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BEST-PRACTICE GUIDELINES FOR FIELD-BASED SURGERY AND ANESTHESIA ON FREE-RANGING WILDLIFE. II. SURGERY

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ABSTRACT: The principles of surgical asepsis apply to field surgeries with few exceptions. The minimum level for performance of surgeries in the field on free-ranging animals should be the same as for domestic animals undergoing surgery in animal hospitals. Surgeries in the field are typically done as part of research and management projects and usually involve a combination of biologists and veterinarians with the possibility of conflicts in scientific cultures. This article outlines a minimum standard of care for field surgeries and will serve as a resource for Institutional Animal Care and Use Committees and biologists and veterinarians planning projects that involve surgeries on free-ranging wildlife in field conditions.

Key words: Biopsy, field surgery, free-ranging animals, guidelines, implantation, surgery, wildlife.

INTRODUCTION

In the vast majority of domestic veterinary patients, surgical intervention is performed to prevent reproduction or to address a disease, anomaly, or traumatic injury. Although therapeutic intervention may occasionally be done on free-ranging wildlife in rehabilitation clinics, most field surgeries on free-ranging animals are performed by governmental, academic, or private conservation personnel for research or management reasons. For the purposes of this article, "surgery" is defined as any procedure that breaches the external barrier (skin or mucous membranes) of an organism by more than the diameter of a hypodermic needle and involves access to or exposure of sterile tissues. These surgeries may include implantation or other invasive transmitter attachment, collection of biopsies, collection of gametes, reproductive sterilization, and identification of sex. This article describes the elements of a well-done surgery done on a free-ranging animal and is paired with a companion article describing the elements of anesthesia and analgesia for such surgeries (Chinnadurai et al. 2016).

A dedicated surgical suite is rarely available when surgeries are done in the field, and procedures are done in whatever shelter is available, or even outdoors. Such shelters include cabins, boats, tents, and aircraft. Despite the unconventional venues, field surgeries can be conducted using a high level of aseptic technique. Doing so ensures that the data being collected are of the best quality and that the welfare of the subject animal is maximized. Despite some controversy over feasibility of applying aseptic technique to fish surgery (e.g., Jepsen et al. 2014; Mulcahy and Harms 2014), principles presented here are as applicable and practical for fish and amphibian surgery as for terrestrial animal surgery, save for differences in skin preparation and thermoregulation (see below) (Harms and Lewbart 2000; Mulcahy 2003; Harms 2005; Tuttle et al. 2006). Guidance to specific procedures done in field settings and preparation for them can be found elsewhere (Mulcahy 2003; Goodman et al. 2013; Haigh 2013; Scott 2013).

GUIDELINES

Planning

Working in remote locations requires extensive planning well in advance of the project. The safety of the humans and animals involved should be given the highest priority, eclipsing the goal of achieving the objectives of the project. It is critically important that applications for all necessary permits be submitted well in advance of the field work. Some permits take many months and sometimes more than a year to obtain. Field work cannot begin until all permits are obtained.

Institutional Animal Care and Use Committee (IACUC) approval

In the United States, the Animal Welfare Act (AWA) exempts "Field studies" from coverage unless the "study involves an invasive procedure, harms, or materially alters the behavior of an animal under study." Surgery by definition is an invasive procedure and would not be exempted. Even though many species are exempted from the AWA, in practice most institutions with an IACUC will review all vertebrate animal use proposals. Approval by an IACUC is increasingly required to obtain collection permits from government agencies and to submit manuscripts to scientific journals for review. Approval should be in hand before work begins. While some scientists may find the need for IACUC approval burdensome, or consider it a purely bureaucratic exercise, it should instead be seen as a form of protection for the researcher, because it is recognized in the scientific community as evidence that the study is not duplicative and that animals are being treated humanely (Rollin 2009). Furthermore, it indicates that the data being collected are unlikely to be confounded by morbidity or mortality resulting from failure to adhere to appropriate medical and surgical standards.

