University of Colorado
Denver | Anschutz Medical Campus

# CU Denver Veterinary Formulary

***Edition 4.11***


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## I. Introduction and Use of this Formulary

Basic Definitions:

- *Anesthesia*: central nervous system depression that provides amnesia, unconsciousness and immobility in response to a painful stimulation. Drugs that produce anesthesia may or may not provide analgesia (*1, 2*).
- *Analgesia*: The absence of pain in response to stimulation that would normally be painful. An analgesic drug can provide analgesia by acting at the level of the central nervous system or at the site of inflammation to diminish or block pain signals (*1, 2*).
- *Sedation*: A state of mental calmness, decreased response to environmental stimuli, and muscle relaxation. This state is characterized by suppression of spontaneous movement with maintenance of spinal reflexes (*1*).

Animal anesthesia and analgesia are crucial components of an animal use protocol. This document is provided to aid in the design of an anesthetic and analgesic plan to prevent animal pain whenever possible. However, this document should not be perceived to replace consultation with the university's veterinary staff. As required by law, the veterinary staff should be consulted to assist in the planning of procedures where anesthetics and analgesics will be used to avoid or minimize discomfort, distress and pain in animals (*3, 4*). Prior to administration, all use of anesthetics and analgesic are to be approved by the Institutional Animal Care and Use Committee (IACUC).

For each species listed in the formulary, the most commonly used anesthetic and analgesic drugs used on this campus are highlighted. These drugs can be considered the "front-line" of care. However, based on the research, procedure, and need, the most common drugs may not suffice and an individual drug or a combination of drugs may be indicated to provide the safest and effective anesthetic and analgesic plan.

Dosages or dose-ranges are obtained from a variety of laboratory animal medicine and veterinary references which fail to precisely agree. Where dosage ranges are provided, the effective minimum and safely administered maximum are represented. Selection of dose can be based on veterinary recommendation, literature references, or procedural experience. Yet, when listing these drugs in an animal use protocol, drugs should be listed with approximate dose ranges. This provides flexibility for titration up or down for the individual animal or for the particular application.

For **anesthetic drugs**, the duration of action has not been provided. Duration of anesthesia is influenced by the drugs used, strain, age, sex, body weight, procedure performed and the amount of stimulus during the procedure. As a result, any published duration of action would be a generalization. For assistance in judging duration of action, consultation with a veterinarian is ideal when developing an anesthetic regimen. Due to all the factors that influence duration of anesthesia, anesthetic drugs should always be titrated to effect. If anesthesia is being maintained by a gas anesthetic (eg. Isoflurane) titration of anesthetic depth can be controlled almost immediately by adjusting the amount of anesthetic gas being administered to the animal. In addition, anesthetic duration can be extended for as long as the anesthetic gas is administered. In contrast, injectable anesthetics do not have this flexibility such that once a dose has been administered, it cannot be "removed" to end anesthesia to coincide with the end of the procedure. However, reversal drugs do exist for some of the drugs used in anesthetic combinations such as Dexmedetomidine, which is efficiently reversed by Atipamezole (see $\alpha_2$ antagonists below). In addition, injectable anesthetics may need to be re-administered so the anesthetic can initiate anesthesia if not achieved after the initial dose or accommodate the duration of the procedure. As a generalization, it is often recommended to re-administer 25-30% of the initial dose of the injectable anesthetic to lengthen the surgical anesthesia time. It is not acceptable to perform a surgical procedure unless the animal is fully anesthetized. Thus, when laboratory experience with injectable anesthetics finds that the recommended dose ranges are consistently too high (prolonged anesthesia or long recovery) or too low (return of reflex requiring repeated administration of drugs) for the procedure, the veterinary staff should be contacted. With veterinary consultation, further flexibility can be provided to more accurately titrate dosages prior to submitting a protocol modification to the Institutional Animal Care and Use Committee.

