

## JHU LABORATORY ANIMAL ANESTHESIA & ANALGESIA FORMULARY FOR COMMONLY USED SPECIES

### MICE

#### Inhalant Anesthesia

Agent(s)	Dose	Comments/Reference(s)
Isoflurane	3-5% Induction 1-3% Maintenance	Administer via precision vaporizer and compressed oxygen or drop method

#### Injectable Anesthesia

Agent(s)	Dose	Comments
Ketamine Xylazine	80-100 mg/kg IP 5-10 mg/kg IP	Surgical anesthesia
Ketamine Acepromazine	100 mg/kg IP 5 mg/kg IP	Immobilization/anesthesia
Ketamine Midazolam	100 mg/kg IP 5 mg/kg IP	Immobilization/anesthesia
Ketamine Xylazine Acepromazine	80-100 mg/kg IP 10-20 mg/kg IP 2-3 mg/kg IP	Surgical anesthesia
Pentobarbital	40-60 mg/kg IP	Considerable dose variation by strain, gender, genetic modifications etc. Starting at low end of dose range is advisable. Note: Euthanasia dose is 90-100 mg/kg or greater
Tribromoethanol (Avertin)	200-500 mg/kg IP	Non-pharmaceutical grade; special preparation and storage required; Adverse effects likely with repeat dosing

#### Analgesia

Agent(s)	Dose	Comments
<b>OPIOID</b>		
Buprenorphine	0.05 - 0.1 mg/kg SC, IP q 8-12 hr	DEA required; Preferred analgesic for rodents
Buprenorphine ER-LAB (extended-release buprenorphine)	0.5-1.0 mg/kg SC q 48 hr *Mouse dose range	Manufacturer: Wedgewood Note: Rat and mouse dose ranges are <u>different</u> . No longer requires refrigeration. <b>Prescription from RAR veterinarian required. Obtain forms from. Please visit the RAR website to obtain a prescription form <a href="https://researchanimalresources.jhu.edu/obtaining-drugs-for-research-use/">https://researchanimalresources.jhu.edu/obtaining-drugs-for-research-use/</a></b>
Ethiq-XR® (extended-release buprenorphine)	3.25 mg/kg SC q72 hr (0.05 mL per 20-gram mouse)	FDA-indexed, available to Researcher DEA license  Once the vial is broached, Ethiq-XR® can be stored at 15° and 25°C +/- 2°C (59° and 77°F +/- 2°F) or refrigerated for 56 days. DO NOT FREEZE.
<b>NSAID</b>		
Carprofen (Rimadyl®)	4-5 mg/kg SC q 24 hr	

Meloxicam (Metacam®)	1-5 mg/kg SC q 24 hr	Note: We do not recommend the use of <b>meloxicam ER</b> as independent studies in rodents have not demonstrated efficacy beyond 24 hours post-administration.
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### Local Block Analgesics

Agent(s)	Dose	Comments/Reference(s)
Lidocaine (1-2%)	Local infusion; do not exceed 7mg/kg	Onset: 5-10 min, Duration: 0.5-1 hr Several methods of administration (field block, infiltrative block etc.).
Bupivacaine (0.5% Marcaine)	Local infusion; do not exceed 8 mg/kg	Onset: 15-30 min, Duration: 4-8 hr Several methods of administration (field block, infiltrative block etc.).
Nocita® (liposomal bupivacaine)	1/mg/kg Local infusion	Duration: up to 96 hr Local infusion of all tissues transected prior to surgical closure.

## RATS

### Inhalant Anesthesia

Agent(s)	Dose	Comments
Isoflurane	3-5% Induction 1-3% Maintenance	Administer via precision vaporizer and compressed oxygen or drop method

### Injectable Anesthesia

Agent(s)	Dose	Comments
Ketamine Xylazine	75-100 mg/kg IP 5-10 mg/kg IP	Provides a good surgical plane of anesthesia for most procedures
Ketamine Acepromazine	75 mg/kg IP 1- 2.5 mg/kg IP	Best used for prolonged restraint or minor surgical procedures
Ketamine Xylazine Acepromazine	40 mg/kg IP 5 mg/kg IP 1 mg/kg IP	Provides a good surgical plane of anesthesia for most procedures
Ketamine Midazolam	75-100 mg/kg IP 4-5 mg/kg IP	Best used for prolonged restraint or minor surgical procedures
Ketamine Dexmedetomidine (Dexdomitor®)	75-100 mg/kg IP 0.15 mg/kg IP	Provides a good surgical plane of anesthesia for most procedures
Pentobarbital	40-50 mg/kg IP	May provide a surgical plane of anesthesia however there is a wide range of dose variability and often a narrow safety margin; caution should be used to avoid overdoses

### Analgesia

Agent(s)	Dose	Comments
<b>OPIOID</b>		
Buprenorphine	0.01-0.05 mg/kg SC, IP q 6-12 hr	DEA required

Buprenorphine ER-LAB (extended-release buprenorphine)	1.0 -1.2 mg/kg SC q 72 hr *Rat dose range	Manufacturer: ZooPharm Note: Rat and mouse dose ranges are different. No longer requires refrigeration. <b>Prescription from RAR veterinarian required. Please visit the RAR website to obtain a prescription form</b> <a href="https://researchanimalresources.jhu.edu/obtainiq-drugs-for-research-use/">https://researchanimalresources.jhu.edu/obtainiq-drugs-for-research-use/</a>
Ethiq-XR® (extended-release buprenorphine)	0.65 mg/kg SC q 72 hr (0.1 mL per 200-gram rat)	FDA-indexed, available to Researcher DEA license  Once the vial is broached, Ethiq-XR® can be stored at 15° and 25°C +/- 2°C (59° and 77°F +/- 2°F) or refrigerated for 56 days. DO NOT FREEZE.
<b>NSAID</b>		
Carprofen (Rimadyl®)	5-10 mg/kg SC, PO q 24 hr	For optimal analgesia, give NSAID and buprenorphine.
Meloxicam (Meloxicam®)	1-2 mg/kg SC, PO q 24 hr	Note: We do not recommend the use of <b>meloxicam ER</b> as independent studies in rodents have not demonstrated efficacy beyond 24 hours post-administration.

## NEONATAL MOUSE & RAT

### Inhalant Anesthesia

Agent(s)	Dose	Comments/Reference(s)
Isoflurane	3-5% Induction 1-3% Maintenance	Administer via precision vaporizer and compressed oxygen or drop method. Good first choice.

### Hypothermia Anesthesia:

**Comments:** When inhalant anesthesia is not available or cannot be used safely, hypothermia is a relatively safe and effective alternative to injectable anesthetics in altricial rodents up to 7 days old.

**Induction:** Place the pup in a latex/nitrile glove finger and immerse the glove finger in crushed ice and water (2-3°C or 35-37°F) up to the level of the head so that the head of the pup is visible. Anesthesia induction takes 5-8 minutes.

**Procedure:** Remove the pup from the ice bath and place on a re-freezable ice pack. A piece of gauze or cloth should prevent direct contact of the pup's skin with the freezable ice pack. Duration of anesthesia on an ice pack is 15 minutes maximum.

**Hypothermia Recovery:** Rapid warming should be avoided. Pups can be placed in a small incubator (32-35 °C or 90-95°F) for gradual warming over 20-30 minutes. Once warmed for this time, circulating warm water blankets can be used until mobile where complete recovery takes 30-60 minutes. Once mobile, pups may be mingled with the litter to aid in covering the procedure odors on the pup then the litter returned to the dam.

**Injectable Anesthesia:** In general, injectable anesthetics are not as safe as hypothermia or isoflurane in neonatal rodents <6-7 days old. Several of the injectable combinations used in adult rodents have been found to be unpredictable and associated with >50% mortality rate. If injectable combinations are used, it is important to begin at the low end of the recommended dose range based on weight and only use the IP route. Also, the recovery period may be prolonged and hypothermia must be avoided by keeping the neonate warm as noted above.

## Analgesia

Neonates require analgesics if the procedure being performed is likely to cause greater than just momentary pain.

Agent(s)	Dose	Comments
<b>OPIOID</b>		
Buprenorphine	0.05 - 0.1 mg/kg SC, IP q 8-12 hr	DEA required; Preferred analgesic for rodents

## HAMSTERS

Hamsters have an exceptional amount of loose skin. When using scruffing for restraint for injections or other procedures, care must be taken that sufficient skin is grasped to prevent the animal from turning and biting the handler. Hamsters have large cheek pouches used to store and transport food. The oral cavity should be swabbed and checked for material after sedation to prevent aspiration.

### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	2-5% Induction, 0.25 -4% Maintenance	Surgical Anesthesia. Lower range expected with ET intubation. (1)
Sevoflurane	To Effect	Surgical Anesthesia (1)

### Injectable Anesthesia

Agent(s)	Dose	Comment
Acepromazine	0.5 – 1 mg/kg IM, SC 0.5 – 5 mg/kg PO	Sedation (1)
Ketamine	5-40 mg/kg IM	Sedation (1)
Ketamine Xylazine	150 – 200 mg/kg IP 10 mg/kg IP	Surgical Anesthesia 30-60 minutes (2)
Ketamine Dexmedetomidine	2-4 mg/kg IM 0.025 mg/kg IM	Anesthesia, Short procedures (1)
Ketamine Medetomidine	100 – 200 mg/kg SC, IP 0.25 mg/kg SC, IP	Anesthesia (1)
Midazolam	1-2 mg/kg IM	Preanesthetic (1)
Medetomidine Midazolam Butorphanol	0.15 mg/kg IM 2 mg/kg IM 2.5 mg/kg IM	Anesthesia (2)
Tiletamine/zolazepam	30 mg/kg IP	Telazol, Zoetis. Hamsters may experience poor respiration with Telazol (1, 2)
Tiletamine/zolazepam Xylazine	20 - 30 mg/kg IP 10 mg/kg IP	Surgical Anesthesia (2)
Pentobarbital	50 – 90 mg/kg IP	Not Recommended, due to respiratory perturbations and high mortality (2)
*Yohimbine	0.5 – 1.0 mg/kg IV, IP	*Xylazine reversal (1)

### Analgesia

Agent(s)	Dose	Comment
<b>OPIOID</b>		
Buprenorphine	0.5 mg/kg SC q8hr	(1)
Butorphanol	1-5 mg/kg SC q4hr	(1)
<b>NSAID</b>		
Carprofen	2-5 mg/kg PO, SC, IM, IV q24 hr	Can divide the total dose into 2x q12hr doses (1)
Meloxicam	0.1 – 0.5 mg/kg SC, PO q24 hr	(2)

## GUINEA PIGS

Guinea pigs are among the most challenging rodents to safely and effectively anesthetize. In general, their response to injectable anesthetics is quite variable and post-anesthetic complications (respiratory infections, GI immobility, lethargy, anorexia) periodically do occur. Gas anesthesia produces consistent and reliable results. However, breath holding when animals are first exposed to irritating gas vapors has been reported. Endotracheal intubation of guinea pigs is difficult due to the narrow oral cavity and anatomy of the larynx and upper airway. Several highly effective methods for intubation have been reported (60). Depth of anesthesia and effectiveness of analgesia is assessed by pinching the pinna with a small hemostat and lack of a pedal withdrawal. As with other small rodents, steps should be initiated to prevent hypothermia. A large cecum can act as a reservoir for anesthetics. Depending on drug solubility, the cecum can alter the pharmacologic effect.

### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	2-5% Induction, 0.25 -4% Maintenance	Surgical Anesthesia. Lower range expected with ET intubation. (1,2)
Sevoflurane	To Effect	Surgical Anesthesia (1)

Guinea pigs are known for being particularly difficult to intubate due to the presence of an extension of the soft palate known as the palatal ostium. This tissue leaves only a small opening to the oropharynx making visualization and placement of endotracheal tubes harder than other similarly sized species. (2)

### Injectable Anesthesia

Agent(s)	Dose	Comment
Acepromazine	0.5 – 1 mg/kg IM, SC 0.5 – 5 mg/kg PO	(1)
Alfaxalone	40 mg/kg IM, IP	Anesthesia (1)
Ketamine	5-40 mg/kg IM	Light Sedation (1)
Ketamine Xylazine	20 – 40 mg/kg IM 2 mg/kg IM	Anesthesia (1)
Ketamine Dexmedetomidine	3-5 mg/kg IM, SC 0.05 mg/kg IM, SC	Anesthesia, Short procedures (1)
Ketamine Medetomidine	3-5 mg/kg IM, SC 0.1 mg/kg IM, SC	Anesthesia, Short procedures (1)
Ketamine Medetomidine Buprenorphine	20 mg/kg IM 0.1 mg/kg IM 0.03 mg/kg IM	Premedication, Sedation (1)
Midazolam	0.4 – 2 mg/kg IM	Premedication, Light Sedation (1)
Tiletamine/zolazepam	40 – 60 mg/kg IM	(Telazol, Zoetis) (1)
Pentobarbital	30-45 mg/kg IP	Anesthesia, Not recommended, autonomic depression and narrow margin of safety (1, 2)
*Yohimbine	0.5 – 1.0 mg/kg IV, IP	*Xylazine reversal (1)

Swabbing the mouth and cheeks after induction may help clear food stored in the caudal oropharynx and help prevent aspiration during sedation and anesthesia in this species. Short periods of fasting (2-3 hours) prior to induction may also be beneficial but fasting longer than this is to be avoided due to their high metabolism and increased risk of GI stasis. (2,4)

### Analgesia

Agent(s)	Dose	Comment
<b>OPIOID</b>		
Buprenorphine	0.05 mg/kg SC q8-12hr	(1)
Buprenorphine ER-LAB	0.3-0.6 mg/kg SC	Give q72hr. Requires veterinary script.
Butorphanol	1-2 mg/kg SC q4hr	(1)
<b>NSAID</b>		
Carprofen	2-5 mg/kg PO, SC, IM, IV q24 hr	Can divide the total dose into 2x q12hr doses (1, 2)
Diclofenac	2.1 mg/kg PO q24 hr	Particularly for neurogenerative or musculoskeletal pain (2, 3)
Ketoprofen	1-2 mg/kg SC, IM q12-24 hr	(1)

Meloxicam	0.1 – 0.3 mg/kg SC, PO q24 hr	(2)
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### Local Block Analgesics

Agent(s)	Dose	Comment
Bupivacaine (0.5% Marcaine)	1-2 mg/kg	Onset: 15-30 min, Duration: 1-7 hr Several methods of administration (field block, infiltrative block etc.). (1)

### References:

1. James W. Carpenter, Craig Harms, Carpenter's Exotic Animal Formulary, Sixth Edition, 2023. Elsevier. ISBN: 978-0-323-83392-9
2. Anesthesia and Analgesia in Laboratory Animals, Third Edition 2023. Academic Press. ISBN: 978-0-12-822215-7
3. Flecknell, P.A., 2015. Laboratory Animal Anesthesia, Fourth Edition, 2015 Academic Press, Elsevier, ISBN: 978-0-12-800036-6, DOI: <https://doi.org/10.1016/C2013-0-13494-0>

## CHINCHILLAS

Chinchillas are normally easy to be work with provided the handler is gentle and moves slowly. Occasionally if startled or presented with an uncomfortable situation they may vocalize, urinate, lunge, or attempt to escape from the handler. They should not be “scruffed” or grasped solely by the fur, as their skin is delicate and this can result in “fur slip” in which a large patch of hair is rapidly shed.

Pre-operative fasting is not required, because chinchillas cannot vomit (4). Fasting for >2-3 hours should not be performed, as chinchillas need to eat frequently to maintain gastrointestinal tract motility; fasting increases the risk of hypoglycemia and gastrointestinal stasis. After sedation or induction, any food residue in the oral cavity should be immediately cleared out with a cotton swab.

In the past, some anesthetic protocols included premedication with atropine or glycopyrrolate to decrease the volume of airway and salivary secretions. However, these drugs increase secretion viscosity and can cause hypertension. Therefore, we do not currently recommend this.

Inhalant anesthesia may be delivered via a fitted nose cone, induction box, or endotracheal intubation. Aversion to the smell may result in struggling or breath-holding; therefore, administration of an injectable sedative agent before inhalant anesthesia may be desirable. Intubation is difficult in this species, therefore a nosecone attached to a non-rebreathing circuit is frequently used. If intubation is desired, direct visualization of the glottis using a 1.0 – 2.7 mm rigid endoscope to assist ET placement has been described (4). A non-rebreathing anesthesia circuit is recommended.

Hypothermia, hypoglycemia, and post-operative gastrointestinal stasis are risks. Recirculating hot water blankets are recommended. However, due to thick fur, active warming can also result in hyperthermia; therefore, body temperature should always be monitored during the procedure and recovery.

### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	3-5% (induction) 1.5-2% (maintenance)	Administer via precision vaporizer, delivered in 100% oxygen, titrated to effect (3, 5)

### Injectable Anesthesia

Agent(s)	Dose	Comment
Acepromazine	0.5-1.0 mg/kg IM	Light sedation. Avoid in dehydrated animals. (5)
Butorphanol	0.5-2 mg/kg SC or IM	Sedation to permit handling or non-invasive procedures; not sufficient for surgery. (5)
Ketamine Dexmedetomidine	4 mg/kg IM 0.015 mg/kg IM	Rapid induction of surgical anesthesia (4)
Ketamine Midazolam	5-10 mg/kg IM 0.5-1.0 mg/kg IM	Moderate sedation (5)
Ketamine Acepromazine	20-40 mg/kg IM 0.5 mg/kg IM	(5)
Ketamine Xylazine	40 mg/kg IM 2 mg/kg IM	Induction of surgical anesthesia (5)
Midazolam	1-2 mg/kg SC or IM	Sedation. DEA required. (5)

## Analgesia

Agent(s)	Dose	Comment
<b>OPIOIDS</b>		
Buprenorphine	0.03-0.05 SC q6-12h	DEA required (5)
Hydromorphone	2 mg/kg SC q2h	DEA required (1)
<b>NSAIDS</b>		
Meloxicam (Metacam®)	0.3-0.5 mg/kg PO or SC q12-24h	(2) No published studies. Dose is anecdotal from exotic mammal practitioners.

