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BEST-PRACTICE GUIDELINES FOR FIELD-BASED SURGERY AND ANESTHESIA OF FREE-RANGING WILDLIFE. I. ANESTHESIA AND ANALGESIA

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ABSTRACT: Field anesthesia is often necessary for both invasive and noninvasive procedures on wild animals. We describe basic principles of safe anesthetic delivery, monitoring, and recovery for application in procedures involving free-ranging wildlife. For invasive procedures, the potential for immediate and lasting pain must be addressed and appropriate analgesia provided. In situations where the minimum standard of safe anesthesia and effective analgesia cannot be provided, the investigator and approving bodies should rigorously evaluate the risk to the patient against the value of the data obtained. This document is intended to serve as a resource for Institutional Animal Care and Use Committees, biologists, veterinarians, and other researchers planning projects that involve free-ranging wildlife in field conditions.

Key words: Analgesia, anesthesia, animal welfare, guidelines, immobilization, surgery, wildlife.

INTRODUCTION

Field wildlife anesthesia is often necessary for both invasive (e.g., surgical) and noninvasive (e.g., blood collection, collaring, metabolic) procedures. Anesthesia for noninvasive procedures is commonly utilized for the safety of the investigators and the animals. Even minimally invasive procedures, such as blood collection, ear tagging, or radio-collar placement, can be stressful for the animal and result in self-trauma or iatrogenic injury during restraint and struggling (Caulkett and Arnemo 2007). Performing general anesthesia in the field can be a source of stress for many veterinarians and biologists and, even under ideal circumstances, it can cause morbidity and mortality in animals (Arnemo et al. 2006). In light of the wide range of anesthetic protocols used, for a number of species in countless settings, this document serves to outline principles for a minimum standard of care for field anesthesia in wild animals.

CONSIDERATIONS

When choosing between chemical and physical methods of capture or restraint, consideration must be given to pain, animal stress, and both human and animal safety. Capture- and anesthesia-related morbidity and mortality is inherent with field immobilizations (DelGuidice et al. 2005, Arnemo et al. 2014). It is essential that the investigator and veterinarian evaluate all aspects of the protocol, including species, terrain, and capture and restraint methodology, to minimize animal risk. In some situations, it may be sufficient or preferable to physically immobilize an animal without inducing unconsciousness. Physical restraint without sedation or anxiolysis should be limited to short, nonpainful procedures or longer procedures in species that are exceptionally tolerant to manual restraint. Physical or mechanical restraint can be stressful to nondomesticated species, and conscious sedation can reduce stress in the animal and decrease risk of injury to the animal and humans (Cattet et al. 2004). In the case of invasive procedures, restraint without consideration for analgesia may be grossly inappropriate and anesthesia or local analgesia should be used.

All investigators should bear in mind that the capture and anesthesia itself can affect an animal's physiology, behavior, reproductive success, and chance of predation (Laurenson and Caro 1994; Cattet et al. 2008; Neumann et al. 2011). Radio-collaring is essential for understanding an animal's movement patterns, but capture and immobilization can alter an animal's activity pattern for days to weeks following capture (Morellet et al. 2009). Restraint and anesthesia also alter numerous physiologic parameters and blood chemistry values, which affects the validity of "normal" data collected during anesthesia (Kock et al. 1987; Boesch et al. 2011).

Anesthesia is defined as the loss of sensation to the entire or any part of the body (Thurmon and Short 2007). General anesthesia involves central nervous system depression resulting in the loss of consciousness and sensation. Characteristics of general anesthesia include 1) complete unconsciousness, 2) analgesia, 3) muscle relaxation, and 4) the absence of reflex responses. Anesthesia should not be mistaken for simple immobilization and recovery, without regard for the importance of monitoring and maintaining a stable patient during the procedure. Conversely, a veterinarian lacking field experience may incline towards over-instrumentation when expeditious completion of a brief procedure would optimize patient safety. Anesthesia also must be a rapidly reversible process, which presents special challenges when working with free-ranging wildlife for which residual sedation or renarcotization can result in injury or death after release. Short-acting or reversible agents (or both) are therefore preferred for field anesthesia.

General anesthesia is inherently a veterinary medical endeavor and thus should be conducted under the supervision and guidance of a licensed veterinarian. In almost every case, the drugs needed for an immobilization are controlled substances or prescription drugs and must be acquired by a licensed veterinarian. All anesthetic protocols should be designed by a licensed veterinarian and ideally with the guidance of a board-certified anesthesiologist or wildlife veterinarian. Unlike domestic animal anesthesia, many field immobilizations are conducted by biologists and field technicians. Nonveterinary personnel should only perform and monitor anesthesia when properly trained by veterinarians or other specialists, and such training should be regularly reviewed and maintained.

