### Surgery

#### General Issues and Requirements

Surgery is defined as any procedure that exposes tissues normally covered by skin or mucosa. Experimental surgery poses a potential for causing pain or distress to animals if not performed properly or if pain is not adequately managed. Surgery can result in pain, damage to tissue and post-operative infections. Therefore stringent guidelines for training, surgical facilities, asepsis, surgical preparation, anesthesia, intra-operative records, analgesia, surgical technique, and post-operative have been established.

Surgery is classified in several ways. There are different requirements depending on the type of surgery being performed.

* Surgery is major if it enters a body cavity (thorax, abdomen, calvarium), or has the potential for having significant complications. Included would be orthopedic procedures and extensive cannulation procedures.
* Other surgery is classified as minor. Minor procedures include peripheral vessel cannulation and skin incisions.
* Surgery is also classified as survival vs. nonsurvival. Asepsis and sterility are not required for non-survival procedures, unless the procedures are of sufficient duration to allow bacterial infections to affect the outcome of the study.
* There are also slightly different requirements for surgery performed on large animals such as rabbits, carnivores or farm animals versus rodents and non-mammals.
* All survival surgeries performed on rodents must be performed utilizing aseptic technique. The [AALAS surgical training](http://www.aalas.org/), modules must be completed by all individuals prior to their approval and conduct of survival surgery. Also, a rodent surgery video is available through Charles River [Rodent Surgery Principles - Charles River](http://www.jove.com/details.php?id=2586)

#### Surgery Facilities

Surgical facilities used for survival surgery must be designed and maintained in such a way that they help prevent the development of post-procedural infections. Design features include:

* Separation of the preparation areas from the surgery area
* Minimization of personnel traffic flow through the surgery area
* Air flow should be away from the surgery area (e.g. positive room pressure, use of filtered, laminar flow air). It may be desirable to have HEPA filtered air for high-risk procedures
* Room surfaces should be non-porous and easily sanitized
* A regular room cleaning and disinfection schedule should be established (i.e. daily cleaning of floors and work surfaces, weekly to monthly cleaning of walls and cabinets)
* The surgery area should be free of all equipment and materials not necessary for the procedure. Any stored items should be in cabinets or drawers.

How these goals are achieved will vary somewhat depending on the type of surgery.

* An approved surgery suite is required for non-rodent animal major survival surgery, with separate rooms for preparation of the patient, preparation of the surgeon, the operating room and a recovery of the animal from anesthesia.
* Non-survival surgery, minor surgery or rodent/non-mammal surgery may be performed in a dedicated work area. This is a room or bench top from which all materials are removed at the time of the surgery. The same concepts described above are important for a dedicated area.

The IACUC will review and approve all surgical areas.

#### Principles of Asepsis

Asepsis is defined as preventing exposure to microorganisms and prevention of infection. Three things that are extremely important in achieving asepsis are the **reduction of time**, **trauma** and **contamination**.

* **Time** of surgical procedure is an important factor, as the longer a procedure takes the greater the possibility of contamination and therefore infection.
* **Trauma** is prevented by gentle tissue handling, keeping tissue moist with isotonic fluids, minimizing dead space during surgical closure.
* **Contamination** refers to introduction of bacteria or foreign matter into the wound.

It may be possible to follow slightly different procedures for achieving asepsis when performing surgery on small patients such as rodents, birds, reptiles and amphibians. Typically, surgical times are short, incisions are small and the amount of tissue trauma is minimal. These all minimize the risk of infection and post-operative pain.

#### Preparation: Surgeon, Patient, Instruments and Supplies

It is essential that anything that will contact the sterile field or surgical site be appropriately sterilized to prevent infections. These will be discussed below. The ARF veterinary staff can provide training. Other aspects of preparation include pre-operative fasting (not required for rodents or rabbits), if necessary, a decision about prophylactic antibiotics, appropriate anesthesia of the patient, and a plan for pre/post-operative pain management and supportive care.

##### Preparation of Instruments and Supplies

Surgical instruments and supplies must be sterilized before they are used for survival surgery. There are a number of ways that this can be achieved.

