THE CRITICAL MAMMAL DISASTER: PART 1

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ANESTHESIA AND ANALGESIA OF THE CRITICAL EXOTIC MAMMAL PATIENT

Introduction in all Species

Pain is present with many diseases as well as in association with surgical and traumatic conditions. The demonstration of pain is not always obvious; therefore, an animal should be assumed to be experiencing pain in any condition expected to produce pain in humans. The assessment and control of pain is an art as well as a science. Humans and animals express three types of opioid receptors, mu, kappa, and delta. The authors have used this information for clinical use of opioids in small mammals. Clinicians should keep in mind that the art of pain management is a continual learning experience requiring assessment and therapeutic adjustment for individual animals, even when they are undergoing similar surgical procedures. Therefore, standard or rule-of-thumb analgesic and anesthetic protocols are not always appropriate.

If animals can experience pain, then how do we assess pain in ferrets, rabbits, and other exotic companion mammals? It is likely that the tolerance of pain by these animals varies greatly from individual to individual. Furthermore, these animals innate ability to mask significant disease and pain, make it difficult for us to assess their degree of pain. Compared with dogs and cats, pain in ferrets, rabbits and other companion mammals is far more difficult to assess. As in cats, the mainstay of pain assessment in these animals appears to be behavioral observation.

Behaviors that are commonly seen in exotic companion mammals suffering acute trauma or postoperative pain include depression, and sitting immobile, silent, and distanced from their environment. They may stand with their eyes half-closed and do not groom. Rabbits and ferrets may exhibit bruxism. They often do not respond normally to petting or attention. Many of these species will hide when experiencing pain.

Multimodal Analgesia in All Species of Birds and Small Mammals

The process of nociception and pain involves multiple steps and pathways, so a single analgesic agent is unlikely to alleviate pain completely. An effective pain management plan should include drugs of different classes with each acting at a different step of the pathway; this is termed multimodal analgesia. For example, a ferret can be premedicated with an opioid, which will modulate pain; ketamine can be used as a part of the induction protocol to reduce wind-up; a local anesthetic block could be incorporated to inhibit pain transmission; and a nonsteroidal anti-inflammatory drug (NSAID) can be added pre- or postoperatively to alter pain transduction. This approach also allows smaller doses of each drug to be used as the effects are either additive or synergistic and reduce any undesirable side effects from larger doses of individual drugs.

Pain Management Options in the Rabbit and Ferret

There is no doubt that ferret and rabbit pain management in clinical practice is presently inadequate. Traditional thought is that these animals have adverse respiratory depression after opiate treatment, but in the authors' opinion, these species become very comfortable and sleep normally after administration of opioids postoperatively. Rabbits are more sensitive to the side effects of most opioids. Ferrets are deficient in the glucuronidation pathway as are cats, and inappropriate dosing of NSAIDs can lead to toxicity. Fear of these adverse effects has resulted in inadequate analgesia after surgery or trauma..

Local Anesthetics

Local anesthetics agents can be employed successfully in ferrets. The two most commonly used agents are lidocaine (Lidocaine HCl oral Topical Soln, USP 2%, Hi-Tech Pharmacal Co.) and bupivacaine (Bupivacaine HCl, 0.5%, Abbott Laboratories). Suitable dosages and anticipated duration of action are shown in Table 1.

Use of local anesthetics for incisional line blocks, wound infiltration, nerve ring blocks, topically or epidural anesthesia is recommended by the authors. For incisional line blocks before surgery the authors use a 25-gauge, ¼-inch needle to infiltrate the subcutaneous tissue and skin. The local anesthetics are used as part of the multimodal approach to analgesia. The calculated dose of the drugs should not exceed the doses listed in Table 1. Local analgesic protocols (eg, ring blocks, incisional blocks) are commonly combined with other drugs (ie, opioids, constant rate infusions (CRIs)) for multimodal analgesia.