GUIDELINES

Guidelines for anesthesia and surgery done in the field on wild animals offer information for biologists and veterinarians on how to perform those procedures at an acceptable technical level. These standards of care can be utilized by ethics committees or Institutional Animal Care and Use Committees (IACUCs) in evaluating the adequacy of procedures proposed in studies presented to them. In addition, biologists and veterinarians can reference these guideline documents when submitting proposals to animal ethics committees to establish the technical level at which their field work will be done. We anticipate that these standards of care will be adjusted and amended over time to accommodate changes in opinion, techniques, procedures, monitors, and drugs.

Regulatory considerations

As mentioned above, most anesthetic drugs must be acquired under the license of a veterinarian, and the use of controlled substances requires strict documentation. Failure to properly use, document, and waste controlled substances will result in fines, loss of license, or imprisonment. It is especially important to apply for permits far in advance of field work conducted abroad. Permits may be required for importing drugs into another country, and there may be great sensitivity to the importation of narcotics or other controlled substances. The United States Drug Enforcement Agency requires anyone taking controlled substances out of the US to obtain an "Exporters" permit from them. Multiple copies of permits should be carried because local authorities may insist on keeping a copy.

Designing the anesthetic plan

Ideally an anesthetic plan needs to be created, evaluated, and approved weeks to months ahead of a field-capture event. Most institutions require objective evaluation of the protocol by an IACUC committee including drug choices, dosages, and emergency and euthanasia protocols.

The anesthetic protocol design needs to account for the animal, type of restraint, and the intended procedure (including degree and duration of pain) as well as the environmental conditions at the capture and work sites. In addition to the target species, plans should be developed for likely nontarget species which may become entrapped or injured and require anesthesia or euthanasia.

Target species: Size, habitat, and activity level can determine drug choice and delivery method. Protocols appropriate for a small carnivore may not translate to larger, more-dangerous animals, as the consequences of sudden arousal are very different. Consultation with veterinarians who have anesthetized the target species in field or captive settings is a valuable tool for designing an appropriate protocol. Knowledge of life history and behavior is essential to plan captures around seasonal peaks in pregnancy, birth, egg-laying, and rearing of young.

Type of restraint: The relative safety and logistics of manual, mechanical, or chemical restraint must be considered for each capture. The animals' stress level, the degree of invasiveness and expected pain, and the anticipated duration of the procedure should be taken into account. In some situations, physical or mechanical restraint of an animal can be performed for nonpainful procedures of short duration. Some species handle manual restraint well and the risk of myopathy and animal or human injury are low. In other cases, potential for stress, pain, or injury necessitate general anesthesia.

Type of procedure, expected duration, and operative risk: Factors to consider when developing an anesthetic plan include the expected degree of tissue trauma, the potential for hemorrhage, the potential for cardiopulmonary instability, the expected overall condition of animals given the season and climate, the level of pain, and the depth of anesthesia required. Operative risk refers to the uncertainty and the potential for an adverse outcome (including prolonged behavioral changes, morbidity, and mortality) as a result of anesthesia or surgery. Risk depends on the skills of the anesthetist and surgeon, the anesthetics used, the resources available, the environmental working conditions, and the physical status of the patient, the duration of anesthesia, and the level of preoperative stabilization.

Capture conditions: The anesthetist must be able to safely deliver the chosen drug combination in the field situation. In many situations, remote delivery of drugs to an unrestrained animal is faster and less stressful to the animal than is physical restraint in a trap (Cattet et al. 2008). Animals can be approached by ground vehicle, stalking on foot, or helicopter. Extended chasing or long restraint in a trap can cause increases in lactate and increase the risk of self-injury (Cattet et al. 2003; Boesch et al. 2011). Remote drug delivery equipment such as dart projectors carry intrinsic risk of injury to the animal (Cattet et al. 2006). Such devices should only be used by trained personnel familiar with the terrain and species at hand. Terrain and capture conditions play an important role if an anesthetic protocol involves a slow induction or recovery. A slow induction protocol increases the chance of overexertion and myopathy as well as increasing the likelihood of escape or injury from environmental hazards (Arnemo et al. 2014). Environmental conditions such as heat, cold, rain, wind, and snow can contribute to hypothermia or hyperthermia associated with capture and the procedure.

All anesthetic plans must take into account human and animal safety. Human injuries and deaths during field immobilizations have occurred from animal attacks, helicopter accidents, drug exposure, and environmental hazards. It is critical that all members of the field team understand the risks inherent with field anesthesia and that appropriate human emergency procedures have been discussed.

