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Anesthesia and Analgesia of Small Mammals

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Anesthesia of small mammals is challenging and often more difficult than the actual diagnostic or surgical procedure. Because of the small size of these patients, sedation or anesthesia is often required for the most simple of diagnostic or treatment procedures including proper positioning during imaging, blood collection, physical examination, etc. There is not one perfect anesthesia protocol as there are many species of animals of vastly different sizes and with variable responses to the wide variety of drugs available for anesthesia. These animals present specific anatomic and physiologic characteristics that will influence the use of drugs and the outcome of anesthesia. Many of the published doses have very little scientific research to justify their use and most reports are of an anecdotal nature. Furthermore, doses used in research vary greatly from those used for healthy or sick pets. The doses proposed in this handout are lower than those recommended in other formularies but are based on our experience at Cornell University.

Effect of Size

Smaller sized patients have higher metabolic rates and, as a result, time becomes a critical factor during anesthesia. A one hour procedure in a mouse bears the same metabolic cost as a 6 hour procedure in a domestic cat. Complications occur faster and the time for intervention is shorter. Smaller reserves of glycogen predispose them to hypoglycemia. There is an increase in alveolar ventilation and a more rapid uptake of inhalant anesthetics. Metabolism and excretion of parenterally administered drugs are faster and injectable drugs have shorter duration of action. Their higher oxygen consumption means they have less tolerance for hypoxemia; irreversible CNS injury can occur in less than 30 seconds of respiratory arrest in these animals.
Most of the small mammals (excluding the ferret) are considered prey species and respond to stress and pain with shock.

Hypothermia is perhaps the most common complication of general anesthesia. Heat loss can occur through conduction to the cooler environment or to cold surfaces and accounts for 15% of lost body heat. Radiant heat loss (convection) to surrounding cooler objects accounts for 60% of heat loss, and evaporative heat loss accounts for 22%. Aggressive heat preservation is of utmost importance. Placing an animal on a warm surface such as a heating pad on a surgery table minimally preserves body heat. Covering a maximum of body surface will slow heat loss.

Blood volumes range from 50 - 78 ml/kg, depending on the species. However, with their higher metabolic rates there is relatively less tolerance for hemorrhage and even small blood losses will be a significant stress in these animals; rigorous hemostasis is critical during any procedure that may be associated with hemorrhage. Small mammals have proportionately less total blood volume and, therefore, less margin of safety for blood loss than do larger mammals. For example, one ml blood loss from a 250 g rat represents 6% of its total blood volume while one ml blood loss from a 30 g mouse represents 43% of total blood volume. Blood loss can be estimated by keeping track of the number of fully or partially saturated gauze sponges or cotton tipped applicators used to absorb blood or fluids from a surgical site. The average 4X4 gauze sponge holds approximately 7 ml of fluid while an average cotton tip applicator holds 0.17 ml; counting saturated sponges or cotton tips is a crude but effective means for estimating fluid loss.

The small diameter of the airways of many small mammals prevents routine endotracheal intubation. Specialized tubes and light sources are available. Intubation can also be complicated by anatomic features such as narrow dental arcade in most species, and a palatal ostium in Guinea pigs and chinchillas. These small airways become easily obstructed by edema or secretions.
In rabbits, intramuscular injections can be given in the epaxial muscles along the spine which are easier to access when the animal is restrained. The muscles of the thigh (quadriceps or semimembranosus) can also be used, but this technique may result in excessive struggling. An approximate volume of 0.1 - 0.2 ml/kg can be injected per site. The semimembranosus or quadriceps muscles are routinely used for IM injections in most other small mammals. Various degrees of tissue damage

result from injecting irritating drugs such as ketamine. Clinical manifestation of this irritation may or not be visible clinically. Lameness, self-trauma, or skin lesion have been reported.

Because of the tremendous species and size differences, drug doses must be calculated based on metabolic size and not on body weight. Allometric scaling is the arithmetic relationship of biological function to body mass. Because it is based on body mass, accurate body weights must be obtained to within 0.5 - 1 g. Allometric calculations enable one to determine the caloric needs of the patient, estimate physiologic variables (e.g.,, normal heart and respiratory rates), and extrapolate treatment regimens from one species to another.