Independent of the method of anesthesia or duration of the procedure, animals should be monitored until awake, also referred to as "Recovered." Recovery from anesthesia is indicated by the ability to right themselves when laid on their side, maintain a sternal body position, and demonstrate spontaneous movement in response to environmental stimulation such as cage manipulation. Monitoring recovery

allows for confirmation that animals will have negligible risk of harm from cage mates and be able/capable to reach water after-hours. In addition, without monitoring the duration of recovery, anesthetic dose cannot be titrated to effect which may result in prolonged anesthesia and recovery for a relatively brief procedure. As a result, plans for intra- and post-operative monitoring must be included in the IACUC protocol, and then practiced as written.

For **analgesic drugs**, doses and frequencies of administration are more difficult to gauge even with close clinical observation for discomfort. As a result, administration frequencies for analgesics are provided as strict guidelines supported by pain research in laboratory animal species or the standard of care in veterinary medicine. If an alternative regimen is desired, consultation with a veterinarian is required. A prime example of the importance of considering administration frequencies in analgesic use is the consideration for overnight pain management. Most of the opioid analgesics (Buprenorphine, Fentanyl, Butorphenol, Oxymorphone, etc.) administered at 5:00 PM will not be effective at 8:00 AM the next morning. Thus, administration after typical business hours, use of extended release formulations, and/or trans-dermal patch can be considered depending on the species. Current longer-lasting non-steroidal anti-inflammatory analgesics (NSAIDs) [Meloxicam, Carprofen, Flunixin, Ketoprofen, etc.] analgesics have longer durations of action than opioids, and can be administered in conjunction with opioids to increase potency of effect and duration of action.

Independent of the analgesic drug(s) selected, the ideal administration regimen of analgesia includes pre-emptive (i.e. pre-surgical, pre-procedural) analgesic administration. This allows the analgesic to take effect prior to anesthesia so that the beneficial analgesic effects are experienced as the anesthesia is wearing off. This method of pre-emptive administration effectively prevents sensitization of pain sensory mechanisms which will prevent the “ramp-up” of pain sensation. Once ramp-up occurs, the threshold of pain stimulus is lowered thus requiring higher doses of analgesic for longer duration to control pain and discomfort as compared to an animal where analgesics were provided before the procedure. Prior administration can effectively be achieved by administering the analgesic regimen at least 30 min to 4 hrs prior to the potentially painful portion of the procedure.

In rodent species, historically, the use of analgesics such as Acetaminophen (Children’s Tylenol® Elixir) and Ibuprofen (Children’s Advil® Elixir) have been administered in the drinking water for post-surgical procedures. This was performed based on the assumption that continuous administration of drug by consumption in the water would provide a hands-off, stress-free, continuously-administered level of analgesic therapy. With continued investigation, it has been demonstrated that water and food consumption post-surgically and/or post-anesthesia are neither constant nor consistent (*5*-*9*). As a result, analgesics may not be consumed by the patient. “Confirmed administration” is encouraged by routes such as injection or oral/gastric gavage to insure that the patient receives the appropriate dose of medication to better manage discomfort.

Independent of the quality of design and integration of an anesthetic and analgesic plan into a research protocol, that plan is only as good as the skill and care with which it is applied. Training is available from the veterinary staff of the Office of Laboratory Animal Resources through routinely scheduled classes or by request for all personnel that work with laboratory animals.

## II. Drug Considerations

**Inhalant agents: Isoflurane (Forane®, Iso, IsoFlo®)**
Isoflurane is the first choice of anesthetic used for animal restraint or surgical procedures in laboratory animal species. Isoflurane is delivered via a nose-cone and inhaled in rodents or provided through an intratracheal tube in larger species. The concentration of drug can be administered to effect by adjusting the percent of displacement of $O_2$ with a precision vaporizer and compressed $O_2$. Maintenance anesthesia is typically between 1.5-3% Isoflurane. Induction of anesthesia with gas is typically achieved with < 2 min exposure to 3-5% Isoflurane.