Preanesthetic patient evaluation

The purpose of the patient evaluation depends partly on the reason for anesthesia. For research studies, an important goal of preanesthetic evaluation is to exclude animals with conditions (injuries, obvious disease, etc.) that render them nonrepresentative of the larger population and may therefore introduce bias into the study. When anesthesia is performed for management or conservation reasons, however, the patient evaluation may be done to eliminate individual animals that might be adversely affected by the procedure or to tailor the anesthetic protocol to the medical status of the individual animal (Stoskopf et. al 2010). In other cases, the injury or disease prompts intervention (e.g., for disentanglement, snare removal, disease investigation). A thorough preanesthetic evaluation allows the anesthetist to identify existing problems, predict complications, and design an anesthetic regimen to suit the needs of the patient and the procedure.

In wildlife patients, the veterinarian does not have the luxury of medical history or many preanesthetic tests. However, some degree of evaluation should be done; even large animals such as whales can be inspected for visible abnormalities such as wounds, atypical behavior, and poor body condition (Moore et al. 2010). An animal small enough to be captured can be inspected for external condition before anesthesia, and a more-thorough examination can be done following induction of anesthesia or sedation. Any abnormality, even of a temporary nature (e.g., wet feathers or fur caused by capture), should be noted on the written record.

There is no substitute for a thorough physical exam, which should be part of every anesthetic process. The physical exam should focus on those systems that are most affected by anesthesia: the central nervous, cardiovascular, and pulmonary systems. Whenever possible, the following parameters should be evaluated: heart rate, rhythm, pulse quality, and presence of a murmur; mucus membrane color and capillary refill time; hydration status, respiratory rate and rhythm; overall demeanor and body condition; mentation, posture, and ambulation.

An accurate body weight should also be obtained, if possible prior to anesthetic drug administration. In cases when preanesthetic weight cannot be measured, an animal should be weighed during anesthesia to allow for accurate dosing of supplemental or emergency drugs and retrospective calculation of the drug doses administered.

Withdrawal of food and water

Most veterinary patients are fasted prior to anesthesia to prevent vomiting or regurgitation and subsequent aspiration of gastric contents. However, neonates, small mammals, and birds can easily become hypoglycemic and are rarely fasted for more than an hour. Free-ranging animals may have been freely feeding just before capture and may have full crops or stomachs. If possible, planning a capture for a time when the target species is unlikely to be feeding may be beneficial. Wild animals rarely eat or drink in the initial hours after capture. In many cases, the amount of time required to transport an animal from the capture site to the surgery site is sufficient fasting time. The biologist and attending veterinarian should assess the biology of the animal involved and decide if a preanesthetic holding time is advisable and how long it should be. Ideally, these decisions should be made during the planning phase of the project.

Anesthetic protocols

Anesthetic drug types: This document provides basic information about some of the most-commonly used wildlife anesthetic agents. The pharmacology, benefits, and disadvantages of each possible drug protocol can be found in textbooks and other publications (Caulkett and Arnemo 2007, Kreeger and Arnemo 2014). Investigators should consult the available primary and secondary literature related to the target species. In general, the two broad categories of anesthetic agents are inhaled or injectable agents. Injectable anesthetics are further differentiated as reversible and nonreversible. Injectable agents are typically administered by an intravenous (IV) or intramuscular (IM) route, and some drugs are appropriate for either route (ketamine) while others can only be administered intravenously (propofol). Any anesthetic protocol must take into account the potential for secondary toxicosis in a predator, scavenger, or human that may consume a recently anesthetized subject.

Inhalant agents: Inhalant anesthetics are widely used in a clinical setting and possess unique advantages and disadvantages for use in a field setting. Isoflurane and sevoflurane are the two most-commonly used inhalant agents in field veterinary medicine. Unlike injectable anesthetics, inhalants are administered and expelled via the respiratory system. This allows for a rapid and precise adjustment of the anesthetic depth of the patient. Disadvantages include the need to transport volatile fluids, expense and bulk of the vaporizers, and logistical concerns of transporting compressed gases (International Air Transport Association 2013). In addition, ungulates may experience a turbulent recovery when inhalants are used as a sole agent. All inhalant anesthetics can cause a dose-dependent decrease in cardiac output and blood pressure. Fish are also commonly anesthetized with immersion respiratory anesthetic agents absorbed through the gills (e.g., tricaine methanesulfonate), and similar principles apply but without the advantages of precision vaporizers used for volatile anesthetics used in air-breathing animals (Mylniczenko et al. 2014). The ideal way of delivering inhalant gas anesthetic is by using a precision, agent-specific vaporizer and compressed oxygen. Inhalant anesthetics delivered by an "open-drop" method, in which the anesthetic is applied to a cotton ball or gauze and allowed to spontaneously vaporize in a closed container, have been used extensively in rodent anesthesia (Parker et al. 2008). Open-drop delivery results in extremely high concentrations of volatile anesthetic, in many cases far exceeding lethal doses. Particularly in mammals and birds, where lethal doses can be inhaled, this method should only be used by experienced personnel with a previously measured volume and calculated amounts of anesthetic. Reptiles typically stop breathing once they lose consciousness and thus are less likely to die with this method; however, caution is still needed. Additionally, for all species, the open-drop method should only be used for brief induction, not continued maintenance, of anesthesia and reserved for situations when transport of the compressed oxygen and a vaporizer are impossible.