An advantage of local anesthetics is low cost and non-controlled drug status. A complete sensory block prevents nerve transmission, making use of these agents attractive for practical pre-emptive techniques. Local anesthetics can be infiltrated into the surgical skin site, or discrete nerve blocks can be preformed. The addition of an opioid to the mixture of local anesthetics for local blocks mixture potentially lengthen the median duration of analgesia (addition of morphine to the lidocaine/bupivacaine mixture prolonged analgesia 10 hours longer with the morphine, and 9 hours longer with the buprenorphine). With the conclusion that adding an opioid to the local anesthetic mixture lengthens the duration of analgesia. In the authors' experience the analgesia is prolonged significantly when an opioid is added to the local block. In another study buprenorphine-local anesthetic axillary perivascular brachial plexus block provided postoperative analgesia lasting three times longer than local anesthetic block

along and twice as long as buprenorphine given by intramuscular (IM) injection plus local anesthetic-only block. This supports the concept of peripherally mediated opioid analgesia by buprenorphine. This study was performed in humans with the dose of buprenorphine was 0.3 mg mixed with the lidocaine/bupivicaine as given above.

Dental Blocks

There are five important dental blocks for small mammals. All five blocks incorporate lidocaine and bupivacaine mixture as given above for the ring block. The total dose of the mixture is drawn up into a syringe and 1/5th of the total dose is given into each of five sites. Use a 25- to 27-gauge needle with a 1-cc syringe.

The following techniques can be used to provide regional anesthesia for rabbits and other small mammals (Dr Dale Kressin, personal communication,). Kressin recommends the following protocol for dental blocks.

Infraorbital Nerve Block. The infraorbital nerve arises from the maxillary branch of the trigeminal nerve. This nerve provides sensory fibers to the upper incisor teeth, the upper lip and to the adjacent soft tissues. The zygomatic nerve also arises from the maxillary nerve just proximal to the infraorbital nerve. This nerve also supplies sensory fibers to the lateral aspect of the face.

The infraorbital foramen is located approximately 5 to 12 mm dorsal to the crestal bone adjacent to the upper first premolar (cheek) tooth, at the lateral aspect of the skull. The foramen is not as easily palpated as in the dog. The facial tuber is a palpable bony prominence at the mesial (rostral) aspect of the zygomatic bone and is approximately 4 to 10 mm ventral to the infraorbital canal. The infraorbital nerve can be blocked by infusion of the local anesthetic at this foramen.

Mental Nerve Block. The mental nerve arises from the mandibular nerve, as it extends into the mental foramina to form the mental nerve. The mental nerve supplies sensory fibers to the ventral and lateral aspect of the mandible, the lip, the lower incisor and motor fibers to local muscles.

The mental nerve exits the mental foramen located at the dorsal lateral aspect of the body of the mandible. The foramen is rostral (2–4 mm) to the first mandibular premolar (cheek tooth) and located ventrally in the dorsal third of the body of the mandible. The mental nerve can be blocked by infusion of local anesthetic at this foramen.

Mandibular Nerve Block. The mandibular nerve arises from the trigeminal nerve and supplies sensory and motor fibers to the ventral mandible as well as the muscles of mastication. The mandibular nerve provides sensory fibers to the mandibular molar and premolar (cheek) teeth as well as adjacent tissues.

The mandibular nerve enters the mandibular foramen on the medial surface of the mandible. An intraoral approach to block this nerve is not practical in the rabbit as in other species, due to the limited access of the oral cavity. An extraoral approach should be made with great care to avoid neurovascular structures (facial vessels and nerves) at the ventral aspect of the mandible. The mandibular foramen is approximately midway between the distal aspect of the last molar (cheek) tooth and the ventral aspect of the mandible. In addition, the foramen is approximately 2 to 5 mm distal to the third molar tooth. After this location is determined, an appropriate length infusion needle can be “walked along” the medial aspect of the mandible to the mandibular foramen for infusion of the local anesthetic. This will effectively block the mandibular premolar and molar (cheek) teeth.

Maxillary Nerve Block. The maxillary nerve supplies sensory fibers to the upper premolar and molar (cheek) teeth and adjacent tissues. Intraoral approaches to the maxillary nerve have not been attempted by this author due to the limited access to the oral cavity. In large breed rabbits the maxillary nerve can be blocked using a “caudal infraorbital” strategy. A 27-gauge needle is advanced 1 to 2 cm into the infraorbital canal. The syringe is aspirated to ensure the needle is not in a vessel lumen. Firm digital pressure is placed over the rostral end of the infraorbital canal while slowly infusing the local anesthetic. This block will anesthetize all ipsilateral premolar and molar (cheek) teeth and the adjacent periodontal tissues. In small rabbits and other small mammals, it may not be possible to thread the needle into the infraorbital canal. It these cases, the author will place the needle at the rostral entrance to the canal, apply firm digital pressure, and infuse the local anesthetic. Application of “splash blocks” of the local anesthetics to the periodontal ligament and adjacent soft tissues may also augment regional anesthesia.