## Local Block Analgesics

Agent(s)	Dose	Comment
Lidocaine (1-2%)	2-4 mg/kg SC	Onset 5-10 min, duration 0.5-1 hr. (6)
Bupivacaine (0.5% Marcaine)	1-3 mg/kg SC	Onset 15-30 min, duration 4-8 hr. (6,7)
Ropivacaine (0.2% Naropin)	1-2 mg/kg SC	Onset 15-30 min, duration 4-8 hr. (6)

## Reversal Agents

Agent(s)	Dose	Comment
Atipamezole	10X the mg/kg dose of dexmedetomidine (e.g. for 0.015 mg/kg dexmedetomidine, give 0.15 mg/kg atipamezole). Give IM.	For commercial Dexdomitor and Antisedan, this equates to the same volume of Antisedan as Dexdomitor.
Yohimbine	0.2 mg/kg IM, SC	(5)

## References:

1. Evenson E.A., Mans C. Analgesic Efficacy and Safety of Hydromorphone in Chinchillas (*Chinchilla lanigera*). J Am Assoc Lab Anim Sci. 2018;57(3):282-285.
2. Frolich J. Chinchillas. Merck Veterinary Manual. 2021.
3. Fox L., Snyder L.B., Mans C.. Comparison of Dexmedetomidine-Ketamine with Isoflurane for Anesthesia of Chinchillas (*Chinchilla lanigera*). J Am Assoc Lab Anim Sci. 2016;(3):312-6.
4. Parkinson L., Mans C. Anesthetic and Postanesthetic Effects of Alfaxalone–Butorphanol Compared with Dexmedetomidine–Ketamine in Chinchillas (*Chinchilla lanigera*). J Am Assoc Lab Anim Sci. 2017;56(3):290–5.
5. Saunders R., Harvey L. Anesthesia and analgesia in chinchillas. Companion Animal Practice. 2012;34:34-43.
6. Chinchilla Anesthetics and Analgesics Formulary. University of Colorado, Denver. 2012. <https://www.colorado.edu/researchinnovation/sites/default/files/attached-files/CU%20Denver%20Analgesic%20%26%20Anesthetic%20Drug%20Formulary.pdf>
7. Saldanha A., Martini R., Basseto J.E., do Carmo M.P.W., Freitag A.V., Lange R.R., Duque J.C. Use of transversus abdominis plane block in chinchillas (*Chinchilla lanigera*). Journal of Exotic Pet Medicine. 2019;31:21-22.

## AVIAN SPECIES

The following issues should be considered when anesthetizing avian species. Supplemental heat should always be used to protect against hypothermia. Techniques to protect against hypothermia include: minimal feather plucking, circulating warm water blankets and water bottles, heat lamps and heated IV fluids. Intravenous catheters are difficult to maintain because avian vessels are very delicate. Intraosseous (IO) catheters are placed in the distal ulna or proximal tibiotarsus are therefore recommended (procedure needs to be approved in your protocol). Note: Pneumatic bones such as the femur or humerus should never be used for IO catheters. Birds lack a diaphragm; breathing occurs through the inward/outward movement of the sternum. Restraint must therefore be performed carefully in a manner that minimizes pressure applied to the thoracic cavity (chest).

Injectable agents may be acceptable for procedures lasting 20–30 minutes or less. Inhalant anesthetics are however, typically considered safer for procedures of even longer duration. Disadvantages of injectable agents include significant dose and response variation between species and individuals, large drug volumes may be unsafe deliver to small birds, potential for overdose by any route, severe secondary cardiopulmonary depression, and recovery periods that vary significantly according to the bird's metabolic and excretory mechanisms (1). Supplemental oxygen delivered via a facemask is recommended when injectable anesthesia is used. Birds should be fasted for roughly 4 hours to ensure the crop is empty prior to anesthesia. Gentle manual manipulation of the crop may also be needed to ensure adequate clearance. The head and neck of the bird should be slightly elevated during anesthesia. Isoflurane is the anesthetic of choice in birds. Inhalation anesthetics can be administered through a facemask placed over the head (or at least the nares), an air sac breathing tube, or an endotracheal tube. A non-rebreathing system should be used when using gas to anesthesia birds < 8 kg (1,24,54).

### Inhalant Anesthesia

Agent(s)	Dose	Comments/Reference(s)
Isoflurane	Induction: 3-5% Maintenance: 1.5-2.5%	Most species. <sup>1,2</sup>
Sevoflurane	Induction: 5-8% Maintenance: 3-4%	Multiple Species <sup>2</sup>

### Injectable Anesthesia

Agent(s)	Dose	Comments/Reference(s)
Ketamine	60 mg/kg	The effect of ketamine may vary by species of bird; recovery is associated with ataxia and excitement; seldom used as sole agent. Restraint is recommended during the recovery period. May fail to produce anesthesia in owls and hawks. <sup>1</sup>
Ketamine Acepromazine	10-25 mg/kg IM 0.5- 1.0 mg/kg IM	Most species. Used higher end of dose range for birds < 250g. <sup>1</sup>
Ketamine Xylazine	10-15 mg/kg IM (owl) 2 mg/kg IM (owl)	Associated with cardiac depression and rough recovery. <sup>1</sup>
Ketamine Midazolam	10-40 mg/kg IM 0.2-4.0 mg/kg IM	Most species. <sup>1</sup>
Butorphanol/ Midazolam	1(B) / 1 (Mi) mg/kg IM, IV	Chickens: Adequate sedation for lateral recumbency <sup>1</sup>
Propofol	1-5 mg/kg IV 5 mg/kg IV (Turkey)	Most species, give slowly for induction, Intubation and Positive pressure ventilation required. <sup>1,2</sup>



**Analgesia:** **Note:** Birds have more kappa opioid receptors than mu opioid receptors. Thus, mu agonists and partial agonists (buprenorphine, fentanyl, and morphine) do not provide adequate analgesia.

Agent(s)	Dose	Comments/Reference(s)
OPIOID		
Butorphanol	1 – 4 mg/kg IM, IV q 4 hr	Recommend analgesic for most species of birds. <sup>1-3</sup>
NSAID		
Carprofen (Rimadyl ®)	1-2 mg/kg PO, IM, IV or SC q 12-24 hr 5-8 mg/kg PO q12 (Chickens)	Most species including raptors <sup>1,2</sup>
Meloxicam (Metacam ®)	1 mg/kg PO, IM q12 hr (chickens) <sup>1</sup> 1-2 mg/kg PO, IM q12 hours (zebra finches) <sup>1,2</sup>	

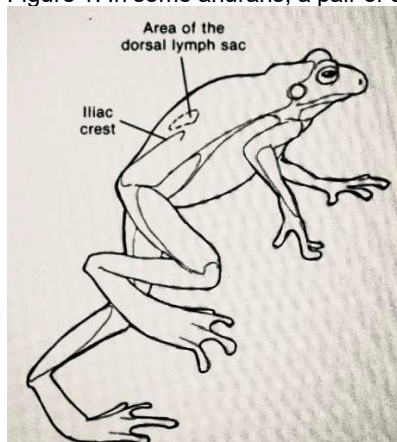
1. Carpenter, J. & Harms, C. *Carpenter's Exotic Animal Formulary, Sixth Edition. Carpenter's Exotic Animal Formulary, Sixth Edition* (2022). doi:10.1016/C2019-0-00378-0.
2. Dyson, M. C., Jirkof, P., Lofgren, J., Nunamaker, E. A. & Pang, D. *Anesthesia and Analgesia in Laboratory Animals. Anesthesia and Analgesia in Laboratory Animals* (2023). doi:10.1016/C2019-0-04422-6.
3. Speer, B. L. *Current Therapy in Avian Medicine and Surgery. Current Therapy in Avian Medicine and Surgery* (2015). doi:10.1016/c2009-0-42653-9.

## AMPHIBIANS

Aquatic frogs such as *Xenopus laevis* or *X. tropicalis* should be handled with soft nets during unanesthetized exams and/or procedures. When indicated, physical restraint should be firm but gentle and care must be taken to preserve the integrity of the protective mucous layer. Use of rinsed and moistened non-powdered gloves are recommended when handling amphibians in order to protect their delicate skin and prevent handler contact with glandular secretions, which may be toxic. Thoroughly rinsed vinyl gloves appear to be the safest option, especially when it comes to the handling of tadpoles (4).

Chemical restraint is required for prolonged or invasive procedures. Some frog species including *Xenopus* have paired lymphatic structures called dorsal lymph sacs (16) (see figure 1) located subcutaneously under the skin of the back. These structures communicate with the venous circulation and are an excellent site for injection. Other routes including intracoelomic, intramuscular and intravenous are also frequently used.

Figure 1. In some anurans, a pair of dorsal lymph sacs lies immediately lateral to the base of the sacrum.



A light plane of anesthesia is characterized by a loss of righting reflexes, but withdrawal reflexes and gular (throat) respiratory efforts remain. As the anesthetic level deepens, abdominal respiration is lost, followed by slowing of gular (throat) movements, which stop as a surgical level is reached. The cardiac impulse (visible heartbeat) should be retained; slowing or loss indicates an anesthetic overdose.

Skin should be kept moist during recovery. Ambient recovery temperatures of 60 - 70<sup>0</sup> F are appropriate for most species; avoid unnecessary warming because cutaneous respiration cannot meet the metabolic demands of increased body temperature (6).