Sample size and caseload

Surgery is inherently an invasive procedure and carries the risk of death. For elective research or management procedures that are not conducted for the health or well-being of the individual animal, the potential for a fatal outcome is a serious ethical consideration. Researchers carrying out such procedures have the responsibility to ensure that the data or outcome they desire is not obtainable by another, less invasive methodology. Similarly, researchers are ethically obligated to determine the minimum number of animals necessary to put at risk in order to obtain the information required (Office of Science and Technology Policy 1985; Association for the Study of Animal Behaviour 2003). A well-designed study is therefore essential. Prior consultation with a statistician can improve study design and minimize unnecessary animal use.

The total caseload, maximum number of surgeries to be done in one day, nature of the surgery, and duration of the field work determine the staffing requirements of the field project. A small number of surgeries done over an extended period (as is often the case when dealing with difficult-to-capture or rare species) can be achieved with a single surgical team. However, if a large number of surgeries must be completed within a short period, consideration should be given to increasing the number of surgical teams at the field site, which will require multiple sets of surgical and anesthetic equipment. It would be prudent to arrange for additional surgical teams if many animals are expected at a single time, or if the specific surgery is complicated and lengthy. Fatigue of surgeons and anesthetists inevitably decreases the quality of work and potentially increases the perioperative morbidity and mortality rates.

It is the surgeon's prerogative to determine the number of surgeries that can be completed successfully in a given timeframe. That decision should consider first the welfare of the animals being used and then the goals of the project. Furthermore, this decision should be flexible such that local conditions (such as storms or extreme weather that precludes capture and/or release) and specifics of surgeries (such as potential for intraoperative complications) are taken into account.

Participants and training

It is wise to include local parties who are familiar with the project location and who might have an interest in the performance and outcome of the field work. Entities such as Native American tribes and First Nations, sportsman's groups, and local conservation groups are more likely to be supportive of a field project if they are informed about it ahead of time and kept apprised of the goals and results. If involved, local veterinarians can also be of great assistance in obtaining drugs, eliminating the need for carrying drugs across international borders. Contacts with local veterinarians should be made well in advance of field work, particularly for international settings. Similarly, knowledge of relevant local laws and regulations should be gathered early in the planning stages of the project, as there is great variability with regard to the practice of veterinary medicine, possession, and transport of controlled substances, hazardous waste disposal, and the execution of the research itself.

The value of experience in performing anesthesia and surgery in field locations cannot be overemphasized. Experience with any kind of surgery is of value, but experience with the specific procedure to be done is the most valuable. It is best to be trained in the field by another surgeon who has performed the procedure under comparable field conditions; there is no substitute for this type of on-the-job training. Training with cadavers may be useful initially, but laboratory-based exercises without live animals (and the anesthetic challenges that accompany them) are not adequate to prepare an inexperienced surgeon for the vagaries of field surgery.

Organizational meetings

The lead biologist and lead veterinarian should agree beforehand on their respective areas of authority and the critical decision points likely to arise during the study. For example, it should be clear who has the authority to make euthanasia decisions and how they will be made. It is of paramount importance for these two leaders to work well together, to be in basic agreement about how the work will proceed and what the overall priorities are, and to respect each other's role.

It is useful to have a preliminary meeting of all of the people involved. This meeting can be held in the field before the onset of work. Topics to be covered are individual responsibilities and assignments. For the surgical team, such a meeting is a chance to educate nonsurgical participants in the techniques to be used, to answer questions, and to caution participants in how to behave around an anesthetized animal, a sterile surgical field, and what they can and cannot touch. Decisions about allowing photography and a policy about sharing images and information on social media should be made ahead of time and passed on to participants. An additional meeting of the surgical team may be useful to discuss roles, responsibilities, and protocols.

Location of surgical suite

Field surgery can be performed in almost any location, such as cabins, boats, tents, and in open air. Of paramount importance is the ability to clean and to maintain the cleanliness of the immediate location of the surgery. Except in rare cases when the patient's size precludes alternatives, surgeries should not be done on the ground or on any surface that cannot be thoroughly cleaned or at least covered with a waterproof clean covering. Protection of personnel, patients, and sterile instruments from the elements (direct sun, wind, precipitation) is critically important. There should be adequate lighting (natural or artificial) and ventilation (to permit adjustment of ambient temperature). Headlamps can be worn to supplement available lighting. Protection from bothersome insects such as mosquitos is important to prevent distraction of the surgeon and anesthetist and to maintain a sterile field; the effects of repellants on sensitive patients may preclude their use, and physical barriers may be the best option to exclude insects. Electricity can be supplied by generators if not otherwise available and if it is necessary for the procedure (e.g., endoscopy).