Intravenous anesthetics: Propofol is an ultra-short-acting injectable anesthetic that is labeled for IV administration. It is considered a sedative-hypnotic with little to no analgesic action. Hypotension, apnea, and respiratory depression are common side effects of propofol administration, and intubation and ventilatory support should be available if apnea occurs (Branson 2007). Alfaxalone is a neurosteriod, with no analgesic properties, that has recently become FDA approved in the US. Like propofol, alfaxalone anesthesia can be prolonged through repeat IV dosing of the drug. Unlike propofol, alfaxalone is considered to have a wide safety margin with little to no cardiovascular or respiratory depression seen with administration. Currently, it is only labeled for IV administration in the US; however, it has been administered by the IM route in other countries (Branson 2007). Neither propofol nor alfaxalone are appropriate sole agents for painful procedures and additional analgesic drugs should be used.

Intramuscular anesthetics (listed agents may also be used intravenously): Ketamine is a fast-acting dissociative anesthetic that is used in combination with a tranquilizer-sedative, usually a benzodiazepine or oralpha-2 agonist. Immobilizations with combinations including ketamine provide a rapid onset of action, immobilization within 10 min, and long duration (up to 2 h). Ketamine provides excellent somatic analgesia, but poor visceral analgesia, and therefore it should not be used as the sole analgesic for procedures expected to cause visceral pain. When used alone, side effects include increased muscle tone, hyperthermia, excessive salivation, catecholamine release, and convulsions. Ketamine has no known antagonist; for this reason the use of a reversible drug in combination with ketamine for field immobilizations is commonly recommended (Caulkett and Arnemo 2007).

Tiletamine-zolazepam (TZ) is a widely used commercial combination of a dissociative anesthetic and a benzodiazepine sedative. When dosed appropriately, this combination provides a smooth induction, good muscle relaxation, and analgesia. Tiletamine-zolazepam can be administered both IV and IM. While the tiletamine is not reversible, the zolazepam can be antagonized with flumazenil. Combinations of TZ and an alpha-2 agonist are partially reversible and can be used similarly to combinations of ketamine and alpha-2 agonists.

Alpha-2 adrenergic agonists, such as xylazine, detomidine, medetomidine, dexmedetomidine, and romifidine, are potent central nervous system depressants but do not produce general anesthesia unless combined with another drug. This class of drugs possesses sedative, muscle relaxant, and analgesic properties. When combined with opioids or dissociative anesthetics, these drugs help to provide reliable anesthesia. Higher dosages of alpha-2 agonists cause depression of the respiratory (hypoxemia) and circulatory (hypertension and bradycardia) systems. Alpha-2 agonists can be reversed with the appropriate alpha-2 adrenergic antagonist to provide a faster, smoother recovery (Caulkett and Arnemo 2007).

Opioids have been used extensively in the immobilization of wildlife. They are relatively fast-acting, and provide analgesia and sedation, but lack the muscle relaxation seen with alpha-2 agonists. Common side effects seen with opioid combinations include excitation, regurgitation, severe respiratory depression and hypoxemia, muscle rigidity, and renarcotization. Most opioids used in a field setting are ultrapotent and should be handled appropriately to decrease the chance of accidental human exposure. The appropriate opioid antagonist should be on hand for rapid reversal of the immobilization.

Intubation

Endotracheal intubation of air-breathing animals undergoing surgical procedures is generally desirable, especially for avian species (Mulcahy 2014), marine mammals, and large herbivores that may not adequately ventilate under anesthesia. Depending on the anesthetic protocol used and the danger potential of the animal, it may not be necessary or possible to intubate safely, but the decision to intubate should be based on the well-being of the patient and the safety of the human personnel, not on the convenience of the surgeon or field team. Intubation should be performed by a veterinarian experienced with the species, as trauma to the trachea can result in serious immediate or delayed consequences, ranging from hemorrhage and inflammation to subsequent tracheal stricture and death. Even if intubation is not employed routinely on every patient, having appropriately sized endotracheal tubes and a manual breathing unit (AMBU bag) available is important to allow rapid correction of apnea or hypoventilation.