MS-222, benzocaine, and eugenol (clove oil) are skin, eye, and respiratory irritants. Wear gloves, eye protection, and lab coat/disposable coat when handling. If preparing solutions from powder form, work under a fume hood to minimize risk of exposure. Alternatively, use goggles and a respirator (note: individual needs to be medically evaluated, and dependent on the type of respirator, be fitted). In case of contact with bare skin, wash the affected area thoroughly. For eye exposure, flush for 15 minutes and follow up with the Occupational Injury Clinic.

### Immersion Anesthesia\*

Agent(s)	Immersion Bath Dosages	Comments/Reference(s)
Tricaine methanesulfonate (MS-222, tricaine, Finquel <sup>®</sup> , Syncaïne <sup>®</sup> )	Larvae: 200 - 500 mg/liter *more sensitive than adults  Adult frogs ( <i>Xenopus</i> ) & salamanders: 500 mg/liter – 2 grams/ liter  Toads: 1 - 3 g/liter	<u>Anesthetic of choice for <i>Xenopus</i></u> . Safest for long and/or repeated procedures - <b>1g/liter</b> provides at least 30 min of surgical anesthesia in this spp. All MS-222 solutions must be buffered: NaHCO <sub>3</sub> 420 - 1,050 mg/liter (10-25 mEq/liter). Unbuffered solutions result in a prolonged induction time and are irritating to skin (6).  Store MS-222 powder in the original sealed container in a dry location at room temperature until the expiration date noted by manufacturer on packaging. Ideally MS-222 stock solutions are utilized the same day as preparation per vendor recommendation. When necessary, stock solutions of MS-222 may be kept up to 30 days. They must be refrigerated and stored in tinted (amber) or opaque bottles. Stock solutions of MS-222 that are older than 30 days, or that have not been properly stored must not be used. All MS-222 powder and stock solution containers must be appropriately stored, labeled (concentration and preparation or expiration date), and used prior to expiration date. Contact Health, Safety, and Environment (HS&E) for appropriate disposal methods as MS-222 solutions cannot be poured down the drain or introduced into the general water supply.
Benzocaine	Larvae: 50 mg/liter to effect  Adult frogs ( <i>Xenopus</i> ) & salamanders: 200 - 300 mg/liter to effect	Immersion anesthetic related to MS-222 but with greater potency, more rapid induction & narrower margin of safety. Less water soluble than MS-222, must be dissolved in acetone or ethanol (6).
Eugenol (clove oil)	360 mg/liter for 15-20 minutes.  310 - 473 mg/liter * large variation by species	Does not need to be buffered. (7).  Not recommended. Highly variable anesthetic duration, narrow safety margin, prolonged recovery. Reversible gastric prolapse reported in 50% of leopard frogs (3, 6).

\*IMPORTANT: Pharmaceutical-grade MS-222 like Finquel<sup>®</sup> and Syncaïne<sup>®</sup> is the recommended agent and should be used instead of the non-pharmaceutical grade MS-222 or eugenol. If non-pharmaceutical grade compounds are used, this must be justified in the ACUC protocol.

### Injectable Anesthesia

Agent(s)	Dose	Comments/Reference(s)
Ketamine	50 - 150 mg/kg SC, IM, IV, or dorsal lymph sacs (considered same as IV)	For minor surgeries or restraint; induction time, depth of anesthesia and recovery time vary greatly with species (6). DEA required.
Alfaxalone	18 mg/kg IM, IV, intracelomic	African clawed frogs/ deep sedation for 1 – 3 hour (IM, IV), 10 – 60 min intracoelomic (8). DEA required.

### Inhalant Anesthesia

Agent(s)	Dose	Comments/Reference(s)
Isoflurane	Induction: 3 – 5% Maintenance: 1 – 2.5%	Induction time can exceed 20 min. Ensure chamber is moistened. Larger amphibians with lungs can be intubated (6).

### Analgesia

Agent(s)	Dose	Comments/Reference(s)
Buprenorphine	14 mg/kg in dorsal lymph sac	DEA required. (6, 15).
Butorphanol	25 mg/kg intracoelomic	DEA required, 12 hour duration. (6, 15).
Xylazine	10 mg/kg intracoelomic	12 - 24 hour duration.
Flunixin meglumine (Banamine®)	25 mg/kg intracoelomic	4 hour duration.
Meloxicam	0.1 mg/kg  0.4 – 1.0 mg/kg PO, SQ, intracoelomic q 24 hours	American bullfrogs/ decreased circulating prostaglandin E2 (PGE2) levels measured 24 hours post muscle biopsy (14).  Analgesia (17).
Lidocaine	2 mg/kg local infiltration, dilute 3:1 with sodium bicarbonate solution, duration 30–60 min.	Do not exceed 5 mg/kg <b>total</b> dose either topically or intra-incisional (5).

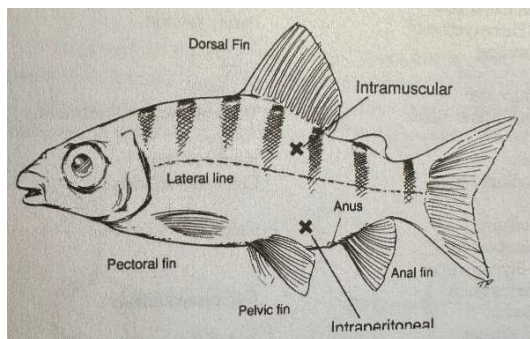
## FISH

Immersion is the preferred method of anesthesia. This technique is analogous to gas induction chamber use for mammals. Agents are absorbed across the gills and exert their impact centrally. It is recommended that two separate tanks of water be used: one for induction and the other for recovery. In addition, animals should be fasted for 24 hours prior to anesthesia and maintained in a calm state until induced. Fish should be handled with wet gloved hands.

Loss of the equilibrium represents the first stages of anesthesia. Surgical anesthesia is attained when there is no response to stimuli and respiration rate is very slow. Gill movements should be maintained through anesthesia. If spontaneous gill movement ceases during anesthesia, the fish should be placed in a recovery bath to increase oxygenation through the gills.

In addition to emersions, traditional routes of drug administration used for mammalian anesthesia and analgesia may also be used with fish, including oral, intramuscular (IM, given above the lateral line under the dorsal fin), intravenous (IV), and intraperitoneal (IP) injection (2) (see figure 2).

Figure 2. Routine sites for intraperitoneal (intracelomic) and intramuscular injections in fish.



Although hypothermia to immobilize fish has been well established, there is little evidence to date demonstrating the process provides sufficient anesthesia or analgesia (13).

MS-222 and eugenol (clove oil) are skin, eye, and respiratory irritants. Wear gloves, eye protection, and lab coat/disposable coat when handling. If preparing solutions from powder form, work under a fume hood to minimize risk of exposure. Alternatively, use goggles and a respirator (note: individual needs to be medically evaluated, and dependent on the type of respirator, be fitted). In case of contact with bare skin, wash the affected area thoroughly. For eye exposure, flush for 15 minutes and follow up with the Occupational Injury Clinic.

### Immersion Anesthesia\*

Agent(s)	Immersion Bath Dosages	Comments/Reference(s)
Tricaine methanesulfonate (MS-222, tricaine, Finquel <sup>®</sup> , Syncaine <sup>®</sup> )	Species specific variation: Induction: 100 - 200 mg/L Maintenance: 50 - 100 mg/L	Anesthetic of choice for fish. MS-222 stock solution (10g/liter) can be buffered with NaHCO <sub>3</sub> at 10g/liter or to complete saturation to reach pH of 7.0 - 7.5. Aerate water to prevent hypoxemia; narrower margin of safety in younger and/or warm water fish (3, 6).  See dose calculator at: <a href="http://Tricaine-S Concentration Calculator (syndel.com)"><u>Tricaine-S Concentration Calculator (syndel.com)</u></a>

		<p>Store MS-222 powder in the original sealed container in a dry location at room temperature until the expiration date noted by manufacturer on packaging. Ideally MS-222 stock solutions are utilized the same day as preparation per vendor recommendation. When necessary, stock solutions of MS-222 may be kept up to 30 days. They must be refrigerated and stored in tinted (amber) or opaque bottles. Stock solutions of MS-222 that are older than 30 days, or that have not been properly stored must not be used. All MS-222 powder and stock solution containers must be appropriately stored, labeled (concentration and preparation or expiration date), and used prior to expiration date. Contact Health, Safety, and Environment (HS&amp;E) for appropriate disposal methods as MS-222</p>
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		solutions cannot be poured down the drain or introduced into the general water supply.
Eugenol (clove oil)	10 - 100 mg/liter bath for sedation to handleable  17 - 25 mg/liter bath	Aqui-SE contains 50% eugenol and Aqui-S20E, 10% eugenol, a compound mixture of eugenol and polysorbate 80 (for solubility); lower doses (6 mg/liter) will produce sedation without anesthesia (12).

\*IMPORTANT: Pharmaceutical-grade MS-222 like Finquel® and Syncline® is the recommended agent and should be used instead of the non-pharmaceutical grade MS-222 or eugenol. If non-pharmaceutical grade compounds are used, this must be justified in the ACUC protocol.

### Injectable Anesthesia

Agents(s)	Dose	Comments/Reference(s)
Ketamine	10 - 80 mg/kg IM	Immobilization for short procedures; complete recovery can take > 1 hour (3). DEA required.
Ketamine + Medetomidine	(K) 1 - 2 mg/kg + (M) 0.05 - 0.1 mg/kg IM	Immobilization; reverse (M) with <b>atipamezole</b> 0.2 mg/kg IM (9). DEA required.