Palatine Nerve Block. The sphenopalatine nerve ends within the sphenopalatine ganglion. Three nerves extend from the ganglion to regional tissues. The nasal cavity is innervated by the nasal rami, the rostral or anterior hard palate by the nasopalatine nerve and the posterior hard palate via the anterior palatine nerve. The oral cavity of the rabbit limits easy visualization; however, the anterior palatine nerve can be blocked as it exits the larger palatine foramen. This foramen is located half way between the palatal aspect of the third upper premolar (cheek) tooth and the palatal midline. Infusion of a local anesthetic will block this nerve and the palate of the ipsilateral side.

Intratesticular Block

The authors recommend that castration in small mammals can be performed with a IM preoperative injection of buprenorphine (0.02 mg/kg) with midazolam (0.25 mg/kg) IM. Mix 0.1 mg/100 g body weight bupivacaine (0.5%) and 0.1 mg/100 g body weight of lidocaine (2%) with buprenorphine 0.0003 mg/100 g body weight. This can be diluted in saline to have a final volume of 1 mL. Use a 25-gauge 5/8-inch needle for guinea pigs or rabbits and a 27-gauge 5/8-inch needle for a mouse or gerbil. Place the needle through the testicle starting from the caudal pole aiming for the spermatic cord. It is desirable for the needle to exit the testicle proximally as it is the spermatic cord that will be ligated. Aspirate before injection. Inject, expressing firm backpressure, while withdrawing the needle, Expect to use about one third of the drug volume per testicle

leaving the organ firmly turgid. Repeat for the other testicle and the remaining drug can be used to place a dermal incisional block. This will provide analgesia for 22 hours (Dr. Stein, personal communication, 2006).

Alpha-2 Agonists

Alpha-2 agonists such as medetomidine (Domitor, Pifizer Animal Health) possess analgesic, sedation, and muscle-relaxant properties. The higher dose (30 µg/kg) drugs are usually reserved for healthy animals because of the cardiopulmonary depression that accompanies their use. One study in healthy rabbits found that the combination of medetomidine and ketamine showed the best sedation, while medetomidine-fentanyl-midazolam had the least cardiovascular effects, and xylazine-ketamine had the greatest cardiovascular side effects.

Micro-dose medetomidine (1–3 µg/kg) minimally affects the blood pressure in animals with normal cardiac output, and provides good analgesic, sedation and muscle relaxation when used with a tranquilizer and opioid. Medetomidine requires only a slight alpha-2-adrenoceptor availability to decrease noradrenaline turnover and very low doses of medetomidine result in sympatholysis. Therefore, patients who require a high level of sympathetic tone to maintain blood pressure may not tolerate medetomidine (ie, animals in shock and in compensated hear failure). In conscious dogs intravenous medetomidine at 1.25 µg/kg increased blood pressure by 15% and decreased heart rate by 26% and cardiac output by 35%.

In postoperative patients sympathetic tone was not entirely abolished by medetomidine. Only the unwanted increases in heart rate and blood pressure were attenuated. Medetomidine has no effect on cortisol levels. Alpha-2 agonists are commonly used in human medicine to decrease the stress response. Their use in small mammals for the inhibition of the stress response may be warranted. The authors recommend micro-dose medetomidate for use in small mammals, with the caution not to use this drug in any animal with a compromised cardiovascular system.

NMDA Agonists

Ketamine is commonly used for induction of anesthesia in small mammals. Reports in human and veterinary medicine indicate variable patient response following ketamine administration which is related to the status of the cardiovascular system at the time of ketamine administration. Ketamine used for induction is well tolerated in the stable patient. Patients that exhibit significant preexisting stress or a patient with hypertrophic cardiomyopathy have an increased risk of cardiovascular destabilization following ketamine administration. Ketamine increases sympathetic tone causing an increase in heart rate, myocardial contractility, and total peripheral vascular resistance. The authors feel that high-dose ketamine used for induction of anesthesia in a stressed small mammal (especially the rabbit) may cause an increased risk of destabilization. The authors avoid using ketamine as an induction agent for the stressed critically ill rabbit. The NMDA receptor plays an important role in the central sensitization, and there is much interest in developing drugs that can inhibit this receptor. In veterinary medicine a commonly used NMDA antagonist is ketamine (Vetaket®, Lloyd Laboratories), which may be effective at preventing, or at least lessening, wind-up at sub-anesthetic doses. When used with inhalant anesthesia and opioids there is a reported opioid-sparing and inhalant anesthetic-sparing effect seen. The interesting perspective about ketamine is that the minute amounts used via a CRI route induce analgesic effect. Micro-dose ketamine does not cause an increase in sympathetic tone and are frequently used for analgesia with a CRI (given below).