Field surgery can be performed while standing or sitting. The surgery table should be of sufficient height to make the posture of the surgeon comfortable. It should be of sufficient size to allow for the anesthetist to reach all parts of the patient and to allow for the placement of instruments, monitoring equipment, and an anesthesia machine, if used. The patient may need to be secured to the table if surgery will occur on an unstable platform, such as a boat. When setting up the work area, attention should be paid to ergonomics as well as patient flow to maximize efficiency and minimize contamination of the surgical field. The surface of the table can be covered by sheets of plastic (such as garbage bags) to help maintain cleanliness and to ease clean-up. If the surgeon prefers to sit or if the location would make standing difficult, then chairs, stools, or boxes of the proper height and stability should be available.

Aseptic technique

Lister (1867) first described the basics of aseptic surgery techniques and demonstrated their usefulness in reducing post-surgical infections. In some cases, such as in the USA and Canada for most mammalian species, the use of aseptic techniques is legally mandated for all surgeries from which the animal is intended to recover. Federal regulations (9 C.F.R. 1A § 2.31 (d)ix) in support of the US AWA (7 U.S.C. §§ 2131–2159) state that "All survival surgery will be performed using aseptic procedures, including surgical gloves, masks, sterilized instruments, and aseptic techniques" and that "Operative procedures conducted at field sites need not be performed in dedicated facilities, but must be performed using aseptic procedures." The Guide for the Care and Use of Laboratory Animals (National Research Council 2011) requires that "General principles of aseptic surgery should be followed for all survival surgical procedures." In Canada, the Guide to the Care and Use of Experimental Animals (Canadian Council on Animal Care 1993) indicates that "All species undergoing surgery should receive a similar level of care and attention. Recovery surgeries in all species of animals should be performed using aseptic technique. Instruments should be sterile" and "Surgery in field conditions should be performed in as clean an environment as possible, with sterile instruments, sterile surgical gloves and aseptic technique" (Mulcahy 2013).

Legal requirements will vary from place to place, do not cover most species, and do not exist in many countries. However, regardless of the legalities, the use of aseptic technique is essential for the collection of meaningful data. Abnormal behaviors due to pain, weakness, and other consequences of infection and inflammation will cloud interpretation of data, and ultimately this morbidity can render the results and conclusions of the study invalid (Muir 2009; Muir and Gaynor 2009). Obviously, premature deaths of study animals due to fatal infection will severely disrupt the study. Given the amount of time, effort, and funding that is typically required to execute field projects, the use of aseptic technique is an insurance policy that protects the researchers' investment of time and money.

Medical supplies

The nature of field-based surgery requires that supplies adequate for the nature and numbers of the planned procedures be brought to the field. Because obtaining additional supplies during a field trip may be difficult, packing surplus anesthetic and surgical supplies is warranted to allow for replacement of contaminated materials or for the need of unanticipated additional materials.

The requirements for sterile equipment and supplies will vary with the procedure, but, at a minimum, gloves, instruments, gauze sponges, suture materials, scalpel blades, and drapes are required. Individual transparent plastic drapes with adhesive centers are ideal for allowing smaller patients to be visually monitored during surgery. These materials should be packed in such a way that their sterility is not compromised during transport (i.e., by water) and that any compromise to sterility is apparent.

Necessary nonsterile accessories include sharps containers, trash bags or boxes, a collection point for biohazard materials, surgical caps and masks, surgical preparation materials, and cleaning supplies. Only empty sharps containers can be transported in checked baggage on commercial aircraft (International Air Transport Association 2013). Therefore, at the conclusion of field activities sharps should be disposed of locally or shipped back as freight. In many field camps trash is burned, and this can be used as a means for disposal of waste, but a mechanism to dispose of sharps will still be needed. Similarly, empty drug vials that once contained ultrapotent opioids could present a hazard and should be packed out or safely disposed of locally.