**Analgesia** Note: Considerable evidence supports the presence of mu and kappa opioid receptors in teleost fish and thus endogenous opioid system that might be manipulated to provide analgesia. In general, however, specific drug and dosing regimens are still lacking for most fish including zebrafish (*Danio spp.*), the species those most commonly used in biomedical research (13).

Agent(s)	Dose	Comments/Reference(s)
Butorphanol	0.05 - 0.1 mg/kg IM	General fish dose range for post-operative analgesia. (3) DEA required.
Morphine	5 mg/kg IM	Koi/analgesia (1). DEA required.
Ketoprofen	2 mg/kg IM	As a post-operative analgesic in koi (11).
Lidocaine	1 - 2 mg/kg	Local anesthetic; use with caution in small fish; do not exceed 2 mg/kg <b>total</b> dose (10).

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## FERRETS

Ferrets, unlike rodent species, can vomit and should therefore be fasted for 4-6 hours prior to anesthesia. This duration is based on their short gastric transit time and concerns for development of hypoglycemia following prolonged fasting. Animals acclimated to handling can easily be restrained for injection of anesthetic agents. Ferrets also respond well to mask induction of inhalant anesthesia. As with the cat, a properly fitted nose cone can be used to administer gas anesthesia after sedation. Furthermore, an induction chamber can be used, but some animals may become excitable during this procedure. Ferrets are easily intubated, but may develop laryngospasm. Topical application of 0.05 mL of a 2% lidocaine solution will help to prevent laryngospasm. Non-cuffed endotracheal tubes ranging from 2.0-3.5 mm should be used. A non-rebreathing anesthesia circuit is recommended for ferrets.

Body temperature is rapidly lost in small mammals such as ferrets and should be monitored throughout the procedure; recirculating hot water blankets and heated recovery areas are highly recommended. In the past, some anesthetic protocols included premedication with atropine or glycopyrrolate to decrease the volume of airway and salivary secretions. However, these drugs increase the viscosity of secretions and can also cause hypertension. Therefore, we no longer recommended this.

### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	3-4% (Induction) 1.5-2% (Maintenance)	Administer via precision vaporizer, delivered in 100% oxygen, titrated to effect. (4,8) Decreases hematocrit (7)

### Injectable Anesthesia

Agent(s)	Dose	Comment
Acepromazine	0.1-0.5 mg/kg SC, IM	(1) Doses above 0.2 mg/kg associated with prolonged recovery times and hypothermia.
Alfaxalone	5 mg/kg IM	(1,3)
Dexmedetomidine	0.04 mg/kg SC or IM	(1)
Ketamine	10-20 mg/kg IM	(1)
Ketamine Dexmedetomidine	5 mg/kg IM 0.03 mg/kg IM	(1)



Ketamine	10-25 mg/kg IM	(1)
Xylazine	1-2 mg/kg IM	
Ketamine	5-10 mg/kg IM	(1)
Midazolam	0.25-0.5 mg/kg IV	
Ketamine	0.3-0.4 mg/kg/hr IV CRI	(10)
Fentanyl	2.5-5 µg/kg/hr IV CRI	
Tiletamine/zolazepam	3 mg/kg IM	(1)
Xylazine	3 mg/kg IM	
Tiletamine/zolazepam	1.5 mg/kg IM	(1)
Xylazine	1.5 mg/kg IM	
Butorphanol	0.2 mg/kg IM	
Propofol	1-3 mg/kg IV	(1)

### Analgesia

Agent(s)	Dose	Comment
<b>OPIOID</b>		
Buprenorphine	0.02-0.04 mg/kg SC or IM q6h	DEA required (2,5)
Ethiq-XR (extended-release buprenorphine)	0.6 mg/kg SC q72h	(9) **Bup-ER-LAB formulation is not recommended for ferrets.
Hydromorphone	0.1-0.2 mg/kg SC or IM	(2,5,10)
Fentanyl	1-4 µg/kg/h IV CRI	(10)
Tramadol	10 mg/kg PO q24h	(10)
<b>NSAID</b>		
Carprofen (Rimadyl®)	2-4 mg/kg PO q24h 1-4 mg/kg SC q12h-24h	(10)
Meloxicam (Metacam®)	0.2 mg/kg PO, IV, SC once, then 0.1 mg/kg PO, IV, or SC q24h	(1,10)
Ketoprofen	1-5 mg/kg IM or PO q24h	(10)
<b>Other</b>		
Gabapentin	3-5 mg/kg PO q8-24h	(1) Neuropathic pain; 1-2 wk to full effect.

### Local Block Analgesics

Agent(s)	Dose	Comment
Bupivacaine	1-2 mg/kg SC	(1)
Lidocaine (1-2%)	1-2 mg/kg SC	(1)

### Reversal Agents

Agent(s)	Dose	Comment
Atipamezole	10X the mg/kg dose of dexmedetomidine (e.g. for 0.04 mg/kg dexmed, give 0.4 mg/kg atipamezole). Give IM.	For commercial Dexdomitor and Antisedan, this equates to the same volume of Antisedan as Dexdomitor.
Naloxone	0.01-0.04 mg/kg SC, IM, IV	(1)
Yohimbine	0.2-0.5 mg/kg IV	(1)

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## DOGS

When formulating a sedation or anesthesia plan, it is important to consider signalment and health status, as well as the procedure performed. Food should be withdrawn 8 – 12 hours prior to sedation and general anesthesia to lessen the risk of vomiting, regurgitation, and aspiration. Prolonged fasting of very young and/or thin animals may lead to hypoglycemia. Consider fasting from food for 4 – 6 hours with provision of water until the time of sedation or premedication.

### Sedatives and Premedication

Agent(s)	Dose	Comment
<b>Phenothiazines + Combinations</b>		
Acepromazine	0.01 – 0.1 mg/kg IM, IV	Duration 6 - 8 hours Slow onset (up to 45 minutes) No analgesic properties
Acepromazine + Opioid	0.05 – 0.1 mg/kg IM, IV	Duration 4 – 6 hours Analgesic effect dependent on opioid
Acepromazine + Opioid + Ketamine	Acepromazine: 0.05 – 0.1 mg/kg IM Ketamine: 1 – 5 mg/kg IM	Duration 6 – 8 hours Analgesic effect dependent on opioid Higher dose of ketamine may result in anesthesia
Acepromazine + Opioid + Alpha 2 agonist	Acepromazine: 0.1 – 0.03 mg/kg IM Medetomidine 5 – 10 mcg/kg IM Dexmedetomidine 2.5 – 5 mcg/kg IM	Duration 6 – 8 hours Analgesic effect dependent on opioid
<b>Alpha 2 adrenoreceptor agonist</b>		
Dexmedetomidine	3 – 10 mcg/kg IM, IV	Reversal: Atipamezole
Medetomidine	5 – 20 mcg/kg IM, IV	Reversal: Atipamezole
Dexmedetomidine/Medetomidine + Opioid	Dexmedetomidine: 3 – 6 mcg/kg IM, IV Medetomidine: 5 – 10 mcg/kg	
<b>Benzodiazepine</b>		
Midazolam/Diazepam + Opioid	Midazolam/ Diazepam: 0.1 – 0.4 mg/kg IM, IV	Duration Up to 2 hours Reversal: Flumazenil Good option for sick or very old animals. Excitement and poor sedation in healthy animals.
Midazolam/Diazepam + Ketamine	Midazolam/Diazepam: 0.1 – 0.4 mg/kg IM, IV  Ketamine: 2 – 5 mg/kg IM, IV	Duration Up to 2 hours Reversal: Flumazenil
Alfaxalone + Opioid	Alfaxalone: 1 – 2 mg/kg IM	Duration ~30 minutes IM doses impractical in dogs >10 kg due to injection volume

		Monitoring oxygenation and ability to provide recommended
Propofol + Fentanyl	Propofol: 0.5 mg/kg IV increments Fentanyl: 2 – 5 ug/kg IV	Duration ~15 minutes IV route only and causes heavy sedation and may induce anesthesia. Be ready to intubate

### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	1 – 3 % Maintenance	Administer via precision vaporizer and compressed oxygen
Sevoflurane	2 – 3% Maintenance	Administer via precision vaporizer and compressed oxygen

### Injectable Anesthesia

Agent(s)	Dose	Comment
Propofol	1-10 mg/kg IV	Onset 60-90 seconds Duration 10 minutes
Alfaxalone	Up to 3 mg/kg IV	Onset 60-90 seconds Duration 10 minutes
Ketamine Diazepam	5 mg/kg ketamine IV or IM 0.25 mg/kg diazepam IV or IM	Onset 3 minutes Duration up to 60 minutes Midazolam can be used in place of diazepam
Tiletamine Zolazepam	1-4 mg/kg IV 3-10 mg/kg IM	Provide premedication to avoid rough and dysphoric recoveries
Etomidate	Up to 3 mg/kg IV	Onset 60-90 seconds Duration 10 minutes Use with midazolam to offset myoclonus

### IV Infusion Rates

Agent(s)	Dose	Comment
Propofol	12 - 30 mg/kg/hour IV	
Alfaxalone	4 – 9 mg/kg/hour	Respiratory depression commonly reported. Oxygen supplementation advised.

