INTRODUCTION
Anesthesia and analgesia is frequently required for swine in research due to the nature of the invasive procedures that are performed. Their use as preclinical models (translational research) frequently involves surgical implantation of devices, major invasive surgery and creation of disease conditions, such as heart failure. Selection of an appropriate protocol which considers the physiologic effects of the pharmacologic agents for anesthesia/analgesia is an important aspect of designing an experiment. This article seeks to provide a practical guide to anesthetizing swine in the laboratory. More detail is provided in recent reference books.1-7 This manuscript is complementary to other fact sheets on this website.8,9 Dosages of all agents in the text are in the tables at the end of the manuscript. For IV infusion protocols for all agents the infusion dosage in the tables is given to effect and cardiovascular parameters must be monitored.

PRINCIPLES OF ANESTHETIC SELECTION & PAIN MANAGEMENT
At the onset of the project, the anesthetic and perioperative care protocol should be determined by consideration of the physiologic effects of the pharmacologic agents, the goals of the experiment and the effectiveness of the protocol to minimize pain and distress.1,10,11

The physiologic effects are especially important if physiologic measurements are being made while the animal is anesthetized. Adverse effects related to the surgical manipulations also have to be considered. For example, if thoracic or cardiac surgery is being performed, proarrhythmic anesthetic agents should be avoided and cardioprotective agents should be utilized.

Some general principles should be considered for anesthetic administration. Isoflurane should be considered to be the default general anesthetic agent for survival surgery in swine, unless its use is contraindicated by the protocol. If injectable anesthesia is being used, it should be continuously infused rather than administered by repeated bolus injections. If paralytic agents are being used, then peripheral surgical procedures should be performed prior to their administration in order to establish baseline hemodynamics and to ensure that animals are fully anesthetized. For example, paralytic agents may be needed in thoracic surgery to prevent movement of the diaphragm and give greater exposure. The initial incisions can be made through the skin and superficial muscles prior to making the actual thoracotomy before the paralytic agents are administered.

Pain can be categorized several ways,1-7 however, the example below is a simplistic method of consideration of the causes of pain that may be useful in designing a protocol for acute pain management:

- **Step 1:** Peripheral nerves (nociception) transmit the pain impulse to dorsal lamina neurons. NSAIDs given preemptively decrease the sensitivity and local anesthetics can be used to block the signal.

- **Step 2:** Dorsal lamina neurons transmit the signal to first order neurons in the CNS. NSAIDs, opioids, and α2-agonists would be effective at this level of pain control.

- **Step 3:** Second order neurons may be stimulated. This may result in postinjury facilitation by non-nociceptive neurons (windup phenomenon). NMDA receptor antagonists may be necessary to inhibit transmission if this occurs.

- **Step 4:** Conscious perception of pain or anxiety may develop in individual animals. Drugs that alter consciousness and anxiety, such as tranquilizers, may be required in the postoperative period by some individual animals which react to stress in a more aggravated manner than others.

Chronic pain and distress is more difficult to control and requires professional judgment by the attending veterinarian in consultation with the investigator to design such a program. The behavioral and environmental aspects, such as husbandry techniques, play an important role in this situation. Non-pharmacologic means of pain control need to always be considered.

A more detailed discussion of clinical observations associated with pain and distress in swine can be found on this website in: Pain Assessment in Swine.

ENDOTRACHEAL INTUBATION (Figures 1-3)
As swine are very prone to laryngospasm, and fluid tends to accumulate in the pharyngeal region under anesthesia, endotracheal intubation should be performed on every anesthetized pig.