Table 1 - Allometric Constants (k) and Equations for Estimating Respiratory and Cardiovascular Variables in Mammals

Variable	Allometric Equation
Basic metabolic rate or minimum energy cost (MEC)	MEC (kcal/day) = K ($W_{kg}^{0.75}$) K= 57.2 in placental mammals K= 46.6 in marsupials
Specific minimum energy cost (SMEC)	SMEC (kcal/kg) = K ($W_{kg}^{-0.25}$)
Heartbeat frequency (min^{-1})	241 ($W_{kg}^{-0.25}$)
Blood volume (ml)	65 ($W_{kg}^{1.02}$)
Oxygen consumption ($ml\ min^{-1}$)	11.6 ($W_{kg}^{0.76}$)
Respiratory frequency (min^{-1})	53.5 ($W_{kg}^{-0.26}$)
Tidal volume (ml)	7.69 ($W_{kg}^{1.04}$)
Minute ventilation ($ml\ min^{-1}$)	379 ($W_{kg}^{0.8}$)
Lung volume (ml)	53.5 ($W_{kg}^{1.06}$)

Sample Calculations for Determining Drug Doses Based on Allometric Formulas
To calculate the dose of butorphanol for a 200 gram (0.2 kg) rat, one must first calculate the dose for a known domestic species. In dogs, butorphanol is given at a dose of 0.2 - 0.4 mg/kg. For a dog weighing 10 kg, the total dose is 2 - 4 mg. This 10 kg dog has a basic metabolic rate of 321 kcal/day [MEC (kcal/day) = K($Wkg^{0.75}$); MEC = (57.2)($10^{0.75}$) = 321 kcal/day]. To determine the MEC dose, the total dose for butorphanol is divided by the dog's MEC (321 kcal/day): 2 - 4 mg/321 kcal and the MEC dose is expressed as mg/kcal; in this example, the MEC dose is 0.006 - 0.012 mg/kcal [2 - 4 mg/321 kcal = 0.006 - 0.012 mg/kcal]. This dose is "universal" for all species and doses can be extrapolated to specific individuals when the corresponding MEC is calculated. The 200 gm rat has a basic metabolic rate of 21 kcal/day, so the dose of butorphanol for this rat when calculated on a MEC basis, is 0.126 - 0.26 mg/rat. When this dose is converted to a mg/kg basis, the result is 0.63 - 1.3 mg/kg which is higher than the dose recommended for use in dogs (0.2 - 0.4 mg/kg), but which is adjusted for the higher metabolic rate of this rat.

Pre-anesthetic Preparation
Ideally all patients should be stabilized prior to anesthesia. However, vascular access can be very difficult, but even in patients difficult to catheterize, intraosseous catheterization is possible (Fig. 1a and Fig. 1b). Intraosseous catheterization is performed in anesthetized animals, or is performed with a local block in moribund animals. The hip and the base of the tail are clipped and prepared as for surgery. Wearing sterile gloves, the clinician palpates the greater trochanter (some authors report using an approach via the trochanteric fossa). A 22 gauge 1 - 1.5 inch spinal needle is inserted into the femur using a light rotation movement of the needle (along its long axis). The needle should be kept parallel to the long axis of the femur to avoid accidentally exiting through the cortex of the bone. Once the needle is in place, the stylet is removed and 0.5 - 1ml of sterile saline is injected slowly. If swelling of the surround thigh tissues occur, the needle has traversed the cortex distally and should be withdrawn or repositioned. Two radiographs showing orthogonal views of the femur will confirm proper positioning of the needle. An injection cap or a fluid administration set can then be attached directly to the needle. Antibiotic ointment and a light bandage are applied.