* Durable instruments and supplies may be autoclaved. This is an extremely reliable and cost-effective method for sterilization. Normally a wrapped "pack" of instruments is prepared and is opened at the time of surgery. Packs may be stored for several weeks if they are kept away from moisture. A preparation date should be put on each prepared pack and packs should not be used without re-sterilization if they are more than 6 months old.
* Instruments and less durable supplies may be sterilized by ethylene oxide. This is also a reliable method for sterilization. However, it is more costly than autoclaving and also takes several hours for sterilization and often longer for aeration (especially for items porous items like PE tubing). Ethylene oxide is hazardous and must be performed using appropriate procedures and equipment. The ARF can support sterilization with ethylene oxide.
* Instruments and some materials may be sterilized in a cold sterilant solutions such as, glutaraldehyde at 2%, iodine (approx. 1:20 dilution of povidone/iodine solutions), chlorhexidine at 0.5%, and benzalkonium chloride at 0.02%. These solutions can be effective at killing vegetative bacteria, but have only minimal efficacy against spores and many viruses. They should only be used for minor procedures or for survival surgery on rodents or non-mammals. It is recommended that exposure times be from 15 minutes to 1 hour and that prior to the start of a day of surgery the instruments be sterilized by one of the other means listed above. Some solutions **must be rinsed from the instruments** to prevent tissue irritation. Solutions should be changed when they become contaminated with blood or debris. Some solutions should be changed at regular intervals due to degradation.
* Instruments can be sterilized in a hot bead sterilizer. This device is appropriate for performing rodent and non-mammal surgery. The efficacy of the sterilization is high and it sterilizes in a very short time (10 sec.) However, only the tips of the instruments are sterilized. It is necessary to allow the instruments to cool before handling tissue to prevent thermal injury. [Ref: Callahan, et. al, 1995. A comparison of four methods for sterilizing surgical instruments for rodent surgery. Contemp. Top. Lab. Anim. Sci, 34:2, 57-60.]
* Instruments and materials are often available pre-sterilized. The packages should have an expiration date on them. Surgical supplies may not be used for survival surgery when they have passed the expiration date.

##### Use of Expired Materials

Expired medical materials such as drugs, fluids and sutures may not be used on any research animal. The use of such materials under these conditions constitutes inadequate veterinary care under the Animal Welfare Act.

##### Preparation of the Patient

Many post-procedural infections are the result of contamination of the surgical site with resident or transient skin bacteria from the patient. Therefore, decontamination of the surgical site and prevention of contamination from other areas is the best means of preventing post-procedural infections.

* Normally, the patient's hair should be removed from the surgical site. This should be done with an electric clipper or depilatory rather than a razor.
* The patient's skin should be scrubbed with a disinfectant such as povidone iodine, alcohol or chlorhexidine. Scrubbing should start at the center of the surgical site and move to the outside in a linear or circular manner. Typically three scrubs alternating between a disinfectant and alcohol are used. Finally the surgical site should be painted with disinfectant prep solution and left to dry. For small mammals like rodents avoid soaking the body to prevent hypothermia. It is not appropriate to scrub the surgical site for fish or amphibians since the detergent or alcohol will remove the protective bacterial slime layer, and may actually increase the risk of infection.
* A sterile surgical drape, with an appropriately sized hole centered over the surgical site, should be used whenever possible to isolate a sterile field. Self-adhesive drapes are also useful and are particularly recommended for use in small patients. In some cases a drape may not be practical or necessary. When a drape is not used is places extra responsibility on the surgeon to maintain aseptic technique.
* Thermal support is required for rodent procedures or for larger species when anesthesia is longer than 15 minutes. Circulating hot water heating blankets should be used and temperatures should be set at approximately 38-40°C (100-104° F).

##### Preparation of the Surgeon

The patient must be protected from organisms that can be carried and shed by the surgeon. These organisms reside on the surgeon's skin, hair, in the nose or mouth, or may be carried on dust particles from the floor or room surfaces.

* Sterile gloves should be used for all procedures. Examination gloves are not sterile. Replace gloves immediately if they become damaged or contaminated. Gloves may be disinfected between surgeries with a cold sterilant for rodent and non-mammal surgeries. Large animal surgeries should be performed with a new pair of gloves for each patient.
* The surgeon's hands and arms should be scrubbed for 3 minutes with a disinfectant detergent such as povidone iodine or chlorhexidine, rinsed with water and dried prior to gloving for any large animal survival surgery. Hand washing is necessary since gloves are often perforated during surgery.
* A cap, face mask, shoe covers and sterile gown must be worn for all large animal major survival surgeries.
* A clean smock or lab coat is recommended when performing rodent surgeries. A hair cover and face mask will reduce the risk of gross contamination of the surgical site.
* Minimizing traffic flow and conversation in the operating room significantly reduces the risk of contamination of the surgical site.