Pigs can be intubated in dorsal, lateral or ventral recumbency, though ventral recumbency is easier for pigs over 50 kg.
Most pigs used in surgical research weigh 10-25 kg, and for these a 6.0-7.0 mm diameter endotracheal tube is indicated.\(^1\) Atropine (.02-.05 mg/kg) should be administered IM 10-15 minutes before intubation to dry bronchial secretions and prevent bradycardia due to vagal stimulation. The larynx should be sprayed with a topical anesthetic while being visualized by a laryngoscope. A blade length of 195 mm is usually adequate for pigs up to 40 kg. The key to successful intubation is to correctly position the blade of the laryngoscope. With the pig in dorsal recumbency, the tip of the blade is directed 45° towards the ventral surface of the neck (Figures 1.1,1.2, 2, 3). This position serves two purposes: it straightens the laryngeal-tracheal pathway and it presses the maxilla dorsally which facilitates visualization of the laryngeal cavity.

The vocal cords in the larynx are readily visible and should be identified prior to the attempted intubation (Figures 1.3, 1.4, 2). The tube may be readily placed in the proximal larynx but is generally obstructed in the mid-ventral portion by the laryngeal diverticulum (Figure 1.3). Passage may be facilitated by gently rotating the tube 90° and simultaneously applying forward pressure - several times if necessary (Figure 1.3, 1.4). Using this method one person can easily perform the intubation without assistance. The more conventional method of using assistants to hold the mandible and maxilla open with gauge actually makes it more difficult to intubate due to the acute angle created in the airway by the traction. Rarely, a stylet may be needed to avoid bending the tube.

The ocular and pupillary reflexes are not reliable in pigs, particularly if atropine or ketamine are included in the drug protocol. The best guide to muscle relaxation in swine is laxity of the mandibular muscles (jaw tone) or the absence of any leg, ear or tail reflex in response to a pinch or similar stimulus.


FIGURE 2. View of the endotracheal tube being advanced into the trachea with the pig in dorsal recumbency.

FIGURE 3. Position of the pig during endotracheal intubation.

**SURGICAL MONITORING**

The ocular and pupillary reflexes are not reliable in pigs, particularly if atropine or ketamine are included in the drug protocol. The best guide to muscle relaxation in swine is laxity of the mandibular muscles (jaw tone) or the absence of any leg, ear or tail reflex in response to a pinch or similar stimulus.
The most sensitive indicators of a light plane of anesthesia are increased heart rate and blood pressure. In our experience these phenomena occur before the commonly used indicator of muscular movements. It is essential to monitor for an increase in heart rate and blood pressure if paralytic agents are used. A cutdown performed to monitor cardiovascular function or the use of peripheral vascular cuffs can be utilized to monitor blood pressure as well. Blood pressure varies widely with anesthetic agents and the breed and size of the pig and the baseline should be established at the start of the surgical procedure.1-7

The pulse may be monitored in the brachial artery on the medial aspect of the humeroradial joint; the saphenous artery over the medial aspect of the distal femur; or the sublingual artery on the ventral surface of the tongue.

Malignant hyperthermia (porcine stress syndrome) is a genetic syndrome (hal gene) that may occur in susceptible animals with the use of halothane and certain other anesthetics. Susceptible animals are mainly those of the Poland China, Landrace, or Pietrain breeds. The syndrome is characterized by a rapid increase in rectal temperature, muscular rigidity, and shock. It may be minimized by avoiding or prescreening animals of susceptible breeds or by using dantrolene (5 mg/kg) as prophylaxis if susceptible breeds must be used.1,2 There is a similar syndrome that occurs in the postoperative period, but which is not related to the genetic syndrome of malignant hyperthermia. In this case the pigs will develop the same types of symptoms as described above but it will occur in the hours following surgery rather than at the time of anesthetic induction, which is the hallmark of classical malignant hyperthermia. The syndrome is sporadic and seems to have an undefined genetic basis because it tends to occur in littermates or lines. It is associated with high blood levels of lactate. If this syndrome is encountered notify the supplier and ask for unrelated individuals. It is important to prevent stress during induction of anesthesia as a preventive methodology. Administration of a tranquilizer with minimal restraint using a butterfly catheter in the neck is recommended.