Catheterization and fluid therapy

Vascular access is desirable for several reasons, including the ease of initiating supportive treatment and the potential difficulty of gaining vascular access in an emergency situation in the field. In field surgical suites with limited light, the potential of physical instability (e.g., on a boat), and minimally trained anesthetists, it is helpful to establish vascular access before the surgeon dons sterile gloves and is no longer available. Of course, the presence of another veterinarian, or a veterinary technician, reduces this need as it is more likely that vascular access can be established if necessary in an emergent situation. In some species, vascular access is difficult, and the amount of time it takes to establish it outweighs the benefit of expeditious completion of the procedure and recovery from anesthesia. Whether or not intravenous catheters will be placed routinely or only during emergencies is another decision that should be made by the field team before the start of fieldwork.

The need for fluid therapy will depend on the species, the anesthetic protocol, the capture-handling-transportation scenario, the surgical procedure, and logistic constraints of the field site such as weight and space limitations. For example, many birds anesthetized with isoflurane become profoundly hypotensive, and fluid therapy can be very helpful in restoring or maintaining blood pressure. Similarly, if a procedure is expected to result in significant blood loss, fluid therapy may be essential.

Emergency preparation

All personnel that will play the role of the anesthetists should have some basic training in anesthetic emergency management. At a minimum, anesthesia and surgical personnel should be trained in the causes of and treatments for apnea, bradycardia, tachycardia, hypothermia, and cardiopulmonary arrest. Ideally, personnel should be prepared to deal with hypoxia, hypotension, and hypoventilation, but accurate responses require reliable monitoring of oxygen saturation, carbon dioxide excretion, and blood pressure, which is not always feasible in a field setting. While it is impossible to be prepared for every eventuality, it is both prudent and ethically required to be prepared for the most-common anesthetic and surgical emergencies including respiratory distress or arrest, bradycardia, cardiac arrest, hemorrhage, hypotension, and gross contamination of sterile tissues.

Personnel in the vicinity of the surgical suite should know the names and locations of various emergency equipment and drugs and how to draw up a measured amount of drug into a syringe. Doses of emergency drugs for the range of weights likely to be encountered in the target species should be readily at hand, either posted somewhere or inside a drug or emergency box. Essential emergency supplies and equipment are listed in Table 1.

Table 1. Essential supplies and equipment that should be on hand for wildlife field anesthetic events.

AMBU bag or ventilator
Oxygen for nasal or tracheal administration
Emergency drugs (atropine, epinephrine) with dosage chart
Intravenous catheters, fluids, and administration sets
Endotracheal tubes

Analgesia

Analgesia should be provided for any penetration of the skin by a tool larger than a hypodermic needle, including biopsy instruments. Exceptions would be when it is impractical to do so, such as during biopsy using a projectile device. Invasive surgeries should be conducted using general anesthetics with the animal at a surgical plane; intraoperative analgesia that continues after anesthetic recovery should be provided in some form to every surgical patient. Minimally invasive surgical procedures, including biopsies and dental extractions, can be performed on conscious patients if general anesthesia would put the patient under extreme risk. Those situations may include aquatic species for which appropriate anesthetic and monitoring equipment cannot be safely used in a boat or where postanesthetic sedation could result in drowning. When general anesthesia is not used, preemptive analgesia is of paramount importance. Analgesic drugs used in field settings include opioids, nonsteroidal anti-inflammatory drugs (NSAIDs), and local anesthetics (Whiteside 2014). Many drugs, such as propofol and isoflurane which affect or facilitate immobilization and anesthesia, do not provide analgesia and should be used in conjunction with an appropriate analgesic agent. For the rare situations where provision of adequate analgesia is impractical, it is imperative that the investigator and the approving IACUC weigh the value of the information gained against the potential suffering of the subject. Guidelines for the recognition and treatment of pain in animal patients are provided by the American College of Veterinary Anesthesia and Analgesia (2006).

The need for analgesia both during and after procedures should be considered. For example, in an effort to reduce adverse effects and achieve more "balanced" anesthesia, combinations of drugs are used so that the dose of each individual agent is minimized. When opioids are used in admixtures of immobilizing drugs and are the sole source of analgesia, care should be taken to ensure that the dose of the opioid is adequate to provide analgesia. Similarly, opioids and alpha-2 agonists are often reversed after surgery; these antagonists presumably reverse the analgesic effects as well as the anesthetic effects. Therefore, postoperative analgesia must be provided by another means.