Disinfection and sterilization

Disinfection “destroys or irreversibly inactivates most pathogenic microorganisms, some viruses, but not usually spores,” while sterilization “destroys or eliminates all forms of life, especially microorganisms” (Dvorak 2008). In the USA, federal laws and professional society guidelines are nearly unanimous in requiring aseptic technique for invasive surgeries (see Mulcahy 2013). Regardless of the existence of a legal mandate, best practice indicates the use of sterile, rather than disinfected, surgical instruments for each surgery. Similarly, all devices intended for implantation should be sterilized rather than merely disinfected. Implantable materials that are contaminated in the field or electronic devices removed from an animal cannot be reimplanted until they are resterilized. Attending veterinarians should make clear in advance of the project that they are bound by professional and legal requirements to perform only aseptic surgeries, which require sterilized instruments for each individual animal.

A separate, sterile surgical pack should be available for each patient. In most cases, surgical packs should be sterilized before leaving for the field, and extra surgical packs should be included to replace contaminated packs or to allow for additional surgeries in case of perioperative mortalities or aborted procedures. Depending on weight limitations and the difficulty in getting to the field site, it may be prudent to include only those instruments that are absolutely necessary in the surgical packs. Chemical sterilants may be used in the field, but when the weight and volume of liquids that must be transported and the contact time for sterilization are taken into account, the advantages of carrying presterilized surgical packs are clear.

Steam sterilization under pressure, in either an autoclave or pressure cooker, is the method of choice for sterilizing equipment and supplies that can tolerate high temperatures and pressures. Operators of autoclaves or pressure cookers need to know the combination of time, temperature, and pressure variables required for sterilization. Items to be sterilized should be cleaned of organic debris and packaged in steam-permeable materials; in most cases two layers of packaging should be used. Sterilizers must not be packed too tightly such that steam cannot freely circulate. Indicator strips should be included in sterilization packages to verify that sterilization has occurred. Minimum standards for steam sterilization are listed in Table 1.

For practical reasons, dry heat ovens are rarely used to support field surgeries on free-ranging animals. While dry heat ovens can successfully sterilize surgical instruments, the high temperatures required mean that the instruments must be placed in metal or glass containers that are heavy and awkward for transportation. Cloth or paper instrument wraps will burn at the temperatures necessary for dry heat sterilization. Indicator strips are

TABLE 1. Minimum acceptable autoclave and pressure cooker parameters for sterilization. Timing begins once pressure and temperature are at prescribed levels.

Type of sterilizer	Temperature, pressure, and time combination
Autoclave	121 C (250 F) at 15 psi for 30 min
	132 C (272 F) at 15 psi for 15 min
Pressure cooker	121 C (250 F) at 15 psi for 30 min

available for ensuring that dry heat sterilization has occurred.

Presently, the only means for chemically sterilizing surgical instruments or and supplies while in the field is the use of glutaraldehyde solutions (e.g., Cidex® Activated Glutaraldehyde Solution 2.4%, Advanced Sterilization Products, Irvine, California, USA). Other liquid chemicals such as benzalkonium chloride and chlorhexidine are disinfectants and cannot be relied on to sterilize instruments. To attain sterilization, glutaraldehyde solutions must be used according to manufacturer's instructions, including proper dilution of stock solution and adequate contact times (typically 12 h) (Dow Chemical Company 2003). Materials must be kept fully immersed in the solution for the full sterilization time, and a sterile instrument or hands wearing sterile gloves should be used to remove the sterilized materials. Instruments must then be thoroughly rinsed with sterile saline or sterile water to remove all residues of the solution, which can irritate tissues. Sterilized materials should not contact nonsterile surfaces before they are introduced into the animal's body. Chemical sterilants should be used in conjunction with the manufacturer's directions to avoid toxicity to animals and people.

For minimally invasive surgical procedures using laparoscopic instruments, sterilization may not be feasible in the field because of the nature of the equipment (i.e., cannot be heat sterilized). For example, waiting 12 h for complete sterilization with chemical sterilants would limit the surgeon to a rate not practical or cost-effective for most remote field projects. In these cases, it is acceptable to start the day with sterilized instruments (e.g., 12 h glutaraldehyde solution contact time or gas or plasma sterilization) and then disinfect instruments between patients in a high-level disinfectant (e.g., Cidex Activated Glutaraldehyde solution for 20 min, Cidex OPA 0.55% orthophthalate solution for 12 min) (Rutala et al. 2008; Spaun et al. 2010).