**ADMINISTRATION OF INJECTABLE AGENTS**

In our experience the injectable anesthetic and analgesic compounds that are labeled for IM injection can be administered SC. In reality, the injections given into the neck are probably being administered into subcutaneous fat. We have noted that injections given IM are more painful and stressful for the animals and that the efficacy and onset of activity between SC and IM are not significantly different. Consequently, it is recommended that these agents be administered using a butterfly catheter placed into the neck. After the butterfly is in place in the neck the pig will become calm and you can then administer the injection by attaching the syringe to the butterfly. This method can be utilized by one person without restraint of the pig (Figure 4).

When administering injectable anesthetic combinations involving tranquilizers and dissociative agents, it is less stressful to the animals if the tranquilizer portion of the injection is administered prior to dissociative agents, which tend to be painful. Allowing 5 minutes for the sedative effects of a tranquilizer will greatly calm the animal and facilitate handling.

On very large or fractious animals, injectable compounds such as tranquilizers and dissociative agents can be administered intranasally (IN) into the snout. The absorption from the nasal mucosa is similar to IV. The calming effect will be noted within minutes and then SC injections can be safely administered.

Likewise, tranquilizers and sedative agents can be administered in a small food treat. Small meat balls made with dog or cat foods are useful to conceal tablets. Powders can be mixed into chocolate syrup. Liquid agents can be injected into marshmallows or pastry. Administration of diazepam or midazolam in this manner facilitates performing procedures on larger animals and minimizes the restraint procedures required.
TRANQUILIZERS

Phenothiazine tranquilizers such as acetylpromazine (0.2-1.1 mg/kg) may be used to decrease both subject anxiety and the dosage of pentobarbital or other general anesthetics. These tranquilizers have an adrenolytic effect, however; they may reverse the effects of epinephrine, which may be important in cardiovascular experiments. The butyrophenone neuroleptic agent azaperone (2-4 mg/kg) may be used as a pre-anesthetic agent. A higher dose (5.3-8 mg/kg) may completely immobilize swine, but it will not provide analgesia. Benzodiazepine tranquilizers such as midazolam and diazepam are also effective sedatives. Midazolam has lasting effects less than 30 minutes and may be used on a daily basis for procedures requiring sedation.

INJECTABLE ANESTHETICS

Ketamine is perhaps the most widely used drug in porcine anesthesia. It is a dissociative anesthetic with a wide range of safety in swine (11-33 mg/kg). Administered IM or SC, it is generally an effective restraint agent, but does not relax muscles sufficiently or provide sufficient analgesia for most surgical procedures. It is best used in combination with other agents.

Ketamine (20 mg/kg) with xylazine (2 mg/kg) has been recommended as a general anesthetic in swine. Due to the porcine tendency to develop fatal cardiac arrhythmias, however, this combination should be accompanied by atropine to prevent the consistent heart block and hypotension associated with xylazine. Likewise, the xylazine has very transient analgesic effects. Ketamine (1 mg/kg) and medetomidine (0.1 mg/kg) is a better combination if an α2-agent is indicated. The combination gives better analgesia and fewer side effects and can be given as a continuous infusion. Ketamine (100mg/ml) 0.1-0.15 ml/kg, diazepam (5.0 mg/ml) 0.2-0.3 ml/kg, medetomidine (1.0 mg/ml) 0.1 ml/kg, + atropine (0.54 mg/ml) 2ml/pig reversed with atipamezole (5.0 mg/ml) 1-2 ml/pig has been used as a low volume injection for short term restraint of sexually mature minipigs.

The combined IM or SC injection of ketamine (22-33 mg/kg) and acetylpromazine (1.1 mg/kg) has been used extensively in our laboratories as a preanesthetic. The addition of an analgesic and/or general anesthetic is necessary to perform surgery using this combination.