### Analgesia

Agent(s)	Dose	Comment
<b>NSAIDS</b>		
Carprofen	4 mg/kg IV, SQ, or PO 2 mg/kg PO (maintenance)	Dose interval 12-24 hours
Meloxicam	0.2 mg/kg SQ or PO 0.1 mg/kg PO (maintenance)	Dose interval 24 hours
Robenacoxib	2 mg/kg SQ 1 mg/kg (maintenance)	Dose interval 24 hours
Grapiprant	2 mg/kg PO	Dose interval 24 hours For treatment of osteoarthritis in adults
<b>OPIOIDS</b>		
Morphine	0.1 – 0.5 mg/kg IV, IM, SQ	Duration 2-6 hours May cause vomiting
Methadone	0.1 – 0.5 mg/kg IV, IM, SQ	Duration 2-6 hours May cause vomiting
Hydromorphone	0.05 – 0.1 mg/kg IV, IM, SQ	Duration 4 hours May cause vomiting
Meperidine (Pethidine)	3-5 mg/kg IM, SQ	Duration 1 – 1.5 hours
Fentanyl	1 – 2 mcg/kg IV – loading dose 3 – 10 mcg/kg hour IV infusion 3 – 5 mcg/kg/hour transdermal	Duration 20 – 30 minutes IV Transdermal duration 72 hours
Buprenorphine	0.01 - 0.03 mg/kg IV, IM, SQ, PO, transmucosal	Duration 4-12 hours
Buprenorphine-ER	0.03-0.06 mg/kg SC	Give q72hrs
Butorphanol	0.1 – 0.4 mg/kg IV, IM, SQ	Duration 1.5 – 2 hours

	0.1 – 0.2 mg/kg/hour IV infusion	Antitussive properties
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### Local Block Analgesics

Agent(s)	Dose	Comment
Bupivacaine	Max safe dose 2 mg/kg Dose dependent on locoregional technique	Duration up to 12 hours
Lidocaine	Max safe dose 10 mg/kg Dose dependent on locoregional technique	Duration 1-2 hours
Ropivacaine	Max safe dose 3 mg/kg Dose dependent on locoregional technique	Duration up to 8 hours

## CATS

Cats should be fasted for 6-12 hours prior to anesthesia. This will help reduce the likelihood of vomiting before induction or during recovery. Water should not be withheld. Cats typically receive a pre-medication and sedation by intramuscular or intravenous injection. If IM injections are administered, the cranial thigh muscles or lumbar muscles should be used.

Cats are prone to laryngospasm during endotracheal intubation. For this reason, lidocaine spray is commonly applied to the laryngeal region. Benzocaine (Cetacaine©) spray should never be used for this purpose in cats because it can cause methemoglobinemia. Gas anesthesia can be maintained with a correctly fitted nose cone for uncomplicated or short procedures. Surgeries and complicated procedures often require endotracheal intubation and inhalant anesthetic for maintenance. Cats < 10-15 pounds should be placed on a non-rebreathing system (54).

### Pre-Medications

Agent(s)	Dose	Comment
Atropine	0.02-0.04 mg/kg IM, SQ, IV	Reduces bradycardia and hypersalivation (10)
Glycopyrrolate	0.011 mg/kg IM, IV	Reduces bradycardia and hypersalivation (10)

### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	1-3% Maintenance	Administer via precision vaporizer and compressed oxygen

### Injectable Sedatives for Induction of Anesthesia

Agent(s)	Dose	Comment
Acepromazine	Dose range: 0.01-0.10 mg/kg IM, SC, IV (slowly) Commonly used: 0.01- 0.03 mg/kg IM, SC, IV	Cat max dose: 1 mg. Note: FDA labeled dose (0.55-2.2 mg/kg) is considered 10X > than necessary per most clinicians. (10)
Midazolam	0.1-0.3 mg/kg SC, IM, IV	Combined with other premeds. DEA required. (10)
Dexmedetomidine	40 mcg/kg IM See dosing table in drug package	(10)
Xylazine	1.1 mg/kg IM, SC	Note: Except for its use as an antiemetic, most prefer using newer alpha-2 agonists in cats & dogs. (10)
Diazepam	0.1-0.3 mg/kg IV. Combination with opioids or alpha-2 agonists highly recommended.	Note: Due to rare idiosyncratic hepatic failure in cats, PO diazepam is often avoided. DEA required. (10)
Tiletamine Zolazepam	9.7-11.9 mg/kg IM (FDA-approved dose).	Similar to ketamine/valium. DEA required. (10)
Ketamine	10 mg/kg IM	DEA required. (1)

Midazolam	0.2 mg/kg IM	
Ketamine Medetomidine	5 mg/kg IM 15-20 mcg/kg IM	DEA required. (1)
Ketamine Butorphanol Acepromazine	5 mg/kg IM 0.2 m/kg IM 0.05 mg/kg IM	DEA required. (1)
Pentobarbital	1-3 mg/kg/hr IV CRI	For chemical restraint, mechanical ventilation advisable. DEA required. (10)
Propofol (Propoflo® 28)	Induction: 8-13.2 mg/kg IV slowly to affect over 60-90 sec  Maintenance: 1.1- 4.4 mg/kg/min IV slowly to affect over 60-90 sec	Wide dose range for induction & maintenance. No analgesic properties alone, monitor respiration closely. Refer to (10)

### Analgesia

Agent(s)	Dose	Comment
<b>OPIOID</b>		
Buprenorphine	0.01-0.03 mg/kg IM, IV, or buccal q 4-8 hr	DEA required. (10)
Buprenorphine SR™ Sustained Release	0.12 mg/kg SC q 72 hr	Manufacturer: ZooPharm No longer requires refrigeration. Prescription from RAR required (59) <a href="http://www.srvet.net/index.php/buprenorphine-hci-sr/companion-animals">http://www.srvet.net/index.php/buprenorphine-hci-sr/companion-animals</a>
Buprenorphine SR (Simbadol® [1.8 mg/mL])	0.24 mg/kg q 24h for up to 3 days. Give first dose ~ 1 hour pre-op.	(10)
Hydromorphone	0.01- 0.05 mg/kg/hr IV CRI following an initial loading dose of 0.025 mg/kg IV. Start at low end of CRI.  0.05–0.1 mg/kg IV, IM, SQ q 2–6 hr	DEA required. (10)
Butorphanol	0.4 mg/kg SQ q 6h for up to 2 days.  0.1-0.5 mg/kg IV, IM, SQ q 2-4 hr	FDA approved analgesia dose. DEA required. (10)
<b>NSAIDs</b>		
Carprofen (Rimadyl®)	4 mg/kg SQ or IV once given at time of anesthetic induction. Combine with an opioid.  2.2 mg/kg PO pre-op once.	Extra label in USA. (10)
Meloxicam (Metacam®)	0.3 mg/kg SC once.  For perioperative pain, 0.2 mg/kg SC once pre-op. Then after 24 hours, using an oral suspension, 0.05 PO q 24 hr for up to 2 days (extra label in USA).	See (10) for details. FDA labeled for single use only due to potential for acute renal failure with chronic admin. Extra label dosing and guidelines do however exist: <a href="http://www.icatcare.org/vets/guidelines">http://www.icatcare.org/vets/guidelines</a> <b>NOTE: Meloxicam SR is contraindicated in cats!</b>
Robenacoxib (Onsior®)	In cats > 4 months of age, 2 mg/kg SQ q 24 hr for up to 3 days. Give first dose ~ 30 min prior to surgery.	Do <b>not</b> use the oral tablets approved for use in dogs for cats. (10)

	In cats > 4 months of age, 1-2.4 mg/kg PO q 24h for up to 3 days. Give first dose ~ 30 min pre-op.	
<b>Feline Antinerve Growth Factor Monoclonal Antibody</b>		
Frunevetmab (Solensia®)	Target dose range of 1-2.8 mg/kg q 30 days.  Cats weighing 2.5-7.0 kg, give 7 mg (one vial) per cat.  Cats weighing 7.1-14.0 kg, give 14 mg (two vials) per cat.	For control of pain associated with chronic arthritis (10).

#### Local Block Analgesics

Agent(s)	Dose	Comment
<b>Lidocaine</b>	2-4 mg/kg for local blocks.	Can be diluted in equal parts saline for additional volume. (10)
<b>Bupivacaine</b>	1.1 mg/kg for local blocks.	(10)

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## SWINE

Documented anesthetic variability exists between domestic/conventional (Yorkshire, Duroc, Landrace etc.) and miniature/micro swing (Hanford, Yucatan, Gottingen etc.). Even within one breed of pig notable physiologic differences in response to specific anesthetic regimens have been observed. Even within one breed of pig, notable physiologic differences in response to specific anesthetic regimens have been observed. Most miniature pigs used in research weigh between 5-30 kg. This not only facilitates easier and safer handling, but also allows for the use of significantly smaller drug volumes compared to domestic pigs. Isoflurane is often considered the default general anesthetic for survival surgery in swine unless its use is contraindicated by the protocol. Whenever injectable anesthetics are used for maintenance anesthesia, they should be continuously infused, not delivered via repeated bolus injections (46). Because swine are very prone to laryngospasm during endotracheal intubation, the larynx is often sprayed with a topical anesthetic such as cetacaine® (Benzocaine 14.0%, Butamben 2.0%, Tetracaine Hydrochloride 2.0%) while being visualized with a laryngoscope. All pigs anesthetized for surgery or prolonged non-surgical procedures should be intubated so as to avoid fluid accumulation within the pharyngeal region. Intubation may be performed with pigs positioned in dorsal, ventral or lateral recumbency, however typically ventral is easiest for pigs > 50 kg (46).

### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	0.5-2.5% maintenance	Administered via precision vaporizer and compressed oxygen.
Nitrous oxide		As a 1:1 or 2:1 ratio with oxygen combined with isoflurane (can reduce iso requirement by 50%). Only for use with vacuum scavenging systems.

### Injectable Anesthesia

Agent(s)	Dose	Comment
Acepromazine	0.2-1.1 mg/kg IM, IV, SC	Sedation only. (1)
Midazolam Butorphanol	0.1- 0.5 mg/kg IM 0.1-0.3 mg/kg IM	Combined for moderate sedation for blood draw, hoof trim etc., will not produce general anesthesia. (46)
Acepromazine Midazolam Butorphanol	0.2-1.1 mg/kg IM 0.1- 0.5 mg/kg IM 0.1-0.3 mg/kg IM	Combined for heavy sedation for blood draw, hoof trim etc., will not produce general anesthesia. (46)
Ketamine	11-33mg/kg IM, IV	Use ¼ to ½ doses IV, slowly to effect (1, 46)
<b>Ketamine Xylazine</b>	<b>20-30 mg/kg IM, IV 2.0-3.0mg/kg IM, IV</b>	<b>Use ¼ to ½ doses IV, slowly to effect (1, 46)</b>
Ketamine Acepromazine	33.0 mg/kg IM, IV 1.1 mg/kg IM, IV	Use ¼ to ½ doses IV, slowly to effect (1, 46)
Ketamine Midazolam	33 mg/kg IM, IV 0.1-0.5 mg IM, IV	Use ¼ to ½ doses IV, slowly to effect (1, 46)
Ketamine Dexmedetomidine	10 mg/kg IM, IV 0.1 mg/kg IM, IV	Use ¼ to ½ doses IV, slowly to effect (1, 46)
Tiletamine -Zolazepam (Telazol®)	2-8.8 mg/kg IM, SC	Cardiovascular and respiratory depressive effects last longer than anesthesia effects following single admin. (46)
Tiletamine/ Zolazepam (Telazol®) Xylazine	4-6 mg/kg IM, SC 2.2 mg/kg IM, SC	Cardiovascular and respiratory depressive effects last longer than anesthesia effects following single admin. (46)
Tiletamine/Zolazepam (Telazol®) Ketamine Xylazine	4.4 mg/kg IM, SC 2.2 mg/kg IM, SC 2.2 mg/kg IM, SC All combined in one syringe	Cardiovascular and respiratory depressive effects last longer than anesthesia effects following single admin; Useful in pigs > 50 kg, less volume to inject compared to ketamine. (46)
Propofol (PropoFlo28®)	0.83-1.66 mg/kg IV 12-20 mg/kg/hr CRI	(46)

### Analgesia

Agent(s)	Dose	Comment
Buprenorphine	0.01-0.05 mg/kg IM, IV, SC	Give q8-12hr (46, 54)
Buprenorphine-ER	<b>0.12-0.24 mg/kg SC</b>	Give q48hr. Requires veterinary script
Fentanyl	0.05 mg/kg IV followed by 0.03-0.2mg/kg/hr	Note: Fentanyl transdermal patch efficacy is highly variable in swine and thus are not recommended as a primary means of analgesia. Must be

		monitored closely if used; overdosing is possible. (46)
Hydromorphone	0.1-0.2 mg/kg IM or IV	Give q2-4hrs for moderate to severe pain.
Carprofen (Rimadyl)	2-3 mg/kg SC, PO	Give q24hrs. (46)

### Local Block Analgesics

Agent(s)	Dose	Comment
<b>Lidocaine 1%</b>	2-8 mg/kg	Typically given at 2 mg/kg. Dilute by 50% if using 2% lidocaine. Lasts 90-180 minutes.
<b>Bupivacaine</b>	2 mg/kg	Lasts 180-300 minutes.

## RUMINANTS: SHEEP & GOAT

Pre-operative fasting of ruminants for up to 48 hours is recommended to reduce rumen volume. Even appropriately fasted ruminants will require the placement of a stomach tube to prevent bloating and to protect the airway from regurgitated rumen contents. Excessive fasting beyond 48 hours should be avoided as it often results in decreased rumen flora, hypomotility, and ketosis in severe cases.

Administration of anticholinergics (atropine, glycopyrrolate) to decrease saliva volume is not recommended in ruminants because only the water component of saliva is reduced; the viscous mucus is left behind and may interfere with intubation. In addition, these drugs may impair GI motility (1).

Ventilation is easily impaired due to both bloating and the mass of abdominal viscera. The use of positive pressure ventilation is highly recommended. During inhalation anesthesia, the palpebral reflex is depressed but not lost. The eyeball is rotated medioventrally when the patient is in a light surgical plane of anesthesia and is in the center during deep anesthesia. A dilated pupil is a sign of anesthetic overdose.

### Inhalant Anesthesia

Agent(s)	Dose	Comments/Reference(s)
Isoflurane	3-5% Induction 1-3% Maintenance	Administer via precision vaporizer and compressed oxygen

### Injectable Anesthesia

Agent(s)	Dose	Comments/Reference(s)
Acepromazine	0.02 mg/kg IV, IM	Pre-anesthetic/sedative. Long duration of action. Will prolong anesthesia recovery. Not an analgesic. Minimal respiratory depression (72)
Acepromazine Buprenorphine	0.05- 0.1 mg/kg IM 0.005-0.01 mg/kg IM	Pre-anesthetic/sedative (1, 50)
Xylazine	Sheep and goats: 0.01-0.02 mg/kg IV or 0.1-0.3 mg/kg IM Calf: 0.05-0.3 mg/kg IV, IM	Pre-anesthetic/sedative (1, 72)
Ketamine Diazepam	4 mg/kg IV 0.4 mg/kg IV	Induction; Rapid onset, duration of effect 15 to 20 min allows intubation; minimum regurgitation; little cardiopulmonary dysfunction (1, 72)
Ketamine Xylazine	Sheep: 3-5 mg/kg IM 0.03-0.05 mg/kg IM  Goat and calf: 3-5 mg/kg IM, IV 0.05- 0.10 mg/kg	Good injectable combination for short procedures, moderate muscle relaxation (1,50)



	IM, IV	
Propofol (Propoflo 28 ®)	4-6 mg/kg induction 0.4-0.5 mg/kg/min CRI	Supplementation with local anesthesia or other systemic analgesic if surgery is performed (1, 50, 54, 72)

### Analgnesia

Agent(s)	Dose	Comments/Reference(s)
<b>OPIOID</b>		
Butorphanol	0.05-0.5 mg/kg IM, IV, SQ q4-6 hr	DEA required (72)
Buprenorphine	0.005-0.01 mg/kg SQ 0.005-0.1 mg/kg IM, IV q4-6 hr	DEA required (72)
Buprenorphine-ER	0.27mg/kg SC	Give q72hr. Requires veterinary script.
<b>NSAID</b>		
Carprofen (Rimadyl ®)	2-4 mg/kg SC q 24 hr	Long plasma half-life 48-72 (1, 10, 50)
Flunixin (Banamine ®)	1.1- 2.2 mg/kg IM, PO q 8-24 hr 1 mg/kg IV q8-24hr	Dosing should be limited to a maximum of four doses to minimize the adverse effects of renal toxicity and gastric hemorrhage (10, 72)
Phenylbutazone	5-10 mg/kg IV, PO q 24 hr	(10)

### References

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## RABBITS

Pre-operative fasting of rabbits is not advisable for several reasons including the inability of this species to vomit, naturally prolonged gastric emptying times (in excess of five days), and the potential for the rapid development of a metabolic acidotic and/or hypoglycemia state. Furthermore, post-operative gastrointestinal stasis is fairly common in rabbits and should be mitigated by providing an ample amount of fresh timothy hay to the animal upon return to home cage. Ideally rabbits should regain consciousness and begin eating as soon as possible. Additional supportive care measures for rabbits exist (pro-motility drugs etc.) and may be recommended by an RAR veterinarian. Anesthetic drug dosages for rabbits are higher than for similarly sized cats or dogs. It is recommended each rabbit be weighed prior to the administration of drugs. In addition, age, sex, breed, pregnancy status and strain and time of day may affect the response to anesthetic agents. Drugs given intravenously should be given to effect. Endotracheal intubation should be used whenever possible in particular for procedure lasting more than 20-30 minutes. Recommended ET tube sizes range from 2.5mm to 4.0mm inner diameter, uncuffed. A non-rebreathing circuit (e.g. Jackson Rees) should be used with rabbits receiving gas anesthesia. In addition, supplemental oxygen is recommended for animals given barbiturates or other injectable agents that reduce respiratory function. The depth of anesthesia is best indicated by response to ear pinch. The reliability of accepted reflex tests as indicators of anesthesia level have been rated (most to least reliable) as follows: pinna, pedal, corneal, palpebral reflex (60). Rabbits have high levels of circulating catecholamines. Sudden awareness of pain can lead to breath holding, which further increase circulating catecholamines and the possibility of fatal cardiac arrhythmias.