Figure 1a. Intraosseous catheterization in a ferret (see text for details). - To view this image in full size go to the IVIS website at www.ivis.org . -

Figure 1b. Intraosseous catheterization in a ferret (see text for details). - To view this image in full size go to the IVIS website at www.ivis.org . -

Pre-anesthetic preparation will vary depending on whether anesthesia is for an emergency or routine procedure. However, even in an emergency situation, obtaining the maximum amount of information prior to anesthetizing the animal is recommended.
A thorough anamnesis and physical examination should be performed prior to inducing general anesthesia. An emphasis should be placed on the respiratory tract for two reasons: most small mammals are primarily obligate nasal breathers (rodents, lagomorphs), and upper respiratory tract infections are common. Assessment of the patency of both nares is essential and can be accomplished by placing a small mirror or dental mirror immediately in front of each naris and looking for fogging. Critically ill ferrets often present with poor cardiovascular function.
An accurate body weight is mandatory, and if possible basic laboratory tests should be obtained. However, blood work may not be available until after the animal is anesthetized. Minimal basic blood work includes packed cell volume, total proteins, blood urea nitrogen (BUN), glucose, and urinalysis.
The use of sedatives and analgesics are highly recommended to offset the risks associated with stress and pain. The safety of the handler and the animal during the procedure should be taken into account when establishing the anesthesia protocol.
The use of cedar shavings for bedding is controversial. The oils from such bedding may induce hepatic microsomal enzyme activity and may significantly affect drug metabolism.

Pre-anesthetic Fasting
For each patient, the advantages and disadvantages of fasting should be evaluated. Fasting has been advocated in order to reduce the volume of contents in the gastrointestinal tract which can mechanically compress the diaphragm and lungs, a particular problem in large breeds of rabbits and obese animals. Fasting appears to reduce (but not eliminate) regurgitation in Guinea pigs. However, fasting exhausts glycogen stores resulting in hypoglycemia and may significantly contribute to peri-anesthesia ileus, especially in rabbits and Guinea pig.
Fasting is contraindicated in a chronically anorexic animal, those with an insulinoma such as ferrets, hepatic dysfunction, or in late pregnancy. Current fasting recommendations vary from 0 - 4 hours prior to anesthesia.

Pre-medication
Pre-medication of small mammals is recommended. Tranquilizers and sedatives reduce anxiety, reduce MAC, and provide smooth induction and recovery. As for domestic mammals pre-emptive analgesia should be administered.

Parasympatholytics
Anticholinergic drugs reduce respiratory and salivary secretions. They may, however, thicken secretions and cause airway obstruction. These drugs are used to treat vagally mediated bradyarrhythmias. Rabbits have circulating atropine esterases and, therefore, require higher doses of atropine which also increases the risk of toxicosis; a better alternative drug is glycopyrrolate.

Phenothiazines
Acepromazine and other related drugs are not used routinely in small mammals. These drugs block alpha 1 adrenergic receptors thus producing vasodilation and hypotension. They have also been associated with prolonged recovery from anesthesia. Peak effect occurs 30 - 45 min after injection. Acepromazine should be used only in healthy animals.

Benzodiazepines
Diazepam and midazolam are anxiolytics, sedatives, anticonvulsants, and centrally acting muscle relaxants; they cause minimal cardiopulmonary effects and are useful adjuncts in drug combinations used for induction. Diazepam can be administered per os (PO) or intravenously (IV), but if used IV, the animals must be monitored for hypotension caused by the propylene glycol used in preparations of diazepam; intramuscular absorption of diazepam is erratic because of the propylene glycol. Midazolam is water soluble and can be administered IM, IV or PO.

Alpha-2 Adrenergic Agonists
These sedative-hypnotics are often used in combination with ketamine because of their analgesic and muscle relaxant properties and sedative effects. They will prolong anesthesia if not reversed. Bradycardia and respiratory depression are often reported. These effects may be antagonized by using partial doses (10 - 20%) of atipamezole without reversing their anesthetic and analgesic effects. The alpha-2 agonists, in order of increasing potency, are xylazine, detomidine and

medetomidine.

Pre-emptive Analgesics
Analgesia should be planned for any painful procedure and the choice of analgesic drugs includes opioids and non-steroidal anti-inflammatory drugs. Local blocks and low doses of ketamine can also be used. These drugs can be combined or used alone. Pre-emptive analgesia is still most beneficial. Opioids are often used as pre-anesthetics to potentiate sedation and provide analgesia.