Residual postanesthetic sedation is a concern with any sedating analgesic (e.g., opioids) and is cited as a reason for denying analgesia to wildlife subjects. With advances in analgesic pharmacology, denying analgesia for fear of sedation is not valid (Whiteside 2014). In many situations, there are multiple options for intra- and postoperative analgesia that do not result in sedation. Nonsedating analgesics such as NSAIDs may provide for some short-term postoperative pain management without impairing sensory-motor function. Nonsteroidal anti-inflammatory drugs have been regularly used in domestic animals to relieve mild to moderate pain associated with surgical and nonsurgical procedures for a short-term dosing interval. Their use in wildlife species is typically limited to one dose for the immediate term. In some species acute renal failure can occur with a single dose of NSAIDs, and doses should be based on pharmacokinetic data in the taxon of concern (Mulcahy et al. 2003).

Local anesthetics limit conduction of peripheral nerve impulses, thus limiting pain sensation. They do not induce unconsciousness but, when used appropriately, they render an area insensitive to painful stimuli. These drugs can be administered topically (such as a splash block) or by injection into tissues, around nerves, into epidural spaces, or into joints. Proper care and aseptic technique should be used when a local anesthetic is injected in order to prevent further damage to tissues or infection. Regional anesthetic techniques require specific training and may not translate easily from one species to another. Landmarks used in domestic species are well described (Skarda 2007).

Procedure-specific analgesia

Discussing the multitude of invasive procedures performed on wildlife is outside of the scope of this document; thus, only the four most-frequent procedures and appropriate analgesic protocols are presented. The listed analgesic protocols are not the only possibilities, and investigators are advised to consult with a veterinarian familiar with loco-regional and systemic analgesia to determine the best-possible plan. For each of the situations listed, general anesthesia with appropriate analgesia is ideal unless general anesthesia puts the patient or staff at undue risk. As a general guideline, procedures performed on conscious humans with analgesia (e.g., dental extractions, small biopsies) may be performed on awake animals when feasible and safe.

Dental extractions: One of the most-commonly performed surgical procedures done on mammals is the extraction of one or more teeth that are then used to obtain an estimate of the age of the animal (Mansfield et al. 2006). Only rarely is analgesia provided beyond the anesthetic period. In those cases, it is not uncommon for the animal to show physical and physiologic reactions to tooth extractions. Local anesthetics such as lidocaine, bupivacaine, and articaine can provide adequate analgesia for extraction of teeth from animals (Ridgway et al. 1975; Carpenter and Manfra Maretta 2007). They are best utilized for this purpose when they are administered as regional nerve blocks, as they are in human dentistry (Woodward 2008). However, use of regional nerve blocks in field extractions of teeth may carry with it undesired side effects such as prolonged paresthesia. If paresthesia is a concern, infiltration of the alveolus with local anesthetic and systemic administration of an NSAID may be the best compromise between providing some analgesia while minimizing postrelease adverse consequences.

Skin and tissue biopsies: Similar to dental extractions, a combination of local and systemic analgesia is most appropriate for these types of procedures. Local and regional infiltration may provide complete desensitization if applied appropriately to a small site (Skarda 2007). In many cases, large or deep tissue biopsies cannot be completely desensitized with a local anesthetic alone and systemic analgesia is indicated. Use caution to avoid systemic overdose of a small patient with a local anesthetic dose.

Surgical implant placement: Incisions into the subcutaneous space or body cavity are intrinsically painful procedures. Similar procedures conducted in domestic animals without adequate analgesia are considered inhumane. An ideal analgesia protocol can involve both systemic and local analgesia (Mulcahy et al. 2003). As repeated dosing of systemic analgesia is not feasible with free-ranging animals, every effort must be made to minimize tissue trauma. Delicate tissue handling (as emphasized in the companion article, this issue) can significantly reduce postoperative discomfort.

Laparoscopic procedures: Minimally invasive procedures have the benefit of minimal tissue trauma with smaller incisions. This does not render the procedure pain-free. In previous studies conducted in human medicine, it was determined that laparoscopic surgery was associated with severe pain and increased analgesic requirements in the immediate postoperative period (Ekstein 2006). It is recommended that in addition to infiltration of an incision site with local anesthetic, additional analgesia be supplied through a systemic route.

Patient monitoring

Physiologic parameters are monitored to help the anesthetist achieve and maintain a surgical plane of anesthesia, anticipate and detect when changes in delivery of anesthetic drugs are required, and promptly identify pre-, intra-, and postoperative complications. The anesthetist may be a biologist or a veterinarian but should be dedicated to the single task of providing safe and reliable anesthesia. It is preferred that experience be concentrated in one or two individuals rather than to rotate the assignment of anesthetist throughout the field team. The entire surgical team should be prepared to deal with anesthetic complications such as reduction in anesthetic depth, sudden recovery, or cardiorespiratory emergencies. If using injectable anesthesia, the volume of additional boluses should be determined for each animal, and supplies of drug and syringes should be immediately at hand (and drawn up if the danger potential of the animal is high). Intubation and ventilation assistance should be available for all but the shortest-duration procedures.