Disinfectants and sterilizing solutions present difficulties in proper disposal in the field, and regulations surrounding these chemicals may not be intuitive. Glutaraldehyde, for instance, is registered as a pesticide with the US Environmental Protection Agency (EPA) and should not be discharged into surface waters because of toxicity to aquatic invertebrates (EPA 2014). A permit from the US National Pollutant Discharge Elimination System is required to discharge registered chemicals into US waters. Guidelines for safe and legal disposal and/or deactivation of glutaraldehyde and local regulations for disposal must be followed; these should be determined and a protocol should be developed for each project prior to the start of the fieldwork.

Antibiotic prophylaxis

The administration of antibiotics should not be necessary to prevent infection if proper aseptic technique is used (Wright et al. 2008; Lundstrom et al. 2010; Rubin et al. 2015) and should never be used as an excuse to disregard the importance of asepsis. However, in some cases, prophylactic antibiotics may be warranted when it is impossible to ensure a sterile field, for example, for intraabdominal surgery on species such as sea otters where the hair should not be removed from the animal, and cannot be completely sterilized, but will likely encroach into the sterile field. Efficacy of single-dose prophylactic antimicrobials to prevent surgical infections is an open question; it has not been studied in wildlife as it has in domestic mammals, where some studies suggest a beneficial effect while others do not (Whittem et al. 1999).

For any beneficial effects, a prophylactic antimicrobial should be administered some time prior to surgery to allow the drug to concentrate in tissues before they are incised or contaminated.

Record keeping

The written record of the procedure is one of the most important products of the work being done. Records should be kept for individual animals if animals are identified by an individual mark such as a tag, transmitter, transponder, or tattoo. Data specific to the procedure being performed and to the goals of the individual project should be included on the data record. The following additional data should be recorded:

1) Date
2) Project Leader's (Biologist's) Name
3) Ambient Temperature
4) Genus and Species
5) Sex and Age or Age Class (if Known)
6) Animal Identification Number (e.g., Tag, Leg Band, Transmitter)
7) Locations of Capture and Surgery
8) Time and Method of Capture
9) Name of Veterinarian of Record
10) Names of Surgeon, Anesthetist, and Assistants
11) Physical Examination Findings
12) Results of Presurgical Laboratory Tests (if Any)
13) Anesthetic Drugs, with Amounts and Times Given
14) Nonanesthetic Drugs (e.g., Analgesics, Fluids) with Amounts and Times
15) Body Mass and Measurements
16) Time and Body Temperature at Important Surgical Events (e.g., Induction, Intubation, Incision, Closure, End of Anesthetic Administration, Recovery, Return to Transport or Holding Cage)
17) Surgical Complications
18) Anesthetic Recovery Time
19) Release Time and Location
20) Behavior of Patient at Release (if Observed)

Preoperative guidelines

Most surgical procedures done in the field are elective. The veterinarian of record has the responsibility of screening candidate patients for anesthetic and surgical readiness. An animal may have subclinical or mild disease that is not readily apparent but that is serious enough to result in death when it is subjected to the stress of capture, anesthesia, and surgery (Sexson et al. 2014). Wild animals also mask signs of disease due to the risk of predation, so an apparently healthy animal may in fact be profoundly compromised. The absence of presurgical laboratory screening and imaging in the field results in some ill animals being subjected to procedures intended for healthy ones. For this reason, mortality associated with field surgeries is not expected to be zero. On the other hand, it is the responsibility of all project personnel to strive for the lowest achievable mortality rate. Preanesthetic assessment and considerations are further discussed in the companion article in this issue (Chinnadurai et al. 2016).

Disease considerations

Surgery on diseased animals: Animals known or suspected to have infectious or noninfectious diseases may be the target of some projects. For example, the survival of animals during an epizootic can be studied by using radio telemetry, which might require surgery to attach the transmitters.

Zoonotic diseases: Prior knowledge of the zoonotic diseases potentially present in field surgery candidates and the use of aseptic surgical techniques will help to minimize the risks of exposure of personnel to zoonotic disease agents. All potentially exposed personnel should be informed of the risks of zoonotic diseases and methods of prevention.