Constant Rate Infusions

CRIs have several advantages over bolus delivery when treating with an analgesic. When using a CRI the drugs can be titrated to effect, resulting in a reduction of the total amount of drug used, fewer side effects, less "rollercoaster" analgesia, fewer hemodynamic effects and improved cost-effectiveness. One disadvantage to CRI is a slow rise in drug plasma concentration to therapeutic levels, which is why a loading dose of the drug is frequently given prior to starting constant rate infusion. Another disadvantage of CRI is the need of a pump, which is the easiest way to administer a CRI. Syringe pumps, most of which use a 1-cc to 60-cc syringe for drug delivery through an IV extension set, allow constant-rate delivery of very small volumes of drug. When these CRIs are combined, there is an overall inhalant anesthetic sparing effect. A common side effect of inhalant anesthesia is hypotension, which is avoided when inhalant anesthesia is combined with ketamine/opioid CRIs. The dose of fentanyl used by the authors is much lower than previously reported for use in small mammals. The authors do see a much greater depressive effect in small mammals when using the high dose ranges of fentanyl. We have not seen fentanyl-induced ileus or other gastrointestinal side effects in small mammals when using the lower end of the dose given in Table 1, when combined with ketamine. The multimodal approach of using two or more drugs combined allows for lower doses with fewer side effects of both drugs than when either drug used alone. We commonly use the lower CRI doses for butorphanol-ketamine CRIs or fentanyl-ketamine CRIs in rabbits with gastric stasis pain (Table 1). Ketamine is an excellent adjunct to opioid therapy and frequently allows reduction in the opioid dose being administered.

Inhalants

Based on available research in dogs, cats and ferrets, there are advantages of both sevoflurane and isoflurane depending in the circumstances. Isoflurane has the advantage if cost is a issue. Sevoflurane may have an advantage if mask induction is necessary or if the anesthetist needs to adjust the depth of anesthesia. Mask induction and changing of the depth of anesthesia are very important in exotics. Sevoflurane has a much less pungent odor. No differences in the speed of

recovery were noted in ferrets in a controlled study. In most animals and birds the MAC for isoflurane is between 1.28 and 1.63, and for sevoflurane the MAC is between 2.10 and 2.60. Isoflurane and sevoflurane both have dose-dependent vasodilation properties leading to hypotension. Neither drug has any analgesic properties following termination of the anesthesia.

Epidural Anesthesia/Analgesia

Epidural drugs achieve pain relief with less or no systemic effects as compared with drugs administered intramuscularly or intravenously. This factor is important in small mammals when the administered drug has negative side effects, such as cardiac and respiratory depression. Epidural drugs may decrease recovery time, which is always an advantage when working with ferrets, rabbits, and other small mammals. The short recovery time occurs because of the inhalant sparing effect induced with an epidural anesthetic.

The local anesthetics lidocaine and bupivacaine are the most commonly used for epidural analgesia. Using local anesthetics can result in sensory, motor and autonomic blocks. This may be prevented by administering the diluted dose and lower dose recommended by the author and given in Table 1. When placing epidural needle as described below, the clinician should lower the local anesthetic dose by ½ when cerebrospinal fluid (CSF) fluid is seen in the hub (CSF fluid may only fill the hub with use of a stylet – see placement below).