As is often stated, the best monitoring device is an experienced and alert anesthetist, another reason for concentrating experience in as few individuals as possible. For an inexperienced anesthetist, having a variety of unfamiliar monitoring devices can result in confusion and anxiety and can be a distraction. When properly used by trained personnel, many anesthetic monitors provide valuable information on patient function and can be easily adapted to field use. Before anesthetizing an animal in the field, it is valuable for a potential anesthetist to have experience using both basic and advanced monitoring equipment in a controlled setting.

An essential part of anesthesia training is differentiating machine malfunction from a true physiologic problem in the patient. The easiest way to distinguish patient problems from equipment problems is to employ redundant monitors; for example, bradycardia on the pulse oximeter can be confirmed by the anesthetist palpating a pulse or auscultating with a stethoscope. Very rarely does an acute change in heart rate, respiratory rate, blood pressure, oxygen saturation, or expired CO_2 occur without a deviation in another parameter.

The most-basic anesthetic monitoring consists of measuring heart rate, respiratory rate, and (for homeotherms) body temperature. While expensive instruments are available for specialized situations (e.g., Doppler flow probes, ingestible temperature capsules, electrocardiographs), these parameters are easily measured with the eyes and ears of the anesthetist, a stethoscope, and a rectal thermometer. Monitoring of oxygenation, ventilation (carbon dioxide excretion), and blood pressure require additional monitors. Pulse oximeters, capnographs, electrocardiograms (ECGs), and oscillometric blood pressure monitors are the commonly used "standard anesthetic monitors" in veterinary anesthesia but require some accommodation for field use. It is important to remember that even though these devices are widely used in wildlife medicine, very few have been objectively evaluated in nondomestic species.

Diagnostic blood tests

In a field setting, detailed laboratory testing is rarely feasible. In some situations a packed cell volume (PCV) and total solids (TS) can be obtained in the field. Often levels of blood glucose (BG), lactate, or blood gases can be evaluated with point-of-care analyzers. In many cases this is not necessary or possible, but for procedures on marine mammals or large ungulates, these data may prove essential in assessing the patient under anesthesia before a crisis or cardiopulmonary arrest occurs. Such information may also prove useful in assessing instances of postrelease mortality of treated animals. Lactate measurements provide invaluable information about adequacy of perfusion and oxygen delivery and can be used as an indicator of extertional myopathy.

Hypo- and hyperthermia

Intraoperative thermoregulation of homeotherms can be a challenge during field surgeries as animals are frequently dysthermic as a result of capture procedures (Arnemo et al. 2014). The surgical team should decide in advance on the limits of high and low body temperatures that, if exceeded, require action to correct. Although either hypo- or hyperthermia may occur, hyperthermia is more common in the immediate postcapture period, as animals have frequently struggled during capture, handling, and transportation. Initial hypothermia may be seen in animals that have gotten wet during capture or in those whose activity was restricted in traps during cold weather. Avoidance or correction of extreme hyperthermia or hypothermia before surgery begins is the best option but may not always be attainable.

Treatment of hyperthermia is most-often done by applying water, alcohol, or cold packs to highly vascular areas of the animal's body as soon as the problem is recognized. Other approaches may be possible. For example, hyperthermic polar bears (*Ursus maritimus*) can be placed into ventral recumbency on snow or ice to expose areas of their bodies that have less hair. Sometimes simply allowing the animal to rest in a dark, quiet environment is adequate, but the time restrictions of some projects (e.g., need to complete a surgery before sundown) may not permit this.

Intraoperative hypothermia often occurs during surgery due to the loss of normal thermoregulatory mechanisms under anesthesia (Stoelting and Hillier 2006). Body heat is lost by four primary routes: 1) radiation (heat lost to the surrounding air), 2) evaporation (loss of warm water vapor from the respiratory tract or from an open body cavity, 3) conduction (heat lost by direct contact with a cold surfaces, such as the operating table, and 4) convection (warmed air around the patient is moved away by air currents). Prevention of hypothermia is much more effective than correcting hypothermia once it has occurred. Heat loss can be slowed by covering or wrapping the animal's body with towels, drapes, reflective blankets, or bubble wrap to reduce the area exposed to the air and wind (radiative and convective heat loss). It is also important to place the animal on an insulated surface to limit conductive heat loss. Warmed fluids can be given intravenously and heat packs can be applied to exposed body surfaces to provide exogenous heat.

Postoperative care

Following the cessation of anesthetic delivery, animals should remain intubated and ventilation continued until recovery is sufficient for the animal to object to the presence of the endotracheal tube. The endotracheal tube can then be withdrawn. Exceptions requiring earlier extubation may be necessary when dealing with animals of high danger potential.