Disease transmission from animal to animal: The use of aseptic surgical techniques will help to prevent the spread of infectious diseases between the field surgery patients. Anesthetic monitoring devices and other medical equipment that come into noninvasive contact with a series of animals should be disinfected between animals. Project personnel should be informed of any disease concerns and the routes of transmission, as well as methods of prevention.

Disease transmission between populations of animals: Sterilization of used surgical instruments before going on the next field trip is required for prevention of transmission of infectious diseases between populations of animals. All surgical and anesthetic equipment that contacted animals in one population should be resterilized or disinfected, as appropriate, between trips to different populations. The attending veterinarian is in a position to encourage adequate disinfection of equipment used for the capture and transport of animals between uses on different populations of animals.

Anesthesia, analgesia, and fluid therapy

Anesthesia, analgesia, and fluid therapy for field surgeries on free-ranging wildlife are reviewed elsewhere in this supplemental issue (Chinnadurai et al. 2016). Anesthesia must be adequate and humane. The type of anesthesia used should be chosen carefully for its utility, adequacy, and the ability of the anesthetists. Adequate intra- and postoperative analgesia must be provided. Nonpharmacologic methods to reduce pain should also be employed. Gentle tissue handling and good surgical technique result in less postoperative pain, as does the use of minimally invasive endoscopic equipment (Yordan and Bernhard 1982; Kehlet et al. 2006). Although advanced endoscopic equipment is not always practical or within the budget of many field projects, its use should be considered whenever possible.

Patient preparation and positioning

Patients should be held in a safe, quiet, dark environment with appropriate husbandry prior to surgery. Wild animals are amazingly inventive at injuring themselves when confined to human-created structures, so considerable attention should be paid to preparing safe holding spaces for pre- and postoperative periods. Animals in temporary enclosures should be visually monitored at regular intervals (excluding overnight) to ensure that they are not in distress.

Prior to surgery, the patient should be examined by the veterinarian. Depending on the species and capture situation, this may occur before or after anesthetic induction. The surgeon and all equipment must be ready so that once it is determined that surgery will proceed, there are no further delays that will prolong anesthesia time. The patient should be positioned such that the surgeon is comfortable and the anesthetist can properly monitor the patient and access necessary areas (i.e., IV catheters). Lighting should be adequate, and the optimal position for lighting should be determined at this time. The animals should be secured to the table if appropriate for the animal, with the specifics being dependent on the physical site, the anatomical site of the procedure, and the species. The patient may require shaving of fur or plucking of feathers or scales; in some cases, any removal of fur or feathers is contraindicated (e.g., sea otters [*Enhydra lutris*]; aquatic birds). For these animals, a mixture of betadine and sterile lubricant can be used to part the fur or feathers and minimize contamination of the surgical field. The incision site should be cleaned and then disinfected using a standard antiseptic such as chlorhexidine or betadine solution and alcohol, keeping in mind the appropriate concentration and necessary contact time for efficacy. Contact of feathers and hair adjacent to the incision site to disinfectants such as alcohol or chlorhexidine should be minimized to reduce wetting and removal of waterproofing oils. Less caustic materials and less abrasive techniques must be used in fish and amphibians due to the fragility of their epidermis and the need to preserve a surface mucus layer (Harms and Lewbart 2000; Mulcahy 2003; Harms 2005).

Preparation of surgical team

While a full scrub at a dedicated surgical sink is unlikely to be available, the surgeon's hands should be as clean as possible. Washing hands thoroughly and cleaning under the nails before each surgical procedure is a minimal requirement. If many surgeries will be performed consecutively, cleaning the hands with an alcohol-based gel between patients is appropriate.

At a minimum, the surgeon and anesthetist will wear a surgical cap, mask, and clean shirt or scrub top, and the surgeon will wear sterile gloves. In a field situation, extra care should be taken to don sterile gloves without contaminating them. A sterile surgical gown can be worn at the discretion of the surgeon. The anesthetist should wear a surgical cap and mask. Anyone present in the room during a procedure when an abdominal or coelomic cavity is open should wear a surgical cap and mask. A new set of sterile gloves will be donned by the surgeon for each patient.