In most small mammals, after epidural injection of lidocaine, analgesia develops within 10 to 15 minutes and lasts 60 to 90 minutes Bupivicaine can provide between 4 and 8 hours of surgical analgesia. It may exert analgesic effects with minimal motor blockage when used in dilute concentration. This dilution may be obtained by mixing 1 part of 0.25% bupivicaine (0.125% bupivicaine at 0.1 mg/kg) with 1 to 3 parts of an opioid by volume and administered at the desired opioid dose. The principal advantages of local anesthetics are the potential for complete regional anesthesia, and marked potentiation of the analgesic effect of the epidural opioids. Morphine (Morphine Sulfate inj preservative free, USP, Baxter Healthcare) at 0.1 mg/kg that is administered into the epidural space provides prolonged postoperative analgesia for up to 24 hours. Morphine is the least soluble opioid and this characteristic delays the epidural and systemic absorption of the drug. The peak analgesic effects may be delayed for 90 minutes following injection, and some analgesia may be present for 6 to 24 hours. It is important to administer it immediately after induction of anesthesia because of the relatively long latency to peak analgesia. Bupivacaine or lidocaine can be administered with morphine epidurally so that analgesia onset is shortened to 15 to 30 minutes and duration for 8 to 24 hours. In humans, postoperative neural blockage has also been associated with attenuation of the stress response, improved respiratory function, and improved hemodynamic stability.[8]We notice marked improvement in postoperative recovery in small mammals after receiving epidural analgesia prior to abdominal surgery or surgery on the rear limbs. When included as part of a patient management strategy, these epidural analgesic techniques as part of the multimodal approach may reduce morbidity and mortality.

The lumbosacral space is the preferred site of injection because of the relatively large space between L7 and S1. In most ferrets the dural sac terminates just cranial to that location (L7-S1). The absence of a complete dural sac at the LS junction reduces the likelihood of subdural injections. The dural sac of many rabbits extends to the sacrum, and attempts at epidural injection of the LS space in this species may result in subdural injections. Most subdural injections will also be subarachnoid, and injected medications will enter the CSF. Possible complications of subarachnoid injection include leakage of CSF, mitigation of the drug to the brainstem, and complete spinal blockage when using local anesthetics. We recommend the use of a 25-gauge hypodermic needle for epidural injections in small mammals and finds the length of the needle rarely enters past the epidural space. A stylet can be cut from orthopedic wire, sire sutures and then sterilized. It is important to have a stylet because it prevents a skin plug from clogging the needle which can prevent visualization of the CSF fluid. If a skin plug were injected into the epidural space, it could serve as a nidus for infection and inflammation. The disadvantage of using a hypodermic needle versus a spinal needle is that the bevel is longer with cutting edges on the hypodermic needle and this will not allow you to sense the pop when the needle passes through the ligamentum flavum. Care should be taken to avoid cutting and traumatizing the spinal cord during the insertion. The authors recommend aspiration with a syringe after placement of the needle. If CSF is seen in the hub of the needle, half of the dose that was intended for epidural administration should be administered instead.

The procedure for epidural anesthesia is similar to that described for dogs and cats. A 25-gauge needle is advanced trancutaneously at a 90 degree angle to the skin in the center of the LS junction. If bone is encountered, the needle is walked cranially or caudally to find the LS space. In small mammals, using a sharp 25-gauge needle, the resistance or “pop” through the ligamentum flavum is minimal. Confirm epidural placement with the use of a syringe and negative suction. There will be no CSF in the hub of the needle.

CESAREAN SECTION ANALGESIA AND ANESTHESIA PROTOCOLS IN SMALL MAMMALS

Stable Patient

Preoperative Drugs. The patient is sedated with midazolam IM, an IV catheter is placed and the animal is started on crystalloids. In some of the smaller mammals (eg, guinea pig, hedgehog), intravenous catheterization is difficult. Inhalant mask anesthesia will decrease the stress of this procedure. The ferret and guinea pig will need a small cut down (use 22-gauge needle bevel to make a hole at catheter entrance) to avoid burring the catheter on entering the skin. Bloodwork, radiographs

Table 1. Analgesic Drugs Used in Small Mammals

The following drug doses are those that are used by the authors in small mammals. Very few pharmacological studies have been done with regard to the listed drugs in the ferret and rabbit.