Animals should be closely monitored during anesthetic recovery to prevent problems and ensure their safety. Restraint may be required if the animal passes through turbulent stages in anesthetic recovery. Once independent breathing is assured, the animal should be placed in a holding or transport container in the appropriate body position for the species, taking into account any hardware attached to the animal (e.g., radiocollar or antenna exit). Observation should continue to ensure that movement during recovery or instrumentation does not result in a body position that compromises respiration (Fiorello et al. 2007). Special considerations are required for recovery of potentially dangerous animals; safety of humans is paramount.

Anesthetic record keeping

Anesthesia records should, at a minimum, document drugs administered including dosage, time of administration, and success of delivery (Fig. 1). Detailed anesthetic record-keeping, including heart rate, respiratory rate, and temperature, should be performed when feasible. In many situations, keeping a detailed record can detract from the actual monitoring of the patient and, in these situations, patient monitoring and treatment should take priority. An accurate and detailed anesthetic record provides valuable information both during the anesthesia and later as data are being analyzed and interpreted. Such records are also valuable for planning future projects. An accurate documentation of the anesthetic episode and drugs used, particularly controlled drugs, is typically a legal and regulatory requirement.

Euthanasia

Perioperative euthanasia in field settings may be required due to severe injuries incurred during animal capture, transportation, or surgery. Because of the limited materials available in field settings, the criteria for and method of euthanasia should be determined in advance, included in the project's study plan, and approved by an IACUC. The anesthesia team should always have the drugs and equipment necessary to perform euthanasia on the target and expected

Elephant Collaring Project

Date/Time: Sex: Male Female

Location: Est. Age: Juvenile Adult

Weather:

Elephant ID:

Drug Delivery and Induction

Drug 1		Dosage		Total Volume:		Injection site:	
Drug 2		Dosage		Injection: complete or partial			
Drug 3		Dosage		Time of injection:			

Time to:	Sedation:	Recumbance:	Non-responsive:

Post Capture Care and Monitoring

Time	Pulse	Resp	Temp	SpO2	MM/CRT	EtCO2	SAP/DAP	MAP	Comments:

Blood Gas

Time	pH	PaCO2	PaO2	Na	K	iCa	Glu	SaO2	HC03	BE

Injection Time **Time to:**

Reversal	Drug	Dosage	Head up:	Sternal:	Standing:	Full Recovery:

FIGURE 1. Example of a field anesthetic record.

nontarget species in the field. The American Veterinary Medical Association Euthanasia Guidelines (AVMA 2013) should be followed unless there is a compelling reason to not do so, and such deviations must be approved in advance by the IACUC.

Postmortem examination

For any perianesthetic mortality in the field, a postmortem examination should be performed. These include deaths during a procedure or in the days after a capture, if the carcass can be retrieved. A thorough necropsy, performed either in the field or off-site, can provide valuable information on the health of the animal and possible anesthetic complications. This information is then used to refine the capture and anesthesia protocol for future animals. Simply ruling a mortality event as "anesthesia-related" without confirmatory diagnostic information does nothing to improve animal care or understanding of perianesthetic complications.

Disposal of carcasses

Disposal of euthanized animal carcasses presents a special problem in the field. Carcasses of animals euthanized with barbiturate-based euthanasia solutions are a hazard to scavengers, which may suffer lethal consequences due to secondary toxicosis (AVMA 2013; Harms et al. 2014). Ideally, carcasses of animals that are chemically euthanized should be returned to town and disposed of following approved procedures. Carcasses that cannot be removed from the field should be incinerated or buried in a manner to minimize the risk of scavenging. When possible in these cases, animals should be euthanized with approved methods that do not pose a risk to scavengers, such as inhalant anesthesia followed by intravenous potassium chloride injection (AVMA 2013). Animal carcasses, especially those of threatened or endangered species, may represent a valuable resource for further scholarly study. In these cases, the return of carcasses is strongly urged. Euthanasia of study animals in the field may be a sensitive subject to some members of the field team. Consideration should be given to warning the field team in advance that such an event may become necessary and to having an open discussion following a euthanasia event.

CONCLUSIONS

Given the pharmacologic and technologic resources available today, it is possible to design appropriate anesthetic and analgesic protocols for nearly any field situation. Careful planning and good communication among leaders of the field team prior to fieldwork will help enable the field team to anticipate and prepare for potential complications, allowing even a novice anesthetist to avoid or respond to many life-threatening situations.

The guidelines in this document are intended for the use of biologists and veterinarians in planning and performing projects that require sedation, general anesthesia, and analgesia on free-ranging animals in the field under sometimes challenging conditions. By implementing a minimum standard of care, the animals involved will receive the level of care that they deserve, regardless of the location of the work being done.

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