decrease anxiety and cause sedation. These include xylazine, tiletamine, medetomidine and dexmedetomidine. They can be reversed with atipamazole (detomidine products) or yohimbine (xylazine). They commonly cause cardiac effects such as irregular and very slow heart rates, and respiratory depression.

Intranasal midazolam (3 mg/kg) and midazolam/butorphanol (3 mg/kg each) result in rapid onset of sedation in cockatiels (Doss et al. 2018).

Injectable anaesthetics

There are advantages and disadvantages to injectable anaesthetics. Advantages include the following:

- when surgery would be complicated by the presence of the endotracheal tube used for gas anaesthesia;
- for surgery of the coelomic cavity, allows a decrease of inhalant dose; and
- in the field when gas anaesthesia/oxygen is not present.

Disadvantages include:

- variability in effect between species;
- poor induction of anaesthesia;
- inadequate muscle relaxation;
- cardiopulmonary depression;
- prolonged/violent recoveries;
- route of delivery can affect efficacy and dosage;
- elimination depends on drug distribution, and liver and/or kidney metabolism; and
- some cannot be reversed and instead must be metabolized.

It is vital to have an accurate body weight when dosing injectable anaesthetics and to calculate emergency/supportive drugs in advance. Close cardiopulmonary monitoring is required, and endotracheal tubes and oxygen should be on hand in case of emergency. Many injectable anaesthetics are controlled substances that must be used under direct supervision of a veterinarian.

Ketamine is an NMDA antagonist that causes anaesthesia but does not provide adequate analgesia (Sinn 1994; Lierz & Korbel 2012); doses are usually 2.5–10 mg/kg IM or IV for induction (Paul-Murphy & Fialkowski 2001; Tully 2009). It has little cardiopulmonary depression but can cause violent recoveries, has no reversal agent and can cause seizures, excitation and salivation in Old World vultures. Dosing is by allometric scaling, meaning that smaller animals require larger relative doses.

Propofol is used at 1 mg/kg/min IV (Paul-Murphy & Fialkowski 2001). It causes smooth, rapid induction of anaesthesia, though apnoea is very common; rehabilitators should be prepared to intubate and ventilate immediately after induction. It causes profound respiratory depression, prolonged recovery and central nervous system signs when used in constant rate infusion, and there are fewer adverse events if given to effect. It is metabolized very quickly in birds, so is not used as a sole agent unless as a continuous rate infusion (Lawtown & Howlett 2000).

Alfaxalone is a neuroactive steroid that binds GABA-a receptors. There is no reversal agent; it is generally given at 5–10 mg/kg IV or IM (Lawtown & Howlett 2000; Heard 2016).

Inhalant anaesthetics – Isoflurane, Sevoflurane and Desflurane

The advantages of inhalant anaesthetics include rapid induction and recovery, the ability to rapidly change the depth of anaesthesia, no requirement of an accurate body weight, little metabolism and recovery is independent of kidney/liver function. Disadvantages include the pollution of the work environment, the expense of anaesthesia and equipment, oxygen is required for use, dose-dependent cardiopulmonary depression and hypotension (decreased blood pressure) is common.

- Isoflurane is considered safe but hypotension is common and can be severe in cranes (Sinn 1994). The respiratory and cardiovascular depressions are dose dependent (Sinn 1994);

- Sevoflurane has lower solubility, faster induction/recovery and is expensive; and
- Desflurane requires expensive, specialized vaporizer and has little data in birds.

Anaesthesia equipment

The veterinarian should be able to guide the rehabilitator in the use of the anaesthesia equipment. Use non-rebreathing circuits and uncuffed tubes inserted only far enough to prevent the tip from slipping easily out of the trachea. Creativity is necessary in providing appropriate tubes for each species. Intubation is usually not attempted for very short procedures, not at all in birds less than 150 g, and not in sharp-shinned hawks (*Accipiter striatus*). In tiny birds, the inside diameter of the tube that would fit in the trachea becomes too small and too prone to blockage by mucus. However, appropriately sized tubes should be available to provide a means for rapid intubation, and ventilation should the bird become apnoeic. Most birds will need an oxygen flow rate of 1–2 L of oxygen/min, and the percent of gas needed to maintain anaesthesia will depend on the pre-anaesthetic drugs used, in which gas anaesthetic is used. Pay special attention to accipiters; do not use injectables except as pre-anaesthetics. Start induction at low levels of isoflurane and increase gradually. They are prone to sudden cardiac arrest, especially during recovery. Careful monitoring of all birds is required during anaesthesia and recovery, especially the heart and respiratory rate and character (see below).

Supportive care during anaesthesia

Fluids are recommended, most often a SQ bolus of 5 ml/100 g body weight before anaesthesia. Larger birds may be catheterized and put on a constant fluid drip. Maintenance fluids in birds are generally 40–60 ml/kg/day. Sites for fluid administration IV include the jugular vein, medial metatarsal vein and, in the pelican, the pouch vein. Avoid the basilic vein in all birds. In some cases, an intraosseous catheter may be used in the distal ulna (not pelicans) or proximal tibiotarsus, avoiding the pneumatic bones.