Intraoperative guidelines

Surgery may begin when the anesthetist is satisfied with the stability of the patient and the surgeon is comfortable with the set-up and patient preparation. Extraneous noise and distractions should be minimized, with all team members staying focused on patient support. Good communication between the surgeon and anesthetist is essential for optimal patient care and for safely minimizing the duration of the procedure. If the patient's cardiovascular or respiratory status is uncertain, the anesthetist should promptly notify the surgeon; similarly, if unexpected hemorrhage or anything that may alter the stability of the patient occurs, the surgeon should inform the anesthetist.

Additional protection of sterile tissues from contamination can be afforded by attaching a second set of sterile drapes to the subcutis immediately after making the initial surgical incision. Alternatively, commercially available wound barriers that provide circumferential protection have been shown to decrease the incidence of surgical site infections in human surgery (Horiuchi et al. 2007; Reid et al. 2010).

Intraoperative thermoregulation can be a challenge during field surgeries as homeothermic animals may be hyperthermic or hypothermic as a result of capture procedures and anesthetic drug effects. Hypothermia often occurs during surgery due to the loss of normal thermoregulatory mechanisms under anesthesia and is worsened by loss of body heat through open surgical incisions. Keeping the procedure as short as possible to minimize both anesthesia time and the time the body cavity is open will also reduce heat loss. This is another good reason why it is so important for the lead surgeon to be proficient at whatever procedure is being performed.

Postoperative care

Animals should be observed closely until they are completely recovered from anesthesia. When possible, body temperature should be monitored and measures to warm or cool the animal instituted when necessary. Animals should be held in appropriate cages or enclosures until they are fully awake; they should be able to ambulate and respond normally to ambient stimuli prior to release.

The duration of holding animals in captivity postoperatively will vary with the species, the procedure performed, the resources available, the climate, and the requirements of the project. Even if it were practical, many species would fare far worse if maintained in captivity for several days rather than immediately released. Data from telemetry research are available to demonstrate that many species can be released almost immediately after anesthetic recovery without increased mortality (e.g., Komdeur 1994; Castro et al. 1995). However, researchers should be aware that the absence of mortality does mean that the animals are behaving and functioning "normally," that is to say, exactly as they would be behaving and functioning had the procedure not occurred (Lee et al. 2013; Dechen Quinn et al. 2014). Captive-bred animals undergoing surgery sometimes benefit from a holding period before release (e.g., Wanless et al. 2002; Teixeira et al. 2007; Mitchell et al. 2011). Release protocols should be carefully evaluated (Moseby et al. 2014). The plan for timing of release should be made after extensive discussions among the biologists and veterinarians during the planning stages of the project, considering the goals of the project as well as the welfare of the animals.

Remote biopsy

Biopsies of skin and subcutaneous fat or blubber can be obtained from large, free-ranging animals such as marine mammals by using biopsy darts propelled by powered projectors such as dart rifles and cross bows. With these procedures, certain aspects of aseptic procedure such as surgical site preparation are not possible. However, the other principles of asepsis, such as the use of sterile biopsy darts for each animal, should be followed to minimize the chance of iatrogenic infections and the transmission of infectious diseases between animals and populations. Remote biopsying should be done only when immobilization or restraint of the animal, which would allow for use of aseptic techniques and provision of analgesia, cannot be done due to practical or safety considerations.

CONCLUSIONS

Surgeries can be conducted in field settings in a humane and skilled way. Standard aseptic surgical techniques can be applied to field surgeries in most cases. Few compromises in anesthetic, analgesic, and aseptic techniques are absolutely required, and when they are, those compromises should reflect the nature of the animal patients rather that the convenience of the anesthetists, surgeons, and biologists involved in the project.

Failing to adhere to minimal anesthetic, analgesic, and surgical standards when performing surgeries in the field can adversely affect the patient's outcome, the data collected, the project's goals, the perceptions of people observing the procedures, and the relationship of scientists with the community. The guidelines in this article are intended for the use of biologists and veterinarians in planning and performing projects that require surgeries on free-ranging animals in the field without the benefit of a hospital setting. By implementing a minimal 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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