General Anesthesia

Injectable Anesthetic Agents
There are several drugs that can be administered IV, IM, SQ, IP, or intraosseously (IO) that will induce anesthesia or heavy sedation. The ideal injectable anesthetic agent should have a wide therapeutic index, a rapid onset of effect, and a short duration of effect; it should be safe for the cardiovascular and pulmonary systems and ideally it should be reversible. In reality, there are no such drugs and each species reacts differently to drugs used in anesthesia.

Following pre-medication, anesthesia can be induced with ketamine (in combination with a benzodiazepine, opioid, or an alpha-2 adrenergic agonist), Telazol ® (tiletamine + zolazepam), or propofol (IV or IO only). These drugs are effective for short procedures. Telazol is more potent than the combination of ketamine and a benzodiazepine such as midazolam, and can cause prolonged recovery. Both ketamine and Telazol can be irritating and lead to self-mutilation or shock from pain. In rabbits, high doses (32 or 64 mg/kg) of Telazol produce renal tubular necrosis within 7 days after injection, and doses as low as 7.5 mg/kg produce nephrosis; the use of Telazol in rabbits is not recommended. There are also species specific differences in the rapidity with which zolazepam and tiletamine are metabolized.
Propofol is a rapidly acting, non-cumulative anesthetic drug for intravenous (or intraosseous) use exclusively. It causes a dose dependent cardiopulmonary depression that may result in apnea and hypotension. Used alone it produces inadequate analgesia.

Inhalant Anesthetic Agents
Inhalant anesthetic agents, such as isoflurane, are versatile and relatively safe to use in all species. They produce rapid induction, changes of anesthetic depth, and recovery from anesthesia. Termination of their effects can be obtained rapidly. They can be used alone or following pre-medication, or induction with parenteral agents. They do require the use of precision vaporizers and the bulkiness of the equipment may complicate access to the patient. Induction with inhalants can be accomplished by placing the animal in an induction chamber or in a mask. An involuntary excitement phase (seen in rabbits and ferrets) can precede induction. Maintenance of anesthesia can be achieved following endotracheal intubation or administration of the agents via mask.

Lagomorphs

The Challenges
Stress is the most important factor to counteract during the pre- and post-anesthetic period. In addition, rabbits have a small thoracic cavity that can be compressed easily by dilation of abdominal viscera (gas accumulation from any source) or inappropriate positioning (See Fig. 2).
At least 2 conditions are routinely seen that may significantly compromise the outcome of anesthesia. Rabbits may have sub-clinical or overt upper respiratory infection (pasteurellosis). These animals have compromised respiratory function that may lead to poor gas exchange during anesthesia, inability to breathe, and death. Renal function may be compromised by infection (although silent) with the microsporidian *Encephalitozoon cuniculi.* These animals often recover well from anesthesia but present a few days later in renal failure. Routine pre-anesthetic blood work will detect this condition; when detected, elective procedures must be postponed until the animal is stabilized.
Intubation is challenging but not impossible. However, repeated attempts and the resulting laryngeal trauma during intubation attempts often result in swelling and respiratory obstruction during the peri-anesthesia period.

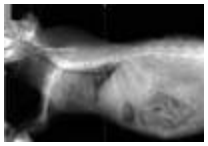

Figure 2a. Rabbits have a small thoracic cavity that can be compressed easily by dilation of abdominal viscera (gas accumulation from any source) or inappropriate positioning. In radiograph A, the rabbit is in lateral recumbency with its body extended. - To view this image in full size go to the IVIS website at www.ivis.org . -

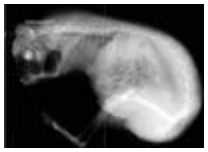

Figure 2b. Rabbits have a small thoracic cavity that can be compressed easily by dilation of abdominal viscera (gas accumulation from any source) or inappropriate positioning. In radiograph B the rabbit's body has been curled. Note how the abdominal contents encroach on the thoracic cavity. - To view this image in full size go to the IVIS website at www.ivis.org . -

Self-inflicted injuries may occur if physical restraint is poor, and the most common complication is fracture of the lumbar

spine. Because at least 50% of rabbits possess circulating atropine esterases, atropine has variable effects and glycopyrrolate is recommended if an anticholinergic is required.