#### Surgical Technique

It has been recognized that one of the greatest influences on the incidence of post-procedural infection rates is the surgeon themselves. Prolonged surgical times expose tissues to contaminants, dry out tissues and compromise the blood flow to tissues. Tissues damaged by crushing or drying, suture and other surgical implants serve as a nidus for infection. There are a number of things that surgeon's can do to prevent post-procedural infections.

* Be aware of instrument and hand position at all times. If an instrument or hand touches something outside of the sterile field (delimited by the drape or the inside of the opened instrument pack) the instrument or glove should be replaced immediately.
* Be gentle when handling tissues
	+ Do not use toothed or crushing instruments if it is not necessary.
	+ Hold the cut edge rather than grasping in the middle of a tissue layer.
	+ When tying off vessels include only a minimum of surrounding tissues.
	+ Use electrocautery or electroscalpels sparingly. They cause significant tissue necrosis.
* Use appropriate suture techniques
	+ Any suture that will be buried in tissues should be either absorbable or monofilament (non-absorbable braided suture, such as silk, is irritating and can harbor bacteria)
	+ Sutures should be placed evenly and as close to the tissue edge as possible to prevent obstruction of blood flow - typically no more than 1 cm from the edge is necessary in large animals and 0.2 cm in small animals. Select the smallest suture sizes possible based upon size required for species, tissue and strength to reduce constriction and inflammation.
	+ Sutures should only be tightened enough to appose the tissue edges. Any tighter will obstruct blood supply, retard wound healing and may result in dehiscence.
	+ The skin should be closed with sutures (non-absorbable monofilament for external), wound clips or tissue adhesive. Sometimes rodents will chew external sutures. Alternatively, a subcuticular pattern using absorbable suture can be used to minimize chewing.
	+ Wound clips typically used in rodents are not recommended. They crush large areas of tissue. The above methods or surgical staples are preferred.
* Reduce all "dead space" during closure. Any pockets or potential space that remains between tissue layers will fill with extracellular fluid or blood and predispose to formation of an abscess. If this is not possible, a drain should be placed and then removed within 12 hours after the wound stops draining.

#### Post-procedural Care

It is required that animals be cared for after procedures to ensure their full recovery. Post-procedural care is the responsibility of the PI group unless arrangements are made with ARF for support.

Post-procedural care includes the following:

1. **Monitoring anesthetic recovery**
	* **Someone must be present** with any animal recovering from anesthesia until that animal is able to hold itself in a **sternal position** (on its chest, able to hold its head up). This includes rodents and rabbits.
	* **Endotracheal tubes**, when applicable, should be kept in place as long as possible; they must be removed when the animal begins to chew or swallow
	* **Ability of animal to maintain normal physiology** such as body temperature and fluid balance, stabilization of body weight should be assessed.
	* Post operative thermal support should be provided for smaller animals like rodents with a heated recovery unit or by placement of a heating blanket underneath ½ of a rodent cage.
	* Administration of body temperature isotonic fluids will hasten recovery. Administer 2-5% of the animal’s body weight depending upon duration, invasiveness or blood loss during surgery (0.5-1 ml for adult mice; 5-7 ml for adult rats s.c. divided into 2-3 sites.) Parenteral analgesics can be added to the s.c. fluids.
2. **Monitoring post-procedural complications**
	* **Provide analgesia** for any procedures with potential for pain or distress
	* **Administer antibiotics** to prevent post-procedural infections is asepsis was compromised
	* **Monitor incisions** for swelling, exudates, pain or dehiscence
	* **Monitor catheters & devices**
	* **Monitor for procedure-related complications** such as organ failure, thrombosis, ischemia
3. **Maintaining records of care given. These records must include a daily assessment and treatments given.** Other items that could be included in the record are anesthetic and analgesics agent administration (dose, time, date), intra-operative assessments and recovery observations. **Post-operative records are required by the USDA on all animals except rats and mice, and must be readily available for review.** Records on rats and mice may be somewhat abbreviated, and can be included as part of research data collected, but should also be available for review.