Another commonly used dissociative agent combination is ketamine with zalazepam (Telazol®). This combination of a dissociative anesthetic and a diazepinone tranquilizer are used IM at 2-4 mg/kg for restraint and 4-8.8 mg/kg for general anesthesia. Telazol may be combined with xylazine 2.2 mg/kg IM to produce short term restraint, but may be associated with cardiovascular depression. In our experience, it should be avoided in patients with cardiovascular or renal compromise. The cardiodepressent effects last much longer than the anesthetic effects. It is useful for sedating pigs >50 kg because the volume of injection is much less than ketamine. For this purpose it can be given as a one time injection for restraint without making physiologic measurements.

INTRAVENTIVE ANESTHETICS

The barbiturates have been extensively used as anesthetic agents in the laboratory. Recommendations for dosage must be considered merely as guidelines since barbiturates are administered IV to effect. Dosage varies widely with the age and weight of the pig, and it is always reduced by one-half to two-thirds when barbiturates are combined with other agents. Reported dosages are: pentobarbital - 20-40 mg/kg, and thiopental - 6.6-30 mg/kg.

In our laboratories, we avoid pentobarbital in procedures of more than two hours because of prolonged recovery time. For procedures of 2-6 hours, we prefer repeated administration of small amounts of the ultra short-acting thiopental. Continuous intravenous drips of these agents provide a more stable plane of anesthesia. For pentobarbital use 5-40 mg/kg/hr and for the thiobarbiturates use 3-30 mg/kg/hr. As laboratory swine are susceptible to apnea when barbiturates are used, a respirator should be available.

IV administration of fentanyl at .03-.05 mg/kg (30-100 µg/kg/hr) in combination with paralytic agents, ketamine, and nitrous oxide has been used successfully in cardiac surgery in swine. Sufentanil is more potent than fentanyl and may be used as a continuous IV infusion of 10-30 µg/kg/hr followed by a bolus IV injection of 5-10 µg/kg in the same manner as described for fentanyl in cardiac surgery. Ketamine 1 mg/ml, xylazine 1 mg/ml and glyceryl guaiacolate 5% mixed in 5% Dextrose will provide stabile cardiovascular function when administrated as a 1 ml/kg IV bolus followed by 1 ml/kg/hr as an IV infusion. Either of these combinations or the sufentanil infusion can replace other described infusion protocols, such as alpha chloralose.
Other infusion protocols are located in the drug dosage table and are discussed in detail in Swindle, 2007. The infusion combinations with ketamine/pentobarbital and propofol/midazolam/fentanyl have been demonstrated to be useful in some long term anesthesia protocols in which an inhalant is contraindicated. Propofol by itself should not be considered analgesic in swine. It is a restraint agent which must be used in combination with analgesics or anesthetics.

**INHALANT ANESTHETICS**

Isoflurane is the best general anesthetic overall for swine and the use of halothane should be discontinued due to its potential for adverse effects on human health and because of its predisposition to induce catecholamine induced arrhythmias. Oxygen flow rates vary between agents, anesthetic machines, and animals, but a rate of 22-44 ml/kg/minute is a good starting point for small pigs.

With isoflurane, 3-4 percent is used for induction and .5-2 percent for maintenance. The effects of desflurane and sevoflurane are similar to isoflurane but the mean alveolar concentration values (MAC) are different. The MAC values for the agents, which approximate the concentration that will induce anesthesia, are: isoflurane 1.2%, desflurane 8.2%, and sevoflurane 2.5%.

Any of the above can be combined with 30-70% nitrous oxide in oxygen to reduce the anesthetic required. Nitrous oxide, when delivered in oxygen without an inhalant anesthetic, can augment analgesia of other drug combinations. Swine are more sensitive to nitrous oxide than many other species, but it is not acceptable as a sole analgesic or anesthetic agent.

In our experience, isoflurane, sevoflurane or desflurane, especially when combined with nitrous oxide, has the least effect on hemodynamics and the least number of anesthetic complications. For some models with severe cardiovascular compromise, sevoflurane may be the most appropriate agent.