Pre-medication
Protocols for healthy rabbits include the following combinations:

1. Ketamine (5 mg/kg), midazolam (0.5 - 1 mg/kg), butorphanol (0.2 - 0.5 mg/kg), and glycopyrrolate (0.01 mg/kg), all given IM.
2. Midazolam (0.5 mg/kg), butorphanol (0.2 - 0.5 mg/kg) and glycopyrrolate (0.01 mg/kg), all given IM.

Induction is then achieved by masking the animal to anesthesia with isoflurane in oxygen. It is important to keep the induction area quiet and the lights dimmed. Depending on the size and the condition of the animal, general anesthesia is maintained with a mask or tracheal intubation is attempted. An intravenous catheter is placed and the monitoring equipment applied as soon as induction is completed.

Intubation Techniques and Anesthetic Protocols
Several techniques have been described and success depends on the experience of the clinician. It is important to remember that rabbits are obligate nasal breathers and the patency of both nares must be assessed, especially after extubation and if the animal has been in dorsal recumbency. Reported complications include post-extubation obstruction and respiratory arrest. There are several intubation techniques: the traditional direct visualization of the glottis with a laryngoscope and intubation; blind intubation with the neck in extension; guided intubation; and nasal intubation. One factor that increases the chances of successfully intubating a rabbit is to have the animal in a surgical plane of anesthesia prior to any intubation attempts. The use of a topical anesthetic such as lidocaine on the glottis will also decrease the incidence of laryngospasm. General anesthesia can be maintained using an inhalant anesthetic agent delivered via the endotracheal tube or a face mask.

Guinea Pigs and Chinchillas

The Challenges
Guinea pigs are easily frightened and are prone to stress-related complications; they will store food or chewed paper in their cheeks which if it becomes dislodged, may obstruct the glottis. Guinea pigs often regurgitate during induction and active monitoring of airway patency is important. They also produce copious amounts of bronchial secretions that may partially obstruct the bronchi or trachea. The lack of readily available peripheral veins makes IV access difficult in an emergency. Underlying vitamin C deficiency and concurrent diseases are also potential problems that can complicate anesthesia.
Intubation is difficult and complicated by the fusion of the soft palate to the base of the tongue creating only a small opening called the palatal ostium, an anatomic feature common to both chinchillas and Guinea pigs (Fig. 3 & Fig. 4). This tissue is vascular, fragile, and will bleed if traumatized. In the absence of intubation, inhalant anesthesia can be maintained with a mask (Fig. 5).

Figure 3. Speculum used to hold mouth open for intubation of a Guinea pig. Note pillars of the palatal ostium at the back of the oral cavity. - To view this image in full size go to the IVIS website at www.ivis.org . -

Figure 4. Narrow dental arcade, hump at base of tongue, the acute orotracheal angle and long incisors make these types of small mammals difficult to intubate. - To view this image in full size go to the IVIS website at www.ivis.org . -

Figure 5. Maintaining inhalant anesthesia with a face mask in a Guinea pig. Note the catheter in the cephalic vein on the lateral aspect of the left forelimb. - To view this image in full size go to the IVIS website at www.ivis.org . -

Anesthetic Protocol
The combination that we frequently use for premedicating Guinea pigs is glycopyrrolate (0.01mg/kg), butorphanol (0.2 - 0.5 mg/kg) and midazolam (0.5 - 1 mg/kg), all given IM. Induction and maintenance is achieved with isoflurane in oxygen

delivered via a mask. It is important to monitor for signs of upper airway obstruction throughout the entire procedure; a stethoscope may be low-tech, but it is a very effective means of monitoring the airway and lungs, especially when it has a pediatric head. In Guinea pigs, an intravenous catheter may be placed in the cephalic vein which is located along the lateral aspect of the forearm (Fig. 5).