Instead of using an endotracheal tube, the veterinarian may instead install an air sac cannula (Sinn 1994; Rupley 1997; Lawtown & Howlett 2000), especially if an endotracheal tube would be obstructive or if the surgery was involving the upper airways. The left abdominal caudothoracic air sac is commonly used. The cannula can remain in place for up to 3–5 days. Use a cuffed tube for this purpose.

Maintenance of body temperature (104–110°F/40–43°C) is important. Because of the high body-to-surface area ratio, birds generally radiate heat rapidly. Once anesthetized, the bird is immobile and relaxed, generating less heat from muscle contraction. The patient is also subject to evaporative loss from the respiratory tract (dry anaesthetic gases), skin surfaces (surgical prep solutions) and open-body cavities, conduction of heat via surface contact and convection of warm gases from around the bird. Anaesthesia redistributes blood flow and depresses thermoregulatory response, promoting heat loss.

Hypothermia can decrease anaesthetic requirement and metabolism and will prolong recovery. Monitoring core body temperature and providing thermal support are mandatory to reduce anaesthetic morbidity and mortality in the anaesthetized and recovering patient. Large species and northern owl species may become hyperthermic due to the insulating effects of the feathers, which can be prevented or reversed by placing ice packs along the body of the patient.

Intermittent positive pressure ventilation is essential during extended anaesthetic periods (>30 min), monitoring excursion of the sternum in dorsally recumbent birds or elevations of the base of the tail in ventrally recumbent birds. Anaesthetic agents depress ventilation to a greater extent in birds than in mammals; therefore, hypoventilation (not breathing enough) should be presumed in all anesthetized birds. IPPV in spontaneously breathing birds at two cycles per minute is sufficient to maintain blood gases in a suitable range. If apnoeic, the rate of ventilation should be 6–12 respirations per minute. The veterinarian should teach the rehabilitator how to properly provide breaths to anaesthetized patients using anaesthesia equipment.

Monitoring

Heart rate can be monitored using stethoscopes: regular, paediatric or oesophageal. Doppler can also be used. Heart rates in avian species vary greatly from 200 beats per minute (bpm) to 1000 bpm, depending on the species; a patient's heart rate should be ascertained prior to surgery as a baseline. Maintenance of an even, steady rate appropriate for the species is more important than an absolute number. Decreased heart rate should prompt a reduction in anaesthetic gas concentration, evaluation and treatment of hypotension and review of the patient's surgical situation (pain, tissue trauma and positioning). Unfortunately, cardiac arrest is typically not successfully reversed. Electrocardiogram can be used to diagnose arrhythmias and monitor the heart rate. In birds, an oesophageal probe is more accurate. Changes in heart rate should be communicated with the veterinarian, so they can determine the need for changing anaesthetic depth.

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Changes in respiratory rate and character usually precede cardiac changes; therefore, respiration is often the single most important factor to monitor. If apnoea occurs, anaesthetic gases should be turned off, the delivery system purged, oxygen flow re-established and the patient manually ventilated. It is vital that any change in respiration be communicated with the veterinarian promptly.

Reflexes are vital to determination of anaesthetic plane. For most surgical procedures, a patient should still have a mild palpebral (eyelid) reflex, a slow but still present corneal reflex and no pedal (foot) withdrawal.

Indirect blood pressure can be monitored for trends. Direct blood pressure is difficult in most birds. Again, the exact number is less important than the overall trends.

Capnography is the measurement of end-tidal carbon dioxide ($ETCO_2$), the amount of carbon dioxide in exhaled air, which is a measure of ventilation. In African grey parrots (*Psittacus erithacus*), $ETCO_2$ consistently overestimates arterial CO_2 by approximately 5 mm Hg. $ETCO_2$ of 30–45 mm Hg indicated adequate ventilation (Edling 2006). Use a side stream capnograph and minimize dead air space.

Pulse oximetry is not useful in birds, and sufficient oxygenation does not necessarily mean that the bird is being adequately ventilated.

Maintaining perfusion of the tissues is vital. Perfusion can be monitored by checking the colour of the mucous membranes as well as the capillary refill time, or the refill time at the basilic vein in birds.

Common emergency treatments

- Doxapram can be used to stimulate breathing. It has a direct action on respiratory centres in the medulla of the brain.
- Isotonic crystalloid fluids can be used to treat or prevent hypotension by expanding blood volume and increasing tissue perfusion.
- Epinephrine hydrochloride can be used in cases of cardiac arrest to initiate heartbeats, as it increases the heart rate and cardiac output.
- Atropine may be used to correct slow heartrate or bradyarrhythmias (slow irregular heartrate) by stimulating supraventricular pacemakers in the heart.

Recovery

Recovery is a vital phase of anaesthesia, and monitoring should be continued through recovery. Recovery is often rapid once gas anaesthesia ceases. The rehabilitator should maintain the bird on oxygen during recovery and be prepared for mechanical ventilation in the event of apnoea. A brief excitatory stage may occur, which may be accompanied by regurgitation. The endotracheal tube should be removed when the bird starts to move its head.

Conclusion

Stress in captivity is considered the primary cause of death of wildlife in rehabilitation. Therefore, it is vital that wildlife rehabilitators work closely with veterinarians to decrease stress, especially for any procedures involving pain. Multimodal analgesia and anaesthesia are important tools to decrease stress, and wildlife rehabilitators familiar with these protocols will have patients that are more comfortable, less stressed and more likely to recover quickly from injuries and procedures with better outcomes.

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