Drug	Pre-op Dose for Rabbit/Ferret	Induction Dose for Ferret/Rabbit	CRI Dose/Post-op for Rabbit/Ferret
Tranquillizers			
Diazepam	0.5 mg/kg IV		
Midazolam	0.25–0.5 mg/kg IM/IV		
Opioids			
Butorphanol	0.2–0.8 mg/kg SQ, IM or IV		0.1–0.2 mg/kg loading dose, then 0.1–0.2 mg/kg/hr
Fentanyl	5–10 µg/kg IV		Intraop: 5–20 µg/kg/hr w/ ketamine CRI Postop: 2.5–5 µg/kg/hr w/ ketamine CRI
Hydromorphone	0.05–0.1 mg/kg IV		0.05 mg/kg IV loading dose, then 0.05–0.1 mg/kg/hr
Tramadol			Post-op-10 mg/kg PO q 24 hr
NMDA Antagonists			
Ketamine		4–10 mg/kg IV	Intraop: 0.1 mg/kg IV loading dose, then 0.3–0.4 mg/kg/hr w/ fentanyl CRI Postop: 0.3–0.4 mg/kg/hr w/fentanyl CRI
Propofol		4–6 mg/kg IV	
Etomidate		1–2 mg/kg IV w/ benzodiazepine	
Alpha-2 agonists			
Medetomidine	1–2 µg/kg IM, IV		1–2 µg/kg q 4-6 hr IV
NSAIDs			
Carprofen			4 mg/kg PO q 24 hr
Ketoprofen			Postop 1–2 mg/kg q 24 hr
Meloxicam			0.2 mg/kg (first dose) SQ, IV, PO and then 0.1 mg/kg q 24 hr (rabbit 0.3 mg/kg q 24 hr)
Local Anesthetics			
Lidocaine			Local infiltration Introp: 1 mg/kg at incision site or ring block
Bupivicaine			Local infiltration Intraop/postop: 1 mg/kg at incision site or ring block
Epidurals			
Morphine preservative -free		0.1 mg/kg epidural w/ or w/o bupivacaine preop	
Bupivicaine 0.125%		0.1 mg/kg epidural w/ or w/o morphine	

and other diagnostics can be done at the same time. When an IV catheter can not be placed, the use of an IO catheter should be attempted.

Induction. Propofol or etomidate IV or intra-osseously (IO) and an epidural injection of morphine and bupivicaine is given.

Maintenance. The animal is intubated or masked and maintain on oxygen. A lidocaine/bupivacaine incisional block is performed. After the fetuses are removed the patient is started on isoflurane or sevoflurane inhalant. The patient is given buprenorphine or hydromorphone IV.

Postoperatively. One dose of NSAIDs can be given postoperatively and the animal may be sent home on tramadol (Table 1).

Critically Ill Surgical Patient

Prior to surgery any preoperative perfusion deficits are corrected. The small mammal is rehydrated over 6 to 8 hours. The animal is treated with sedative-analgesics (ie, opioid and midazolam) as required for pain during resuscitation. In some of the exotic patients, such as the guinea pig, intravenous catheters are difficult to place while they are conscious. They have short legs and pull away when the catheter is inserted into the skin. The mammal can be anesthetized with an inhalant using a mask. This will decrease the stress on the mammal. Blood pressure can be taken at that time. The mammal is taken off of anesthesia after catheter placement and stabilized on fluid therapy. Many critical mammals are hypothermic and will need heat support. When blood pressure is stabilized the mammal is taken to surgery.

Preoperative Drugs. One half hour prior to surgery the dose of the small mammal is given a preoperative loading dose of fentanyl IV along with ketamine microdose (1 to 2 mg/kg IV). A CRI of fentanyl and ketamine is prepared.

Induction. The animal is induced with etomidate (1–2 mg/kg) IV and midazolam (0.25 mg/kg) IV and intubated if possible, otherwise maintained on mask with inhalant. An epidural injection of morphine +/- bupivacaine can be used in the painful animal (Table 1).

Maintenance Anesthesia. The CRI of fentanyl and ketamine is started at the lower CRI dose (Table 1). The fentanyl/ketamine CRI requires that a loading dose of the drugs be given prior to starting the CRI (Table 1). The dose can be mixed with saline in a syringe. The CRI can be piggy-backed with a Y connector to the crystalloids and/or colloids being administered during surgery.

The animal is maintained on sevoflurane at the lowest possible concentration. Using the CRI of fentanyl/ketamine lowers the inhalant concentration. The maintenance isoflurane or sevoflurane is at 1 and 2 %, respectively. A lidocaine and bupivacaine incisional block is used (Table 1). Isotonic crystalloids (LRS, Plasma-Lyte® R, Normosol®R) are used as a constant rate infusion at 10 mL/kg/hr with colloids at 0.8 mL/kg/hr during surgery.

Hypotension during Surgery. If hypotension occurs during the surgery, the inhalant anesthesia is reduced first, while the CRI is increased. The animal should also be treated for hypovolemia if there is blood loss or fluid deficits are suspected until the blood pressure is normal. Checking blood glucose, PCV/TP and blood gas analysis intraoperatively is recommended. Monitoring devices such as the pulse oximeter, end tidal CO_2, temperature, ECG rhythm and rate are checked for abnormalities.