Small Rodents

The Challenges

Because of their small size, pre-anesthetic preparation of these animals may be difficult if not impossible. Routine procedures are rare and you often have a compromised and high risk animal to anesthetize. Peripheral IV access is rarely available and intubation is very difficult. Their small muscle masses must be taken into account when giving intramuscularly proportionally large volumes of drugs; irritating drugs, such as those with a low pH or that include an irritating solubilizing agent, often result in self-mutilation. Pain and fear may cause aggression and other defensive behaviors. Because of their small body mass, hypothermia occurs rapidly under anesthesia.

Anesthetic Protocol

Pre-medication can include the use of midazolam, butorphanol and glycopyrrolate singly or in combination. For short procedures in a healthy animal, masking with isoflurane can be done without pre-medication (may be more stressful). Anesthesia is maintained with iisoflurane in oxygen delivered via mask or in larger species after endotracheal intubation.

Ferrets

The Challenges

Ferrets often present with severe underlying diseases such as insulinoma, hyperadrenocorticism, foreign body ingestion, etc. Stabilizing these patients prior to anesthesia is very important. Prolonged fasting or ongoing diseases may result in hypoglycemia. Because of their small size, hypothermia is also a common complication that must be prevented or corrected aggressively.

Although they have small peripheral veins, catheterization of the cephalic, saphenous or jugular is relatively easy and should be attempted. Hypotension is commonly seen in ferrets under general anesthesia; this condition results from poor cardiovascular function (pre-anesthesia), compression of the vena cava by the viscera when the animal is in dorsal recumbency and/or a direct effect of the drugs. It has been our experience that using dopamine for blood pressure support in ferrets during anesthesia has resulted in irreversible renal injury (personal observation). There are no published studies to support our observation, but clinicians should be aware of this potential effect.

Ferrets are sensitive to the sedative effects of butorphanol and doses commonly used in domestic animals are recommended: 0.05 - 0.1 mg/kg, rarely 0.2 mg/kg.

Anesthetic Protocol

To avoid hypoglycemia, healthy ferrets should not be fasted for more than 4 - 6 hours. Ferrets with insulinoma can be fed up to 2 - 3 hours prior to surgery. Monitoring of blood glucose should be performed every 30 - 60 minutes while the animal is under anesthesia and frequently during recovery. Glycopyrrolate (0.01 mg/kg) and butorphanol (0.05 - 0.1 mg/kg) combined with midazolam (0.4 mg/kg) or diazepam (0.4 mg/kg) is a good combination for pre-medication. The animal can then be masked with isoflurane in oxygen, intubated and maintained with inhalant anesthetic agents. For short procedures, healthy animals can be induced with a combination of ketamine (15 - 20 mg/kg) and midazolam (0.4 mg/kg), both given IM; diazepam may be substituted for midazolam. This combination allows for short surgical procedures (10 - 20 min) and, if necessary, anesthesia can be prolonged with inhalant agents. Complete recovery occurs in 2 - 3 hours.

Marsupials and Insectivores

The Challenges

Sugar gliders and hedgehogs may require anesthesia in order to perform a simple physical examination or radiography. Their small size including small airway diameter and limited access to peripheral veins, limit our abilities to provide life support during anesthesia. As is true of other mammals, these animals are prone to hypothermia.

Anesthetic Protocol

Sugar gliders and hedgehogs are often masked to anesthesia without pre-medication. The combination of midazolam, butorphanol and glycopyrrolate will reduce the stress of induction and decrease the Minimum Alveolar Concentration (MAC) of the inhalant agent. These animals have small muscle masses and only small volumes should be administered IM. Anesthesia can be maintained via mask or if possible after endotracheal intubation.

Monitoring / Instrumentation

Once the animal is induced and the eyes lubricated, an intravenous catheter should be placed whenever possible. Alternatively, an intraosseous catheter in the femur will provide access to the central vascular system. Because the amount of fluid to administer is relatively small, a syringe pump or fluid pump must be used to deliver accurate volumes of the solutions. If a catheter has been inserted, fluid therapy should be instituted at a rate of 10 ml/kg/hour IV or IO.

Alternatively, pre-anesthetic administration of a bolus of 30 ml/kg of fluids given subcutaneously will allow for fluid preloading prior to potential blood loss.