**ANALGESICS**

Pre-emptive analgesia is preferred for surgical procedures in swine. It has been demonstrated that pre-emptive administration of an analgesic preoperatively or intraoperatively provides better analgesia and a shorter recovery time. Use of analgesics must be based upon a clinical assessment of need rather than a predetermined protocol. Use of analgesics postsurgically when they are not required can be harmful.

For major procedures we administer an opioid and use an infiltration of a local anesthetic along the incision line. We also utilize an epidural injection with morphine for procedures caudal to the thorax or a dorsal nerve root block for lateral thoracotomies.

Opioid analgesics do not tend to be long-acting in swine when delivered IM. Fentanyl at .02-.05 mg/kg, oxymorphone at .15 mg/kg, and meperidine at 10 mg/kg are potent but last only a few hours.

Butorphanol (0.1-3 mg/kg q4-6h) and buprenorphine (0.005-.1 mg/kg q12h) are newer opioids having a longer duration of action in swine. There is an extremely wide dosage range published for buprenorphine. The lower dosage ranges are only effective for preemptive analgesia and the higher dosage range is only used for highly painful procedures. Currently buprenorphine is our preferred parenteral opioid analgesic in swine. A dosage of 0.01 mg/kg or higher has been shown to provide 8-12 hours of clinical analgesia in most swine and is the recommended dosage for most surgical procedures. A sustained release version which provides a blood level for 5 days has been developed and the recommended dosage is 0.12-0.24 mg/kg sc.

Aspirin (10-20 mg/kg) and phenylbutazone (4-20 mg/kg) may be given PO, but they are not potent visceral analgesics suitable for major surgical procedures. However, they may be used in addition to opioids for their anti-inflammatory effects.

The newer generation NSAIDs are our preferred analgesics for surgical procedures. They may be contraindicated for some orthopedic procedures. The gastrointestinal, renal and coagulopathy complications associated with their chronic usage in humans are not a problem when they are used for short term administration perioperatively in swine. Their site of action (see above) makes them valuable for preemptive analgesia. The NSAIDs may be combined with the opioids for greater efficacy. Carprofen, flunixine and meloxicam are labeled for use in swine in Europe as a single daily injection (sid). Ketaprofen and ketorolac have also been demonstrated to be efficacious. Currently, preemptive and postoperative analgesia with carprofen 2 mg/kg SC sid is our preferred analgesic regimen. Our experience is that only 1-2 dosages have to be given postoperatively for major procedures especially if local analgesic infiltration and/or epidural
invasive procedures. Morphine epidural solution 0.1 mg/kg is administered as a pre-emptive analgesic. It is important to utilize the solution without preservatives that is prepared specifically for epidural administration. In order to administer the injection, the pig’s hindlimbs are hung off the back of the table with the pig in sternal recumbency. This flexes the lumbar vertebrae and widens the space between the dorsal processes of the spine. The injection is administered with a spinal needle on the midline at a line drawn between the most anterior aspects of the tuber coxae. The epidural injection is administered after there is a clear flow of cerebrospinal fluid or if there is no resistance to the injection. Strict aseptic technique must be followed.1

Fentanyl and buprenorphine transdermal patches are highly variable in swine in their activity. Factors which may influence absorption include breed, age, site of application, presence of moisture or heat and type of procedure. Yucatan pigs may require higher dosages than farm pigs. Clinical monitoring of the pigs is essential because of the possibility of an overdose. Patches come in 25, 50 and 100 µg/hour sizes.3, 27 Fentanyl has also been associated with induction of the windup phenomena leading to pain facilitation. Animals must also be monitored for this condition if the patches are used. Transdermal buprenorphine patches have been developed but the same precautions should be considered. Unless blood levels have been determined for patches applied in a particular area on a particular sized pit, it is unlikely that most animals would actually be receiving appropriate therapeutic levels of analgesia and consequently they should not be used for routine analgesia in swine. Lidocaine transdermal patches work well in swine for up to 12 hours of local analgesia and are very useful for pain prevention when giving repeated injections or accessing a vascular access port.