### Inhalant Anesthesia

Agent(s)	Dose	Comments
<b>Isoflurane</b>	3-5% (for induction) 1-3% (for maintenance)	Administer via precision vaporizer and compressed oxygen

### Injectable Anesthesia

Agent(s)	Dose	Comments
Alfaxalone	2 mg/kg IV (to effect for induction)	
Acepromazine	0.25-1 mg/kg IM	Typically with other sedatives.

Ketamine	25-50 mg/kg IM	
Ketamine: Acepromazine	25-50 mg/kg: 0.25-1 mg/kg IM	
<b>Ketamine: Xylazine</b>	35 mg/kg: 5 mg/kg IM	
Ketamine: Midazolam	20-40 mg/kg : 0.5-1.5 mg/kg IM	Note: sedative effects of midazolam may last several hours
<b>Ketamine: Dexmedetomidine</b>	20-40 mg/kg: 25-40 mcg/kg IM	
Propofol bolus (induction)	3-10 mg/kg IV (to effect for induction)	

#### Constant Rate Infusions (IV)

Agent(s)	Dose	Comments/Reference(s)
Ketamine: Fentanyl	5-20 µg/kg/h: 0.3-0.4 mg/kg/h IV	
Propofol (surgical maintenance)	0.2-0.6 mg/kg/min IV	

#### Analgesia

Agent(s)	Dose	Comments
OPIOID		
Buprenorphine	0.01 – 0.05 SC, IM, IV	Give q6-12hrs
Buprenorphine ER	0.12 mg/kg SC	Give q72hrs
Butorphanol	0.1-0.8 mg/kg SC	Give q4hrs
NSAIDs		
Carprofen	2-4 mg/kg SC	Give q24hrs
Ketoprofen	1-2 mg/kg q24h IM, SC	
Meloxicam	0.3 mg/kg q24h SC 1 mg/kg q24h PO	
Meloxicam SR	0.6 mg/kg SC	Give q72hrs

#### Local Block Analgesics

Agent(s)	Dose	Comments
Lidocaine (1-2%)	2-4 mg/kg	Onset: 5-10 min, Duration: 0.5-1 hr (21)
Bupivacaine	1-2 mg/kg	Onset: 15-30 min, Duration: 4-8 hr (21)

## Non-Human Primates

When considering pre-anesthesia, anesthesia, and analgesia for nonhuman primates, one needs to consider the diversity of species and appropriate dosage and choice of drug. There is a wide range of body size and types of primates, and extrapolation of doses from primate to primate should be avoided. There are significant differences in responses to anesthetic agents between Old World (e.g. macaques, baboons) and New World (e.g. marmosets, owl monkeys) nonhuman primates. Generally, New World monkeys require higher doses of anesthetics per kilogram body weight compared to Old World monkeys (ketamine), although this is not the case with all agents (opioids). Careful clinical examination should be performed prior to any anesthetic procedure. Both Old World and New World nonhuman primates may vomit upon induction so withholding food for 12-16 hours and water 2 hours (depending on procedure) is advisable (64). An exception to this are nonhuman primates < 2 kg; food should not be withheld longer than 4 hours due to their higher metabolic rate and propensity to develop hypoglycemia (64). Most sedatives and anesthetics are given IM in consideration of safety for the animal handler. After initial IM sedation, additional drugs can be administered IV and/or the monkey can be intubated and maintained under gas anesthesia. Depending on the species and surgical procedure, adjunct pre, intra and post-operative supportive care measures may be indicated. Examples include 1) use of pre and/or post-operative gastroprotectants (famotidine, omeprazole etc.) and anti-emetic/promotility drugs (maropitant, Cerenia ®) for GI surgeries (or any long duration procedure) 2) use of 5% dextrose in lactated ringers solution as the intra-operative IV fluid of choice for marmosets (any age) or macaques (typically only infants unless otherwise indicated based on blood work).

### OLD WORLD NON-HUMAN PRIMATES: MACAQUES AND BABOONS

#### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	1-3%	Administer via vaporizer and compressed oxygen

#### Injectable Anesthesia

Agent(s)	Macaque Dose	Baboon Dose	Comment
Ketamine	10-15 mg/kg IM		Moderate sedation, immobilization
Ketamine + dexmedetomidine*	5 mg/kg ketamine and 0.025 mg/kg dexmedetomidine IM		Moderate sedation, reversible* Good for quick procedures **Do not use in animals with sick animals, animals with cardiac disease or advanced age.
Ketamine + xylazine*	5-10 mg/kg ketamine and 0.5-1mg/kg xylazine		Moderate sedation with muscle relaxation, reversible*
Ketamine + midazolam	8 mg/kg Ketamine and 0.2 mg/kg Midazolam IM	5 mg/kg Ketamine and 0.1 mg/kg Midazolam IM	Moderate Sedation
Midazolam	0.05-0.1 mg/kg IM, IV		Mild muscle relaxant
Propofol	Induction: 2.5-5 mg/kg IV bolus Maintenance: 0.3-0.4 mg/kg/min CRI		For facilitating intubation and/or total intravenous anesthesia
Telazol (tiletamine/zolazepam)	4-6 mg/kg IM		
Pentobarbital	20-30 mg/kg <i>slowly</i> to effect		Generally, not recommended for sedation; preferred for euthanasia only due to considerable variation between species and the inability to modulate depth of anesthesia. Severe respiratory depression.
Yohimbine	0.1-0.5 mg/kg IM, IV*		IV emergency situations only. Reversal for xylazine.
Atipamezole	0.25 mg/kg IM, IV*		IV emergency situations only. Reversal for dexmedetomidine.

### Analgesia

Agent(s)	Dose	Comment
Buprenorphine	0.01-0.03 mg/kg IV, IM, SC q6-24 hours	Opioid
Buprenorphine Extended Release	0.2 mg/kg SC q48 hours	Long-lasting opioid
Carprofen	2-4 mg/kg SC, PO q24 hours	NSAID; better for anti-inflammatory purposes; do not combine with steroids as it is more likely to GI ulceration

### Local Block Analgesics

Agent(s)	Dose	Comment
Bupivacaine	2 mg/kg (max) SC	Longer lasting
Lidocaine	1-3 mg/kg SC	

## NEW WORLD NON-HUMAN PRIMATES: MARMOSETS

### Inhalant Anesthesia

Agent(s)	Dose	Comment
Isoflurane	0.5-2.0% (ideally remain below 1.5%)	Administer via precision vaporizer and compressed oxygen. Moderate to severe respiratory depression possible; careful monitoring is essential.

### Injectable Anesthesia

Agent(s)	Dose	Comment
Ketamine	Ketamine 15-20 mg/kg IM	Moderate sedation, immobilization (1)
Midazolam	Midazolam 0.03-0.09 IM, IV	Sedative, muscle relaxation. Not general anesthetic alone. (1,64)
Ketamine Acepromazine	20-40 mg/kg IM 0.1-0.75 mg/kg IM	Used for major marmoset surgeries, neuroimaging and ABRs (+/- isoflurane for maintenance). Ace dose most often used: 0.50 mg/kg.
Ketamine Midazolam	20-40 mg/kg IM 0.03-0.09 mg/kg IM	Used for major marmoset surgeries, neuroimaging and ABRs. Midazolam dose most often used: 0.05 mg/kg. Superior to ket/ace for muscle relaxation.
Propofol (PropofloFlo ® 28)	Slow IV bolus to effect over 60-90 sec followed by 0.9 mg/kg/min	Requires CRI, dose varies widely (64), Maintenance anesthetic of choice for some unconscious neuroimaging (physiological fMRI) studies in combination with agent such as fentanyl
<b>Alphaxalone (Alfaxan ®)</b>	5- 12 mg/kg IM (surgery=10-12 mg/kg IM (71)). CRI = 2-5 mg/kg bolus IV followed by 0.17 mg/kg/min IV *IV bolus & CRI are often preceded by initial IM dose of ketamine or alphaxalone (64)	Neuroactive steroid labeled as an induction agent (IV delivery), but safe and effective when given IM for short to moderately long procedures. Repeated IM redosing is also safe. Minimal to no cardiovascular or respiratory depression.

### Analgesia

Agent(s)	Dose	Comment
Buprenorphine	0.005-0.01 mg/kg SC, IM q 8-12hr (1) Full or partial reversal with naloxone (0.1 mg/kg IM, IV Repeat admin PRN based on clinical response)	In general NW spp. are very sensitive to opioids and may exhibit profound respiratory depression following admin of doses > 0.01 mg/kg. <u>NEVER GIVE PRE-OPERATIVELY.</u>
Buprenorphine-ER	0.1-0.2 mg/kg SC	Give q3-3.5d. Use with caution. May cause ataxia, lethargy, and inappetence.
Meloxicam (Metacam ®)	Loading dose: 0.2 mg/kg SC once followed by 0.1 mg/kg q 24 hr x 2-3 days PRN	

Carprofen	2.2-4.4 mg/kg PO, SC	Give q12-24hrs.
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**Local Block Analgesics**

Agent(s)	Dose	Comment
Lidocaine	2-4 mg/kg	