Postoperatively. Continue the CRI of fentanyl for 12 to 36 hours postoperatively or until the patient is stable. NSAIDs can be given if perfusion, hydration, gastrointestinal and renal function are normal.

CASE EXAMPLE: URINARY OBSTRUCTION IN A FERRET

This case is aimed at treatment of a critically ill ferret with UO (urinary obstruction) by correcting perfusion, dehydration, azotemia, electrolyte, acid–base abnormalities and placement of a urinary catheter. The use of percutaneous cystostomy tubes for patients in which urethral catheterization fails will also be discussed. Electrocardiogram and blood pressure monitoring are used for treatment of the ferret presenting with UO. Definitive treatment for adrenal gland disease and prostatomegaly are listed.

Diagnostic and treatment protocol for urinary obstruction in the ferret: (Note dosages used are listed in Table 1.)

1. Place an IV (intravenous) catheter using the cephalic or saphenous vessel.
2. Anesthesia for placement of a urinary catheter is always required in the ferret. The ferret is first given analgesia using butorphanol intravenous [IV]) or fentanyl IV. In the unstable cardiovascular patient, the author prefers etomidate IV with either diazepam IV or midazolam IV because of the minimal cardiovascular effects of these drugs. Other choices include a combination of: ketamine (5 mg/kg IV) with diazepam or midazolam IV or propofol (4–6 mg/kg IV) with diazepam or midazolam IV. Most ferrets should be intubated and maintained on isoflurane or sevoflurane for extended anesthesia time.
3. Heat support using a forced air warmer, heating pad or warm water bottles is required during the procedure. Due to small size, ferrets commonly become hypothermic under general anesthesia.
4. Monitoring

Electrocardiogram (ECG)

If hyperkalemia is present without an arrhythmia and perfusion is normal (ie, normal BP and heart rate), forced diuresis and relief of the obstruction is generally effective at correcting the potassium excess. Treat for hyperkalemia (as given below) if an arrhythmia is present. In the author's experience hyperkalemia is the most life threatening consequence of UO.

Hyperkalemia may result in ECG changes. These changes include loss of the P wave, widening of the QRS complex, peaked T wave, and a short QT interval; as the QRS and T waves merge, a sine wave is

recognized. In the authors experience the severity of the ECG of hyperkalemia does not correlate with the magnitude of change in the plasma potassium level, and therefore treatment of hyperkalemia should be guided by monitoring the ECG with return of normal rhythm.

Treatment for Hyperkalemia

Calcium gluconate is given at a dose of 50 to 100 mg/kg slowly IV with continuous ECG monitoring. This antagonizes the membrane effects of hyperkalemia by decreasing the threshold potential and re-establishing the potential difference between resting membrane potential and threshold potential. This protects the myocardial muscle but does not decrease the serum potassium concentration. The effects will last about 20 to 30 minutes.

Regular insulin administered at a dose of 0.2 to 0.2 U/kg IV stimulates cell membrane sodium-potassium-adenosine triphosphatase and causes potassium to move intracellularly. Insulin administration should be followed by a glucose bolus of 1 to 2 g/U of regular insulin given to prevent hypoglycemia. This treatment should begin to lower potassium concentration and return of normal rhythm in 2 to 5 minutes. The ferret should be continued on a 2.5% dextrose solution in the IV fluids. Monitor blood glucose during the treatment to prevent hypoglycemia, which is of particular concern in the insulinomic ferret.

Doppler Blood Pressure

Correction of hypotension using crystalloids (15 mL/kg) and colloids (Hetastarch at 5 mL/kg) boluses are used once the obstruction is relieved and given below under fluid therapy.

Unblock the Urethra

- Relieve the obstruction by catheterization (eg, Slippery Sam, 3 French or red rubber, 3.5 French) and retropulsion with hydraulic forces using a sterile physiological solution. An indwelling catheter should be placed and sutured to the prepuce as discussed elsewhere. The catheter is connected to a closed collection system. If a catheter cannot be placed use of a percutaneous cystostomy tube is recommended. Cystocentesis is not recommended because it can lead to rupture of the urinary bladder and uroabdomen.
- Percutaneous cystostomy tube placement (prepubic catheterization)
  - Temporary cystostomy is performed to provide cutaneous urinary diversion in ferrets with urinary obstruction until definite treatment allows decrease in size of the prostate.
    - Make a small midline incision adjacent to the prepuce in male ferrets
    - Locate the bladder and place stay sutures and a purse-string into it
    - Place the tip of the Foley catheter (silicone, 5 French catheter) into the abdominal cavity through a separate incision in the abdominal wall. A second incision for the catheter uses the tunneling effect principle; a better seal of catheter into the abdominal wall.
    - Make a small stab incision within the purse-string suture (while suctioning the urine out of the bladder) and place the Foley catheter into the bladder lumen
    - Inflate the balloon with saline and secure the catheter by tieing the purse-string suture around catheter
    - Tack the bladder to the body wall with several absorbable sutures
    - Close the initial incision and tack the catheter to the skin by placing sutures through a piece of tape attached to the catheter
    - The catheter is removed after treatment is performed for prostatomegaly and the ferret is urinating on his own (usually requires 1 to 3 days). Catheter removal is performed by simply removing sutures in the skin, and deflating the foley catheter. The wound will heal by second intention.