Our highest recommendation would be to use local anesthetics combined with carprofen or meloxicam preemptively at the time of surgical preparation prior to making any incision. Carprofen does not extend the activated clotting time but meloxicam does if that is an issue with a particular protocol. Buprenorphine may be necessary with orthopedic procedures, trauma models or other major invasive procedures.

### OTHER AGENTS

Agents such as muscle relaxants, paralytic agents, and antiarrhythmic agents may be necessary as adjuncts to certain surgical procedures.

Vecuronium (1.0 mg/kg) is a longer-acting paralytic agents useful in cardiac surgery.1, 2 Mechanical ventilation must be provided when using these agents. Paralytic agents are never administered until adequate analgesia has been ascertained by making the skin and muscular incisions first.

Lidocaine (2-4 mg/kg) followed by a continuous IV drip (0.6-5 µg/kg/min), amiodarone (10 mg/kg IV followed by an IV infusion 0.05-5 mg/kg/hr) is useful in prophylaxis against fatal cardiac arrhythmias.1, 2, 28, 29 The IV infusion must be monitored to prevent hypotension.

### DISCUSSION

This article is meant to provide guidelines for anesthetizing swine in the research laboratory. Use of the drugs and combinations described herein may have to be modified for specific protocols. Anesthetics and analgesics should be selected for a research protocol on the basis of the physiologic effects of these agents and their potential adverse effects on scientific results.1, 10, 11 In our laboratories, we attempt to design our anesthetic protocols following this premise. In our experience, isoflurane, especially when combined with nitrous oxide, has the fewest physiologic effects for cardiovascular protocols.1 We perform sole agent anesthesia by restraining swine in a humane restraint sling, induce them with isoflurane using a canine face mask, intubate them and maintain them with the inhalant agent. Our recommended best practices in anesthesia and experimental care have been recently published.30

The IV infusion techniques described in this manuscript are also used when inhalant anesthetics are contraindicated. This would include performing surgery on animals in heart failure and some long term by-pass procedures.1

When postoperative analgesia is indicated we consider buprenorphine to have the fewest complications. It has been demonstrated that intraoperative or preoperative use of this opioid reduces the postoperative recovery period.1, 2, 24 For restraint for minor procedures, midazolam 100-500 µg/kg is a very useful agent with few hemodynamic effects.1, 2, 13, 14 Porcine anesthesia is not as difficult a problem with the introduction of new agents in the last decade. Most of
the problems previously encountered can be resolved by following some of the protocols described in this manuscript. Recent reviews which include cardiopulmonary bypass procedures have been written. A CD Rom series has been developed to train personnel in handling, injection, and anesthetic techniques (http://www.latanet.com/desktop/drs.html).

**SELECTED DRUG DOSAGES**

I. **Dissociative Agents and Combinations**
   - Ketamine 11-33 mg/kg, IM, SC, IV*
   - Ketamine 10-33 mg/kg/hr IV infusion*
   - Ketamine 22-33 mg/kg: Acetylpromazine 1.1 mg/kg IM, SC*
   - Ketamine 15 mg/kg: Azaperone 2 mg/kg, IM, SC
   - Ketamine 20 mg/kg: Xylazine 2 mg/kg IM, SC
   - Ketamine 2 mg/kg: Xylazine 2 mg/kg: Oxymorphone 0.075 mg/kg IV (2x dose for I.M.)
   - Ketamine:Xylazine:Glyceryl guaiacolate 1 ml/kg/hr (see text for mixture) IV infusion*
   - Tiletamine - Zolazepam (Telazol®) 2-8.8 mg/kg IM, SC
   - Tiletamine - Zolazepam (Telazol®) 4-6 mg/kg IM, SC: Xylazine 2.2 mg/kg IM, SC