A Doppler flow monitor (Fig. 6) with the probe secured over the medial aspect of the elbow will allow for continuous monitoring of pulsatile blood flow in a peripheral artery, and of the heart rate and rhythm as well as an estimation of arterial blood pressure if it is used in combination with a cuff and sphygmomanometer. Temperature should be recorded regularly even after the animal is draped and under going surgery. An electrocardiogram can provide useful information if there is room on the patient or if a Doppler is not available. The measure of the hemoglobin saturation in oxygen can be obtained with a pulse oximeter. Although debatable, this instrument may be of limited value because the probes are difficult to stabilize on these small patients, and this technique has not been validated for these species. Active monitoring and early detection of complications and intervention are keys to successful anesthesia.

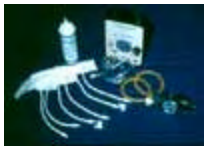

Figure 6. Doppler device made by Parks Medical Electronics (www.parksmed.com/products/?page=3.php). This unit is the 811 series commonly used in veterinary medicine. - To view this image in full size go to the IVIS website at www.ivis.org . -

The following variables should be monitored:

1. Cardiovascular system:
    - Heart rate & rhythm - Doppler; ECG
    - Blood pressure - Doppler
    - Mucous membrane color and capillary refill time - visual inspection
    - Blood loss - visual assessment and measurement (gauze sponges, cotton-tipped applicators)
2. Respiratory system:
    - Respiratory rate & rhythm - visual inspection
    - Tidal volume (estimation) - visual inspection
    - Irway obstruction - visual inspection of chest and abdominal wall movements; use of stethoscope
3. Body temperature - thermistor probe inserted into esophagus
4. Depth of anesthesia - all available variables; if results are contradictory, it is safer to lighten the plane of anesthesia than to deepen it.

Recovery

Good post-operative care requires attentive and frequent monitoring of the animal. The patient should be provided with a warm, quiet, padded cage that is escape-proof. Oxygen supplementation must be administered when necessary. A plan for analgesia should be implemented and continued during recovery for as long as necessary. Animals recovering from anesthesia should be kept separate from cage mate(s) until fully recovered.

Complications

It is not uncommon to shorten a procedure because the animal's condition is deteriorating or is poorly stabilized under anesthesia. However, the use of appropriate pre-medication, reduction of pre-anesthetic stress, and active monitoring of the patient will reduce the risk of complications arising during anesthesia. Hypothermia, anesthetic overdose, cardiovascular collapse, respiratory depression, laryngeal trauma or airway obstruction, pre-anesthetic excitement, and hypoglycemia are common complications.

Analgesia

Immobility caused by unrelieved pain is not ethically acceptable. An animal in pain will have prolonged recovery from surgery, decreased food and water consumption, delayed healing, and may go into shock and die.

The clinical expression of pain varies by species. Assessing pain in small mammals requires knowledge of their normal behavior which can then be compared to their post-operative behavior. Subtle changes in the level of activity and shifting of body position may be the only clues that the animal is experiencing significant discomfort. Vocalization is unusual but possible, while bruxism or hypersalivation are seen more often. A decreased appetite or lack of grooming may also be seen.

Options for analgesia include:

1. Nonsteroidal anti-inflammatory agents
    a. Ketoprofen (1.5 mg/kg SID IM)
    b. Carprofen (1.5 mg/kg BID IM)
2. Opiates
    a. Buprenorphine (0.02 - 0.03 mg/kg SQ or IM)

b. Butorphanol (0.2 - 0.5 mg/kg SQ or IM)

3. Local anesthetic drugs (lidocaine; bupivacaine for more prolonged analgesia, up to 6 hours) have been used for nerve blocks. Because of their small size, the total maximal dose should be calculated and not exceeded (e.g., 1 - 2 mg/kg of lidocaine). Whatever the dose is, it may have to be diluted to a more convenient volume for administration to these small animals.

Possible Sources of Equipment

Braintree Scientific Inc. MA 02185-0929, USA
www.braintreesci.com/Products/default.asp

Hallowell Engineering and Manufacturing Corporation, MA 01201, USA
www.hallowell.com

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