Fluid Therapy

- Perfusion abnormalities (ie,, hypotension) are corrected first with crystalloids and colloids.
- Rehydration requirements are calculated by % dehydration and multiply by body weight in kilogrammes (5 kg cat that is 8% dehydrated will require 5 x 8/100 liters = 0.4 liters to correct the deficit). This should be administered over 6 hours. Output is measured every 1 to 2 hours once the animal is rehydrated. Output must be at least 1 to 2 mL/kg/hr, otherwise fluid input is adjusted with outflow during the diuresis phase. The fluids are adjusted by determining the urine produced and add the insensible loss (1 mL/kg/hour). Medical management for adrenal gland disease is initiated at this time. Fluids can be gradually discontinued when hydration and urine production are restored (fluids in and urine out are matched), correction of urinary obstruction takes place (ie, ferret is urinating normally), blood urea nitrogen, creatinine, acid–base and electrolytes are normal and patient is eating and drinking.
- If the clinician chooses surgical management for adrenal gland disease (given below), then surgery is performed only after hydration and urine production is restored (fluids in and urine out are matched), blood urea nitrogen, creatinine, acid–base, and electrolytes are normal. In the authors experience this requires about 24 to 36 hours for stabilizing the ferret prior to surgery.

Diagnostics

- Chemistry panel
  - Azotemia (ie, increased blood urea nitrogen, creatinine) is present in most cases of UO in the ferret and will be corrected with fluid therapy after relieving the obstruction.

- Acid-base and electrolytes
  - The most common abnormalities are metabolic acidosis and hyperkalemia. The hyperkalemia should be corrected immediately when electrocardiogram changes are present (as given above). The author uses fluid therapy to correct the metabolic acidosis.
- Urinalysis with culture and sensitivity since urinary tract infection often accompanies UO.
- Ultrasound to evaluate kidneys, bladder and prostate

Pain Relief and Sedation in the ICU

The author commonly uses the following drugs for sedation, pain relief and restraint (most ferrets will try to remove the percutaneous cystostomy tube without proper sedation and analgesia) after placement of the catheter.

- Narcotics
  - Butorphanol continuous rate infusion (CRI) at 0.025–0.1 mg/kg/hr
  - Fentanyl CRI at 2.5–5 µg/kg/hr
- Ketamine CRI (mix together with one of the narcotics) at 0.4–0.8 mg/kg/hr
- Tranquilizer such as diazepam/midazolam (0.25–0.5 mg/kg) as needed

TREATMENT FOR ADRENAL GLAND DISEASE

Treatment options for adrenocortical tumors are surgical removial/debulking, or medical management. Surgery offers the only potential cure for adrenal disease; however, local invasion of neoplasia of the right adrenal gland into the vena cava and the presence of ectopic adrenal tissue makes complete cure unlikely. Surgery is delayed until correction of electrolyte, acid/base, fluid and perfusion abnormalities. Medical treatment has not been proven to slow growth of the tumor, but can be effective in relieving clinical signs.

- **Adrenalectomy.** Techniques for adrenalectomy in the ferret have been described. In cases of secondary prostatic enlargement, it is important to collect biopsies and culture and sensitivities of prostate tissue.
- **Medical Management.** A number of drugs have been proposed for control of the symptoms related to adrenal disease, including leuprolide acetate (Lupron, TAP Pharmaceuticals) and melatonin. Other drugs are currently under investigation, including desorelin implants. Research currently supports Lupron as the most effective currently available drug for medical management of adrenal disease. A recent study indicated that while melatonin was effective in reversal of alopecia, effects were temporary in most cases (nine months).

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