II. **Barbiturates**
   - Pentobarbital 20-40 mg/kg I.V.; 5-40 mg/kg/hr continuous IV infusion
   - Thiopental 6.6 - 30 mg/kg I.V.; 3-30 mg/kg/hr continuous IV infusion*

III. **Miscellaneous Injectable Restraint Agents**
   - Acepromazine 0.2-1.1 mg/kg IM, SC, IV
   - Azaperone 2-8 mg/kg IM, SC

α-Chloralose 55-100mg/kg IV
Diazepam 0.5-10 mg/kg IM, SC
Etomidate 4-8 mg/kg IV
Etomidate 4-8 mg/kg: Azaperone 2 mg/kg IM, SC, IV
Etorphine/Acetylpromazine (Imobilon®) 0.245 mg/10 kg: Diprenorphine (Revivon®) 0.3 mg/kg IM
Midazolam - 100-500 µg/kg IM, SC, IV*
Metomidate 4 mg/kg IV
Meperidine 1 mg/lb: Azaperone 1 mg/lb followed in 20 minutes by Ketamine 10 mg/lb: Morphine 1 mg/lb IM
Propofol 0.83-1.66 mg/kg IV; 12-20 mg/kg/hr continuous IV infusion
Propofol 2-4.4 mg/kg/hr: Midazolam 0.4-0.7 mg/kg/hr: Fentanyl 0.003-0.005 mg/kg/hr continuous IV infusion

IV. **Analgesics**
   - Aspirin 10-20 mg/kg PO qid
   - Butorphanol 0.1 -0.3 mg/kg IM qid
   - Buprenorphine 0.01-0.05 mg/kg (range 0.005 -0.1 mg/kg) IM or SC q 8-12 h*
   - Buprenorphine Sustained Release (SR) 0.12-0.24 mg/kg SC
   - Carprofen 2.0-3.0 mg/kg SC,PO BID*
   - Fentanyl .02 - .05 mg/kg IM q 2h; 30-100 µg/kg/hour IV drip
   - Fentanyl transdermal patches 5µg/kg/hr topical (highly variable, not recommended)
   - Flunixin 1-4 mg/kg SC, IM, sid or bid*
   - Ketaprofen 1.0-3.0 mg/kg IM, SC, PO bid*
   - Ketorolac 1.0 mg/kg IM, SC, PO bid*
   - Meloxicam 0.4 mg/kg IM, SC sid*
   - Meperidine 2-10 mg/kg IM qid
   - Morphine epidural 0.1 mg/kg
   - Oxymorphone 0.15 mg/kg IM qid
   - Pentazocine 1.5 - 3.0 mg/kg IM qid
   - Phenylbutazone 4-20 mg/kg PO sid or bid
   - Sufentanil 5-10 µg/kg IM q 2h; 10-30 µg/kg/hour IV drip
   - Tramadol 1-4 mg/kg PO tid

V. **Miscellaneous Drugs**
   - Antiarrhythmics
     - Lidocaine 2-4 mg/kg IV; 50 µg/kg/minute continuous
IV infusion
Amiodarone 10-12 mg/kg IV followed by 0.05-5 mg/kg/hr IV infusion

B. Calcium Channel Blockers
Diltiazem 2-4 mg/kg PO TID

C. Paralytic Agents
Vecuronium- 1.0 mg/kg IV

D. Coronary Vasorelaxant
Nitroglycerine 200 µg diluted in 2 ml saline and infused slowly into coronary sinus

E. Anticholinergic
Atropine 0.05 mg/kg IM, 0.02 mg/kg I.V.
Glycopyrrolate 0.004-0.01 mg/kg IM, SC, IV

F. Malignant Hyperthermia Treatment and Prophylaxis
Dantrolene 5 mg/kg IV

See text for references. This list represents only a list of commonly used agents. The reference books in the introduction provide complete information on drug dosages and administration techniques. Comprehensive information on the physiologic effects of these agents and design of protocols is published in Reference 1. The most highly recommended agents are marked with an *.

REFERENCES


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