Advantages: Rapid induction and recovery. A precision vaporizer provides the ability to precisely titrate the level of anesthesia during a procedure. Liquid Isoflurane is not a DEA controlled drug.
Disadvantages: Upfront cost associated with a precision vaporizer; requires either passive or active scavenging of waste and exhaled anesthetic gas; occupational health exposure to anesthetic gas should be limited; prolonged analgesic effect is not achieved after the animal is awake; depressed respiratory rate and decreased blood pressure.

Additional Notes: Advantages typically outweigh disadvantages as gas anesthesia is the first recommendation for anesthetic administration due to rapid induction, recovery, and precise dose titration during the procedure. In addition, the duration of anesthesia can be easily adjusted for a variety of procedures ranging from 30 seconds up to many hours. To overcome cost and logistics, the CCM provides and maintains precision vaporizers with accompanying compressed $O_2$ for use while within the animal facilities. Concurrent use of analgesics such as opioids or NSAIDs is encouraged as Isoflurane has no analgesic properties once the animal is awake from the procedure. Occupational exposure is always a concern. Gas anesthesia must be vented from the room (table-top back-draft vents, biosafety cabinet [BSC] with 100% exhaust outside the building) or filtered through passive scavenging using F/Air® activated charcoal canisters. F/Air® canisters must be weighed on a very regular basis and replaced before the canister gains 50 grams of weight during use.

**Cyclohexamines: Ketamine (Ketoset®), Tiletamine**
Ketamine is the most commonly used injectable anesthetic used in a variety of species. However, Ketamine used as the sole anesthetic is not recommended. In most cases, Ketamine is used in combination with other injectable agents such as $\alpha_2$ agonists or benzodiazepines to reduce or eliminate many of the less desirable side effects if used alone. In rodents, Ketamine combined with Xylazine or Ketamine + Xylazine + Acepromazine are the preferred anesthetics when gas anesthesia cannot be used.

Advantages: Ketamine has a wide margin of safety in most species; residual analgesic effect following anesthetic recovery, most commonly used drug (in combination) for injectable anesthesia in rodents.
Disadvantages: Ketamine alone does not provide muscle relaxation and muscle spasms may be observed; DEA license required for use as Ketamine is a Class III controlled substance; surgical anesthesia may be limited depending on the species; prolonged recovery as compared to gas anesthetics (true for any injectable anesthesia)

Additional details about Ketamine combinations:

**A) Ketamine + Xylazine** or **Ketamine + Xylazine + Acepromazine**. Both or all 3 drugs can be mixed in a single syringe prior to administration. Ketamine + xylazine (with or without acepromazine) is the most common injectable anesthetic cocktail used in rodent species. In rodents, the addition of acepromazine to the ketamine/xylazine cocktail increases the depth of

anesthesia and substantially prolongs the duration of anesthesia as well as recovery time (*10*). The benefit of adding acepromazine to the combination will be dependent on the duration of anesthesia needed for the procedure. If following the first injection of anesthetic the animal does not achieve the desired level of anesthesia, it is generally recommended to re-dose with 25% of the initial dose of the cocktail used. If after re-dosing, the animal still has a withdraw reflex (i.e. toe pinch present), re-dosing as second time increases the potential for surgical complications and death. It is recommended to consult with a veterinarian. If after an adequate surgical plain is achieved and withdraw response returns yet additional surgical time is needed, it is recommended to re-dosing with either 50% of the initial dose of ketamine only, or 25% of the initial ketamine + xylazine dose (*11*). It has been demonstrated that the anesthetist should wait for the return of a toe pinch reflex before administering additional anesthetics to avoid unacceptable mortality. It should be known that the duration of action of the $\alpha_2$ agonist (xylazine, Dexmedetomidine, etc.) is much longer than the duration of effect of ketamine. Acepromazine should never be re-dosed in rodents due to the long duration of effect.

**B) Ketamine + Diazepam:** Both drugs can be mixed in a single syringe prior to administration. Advantages include limited cardiovascular effects including minimal hypotension as compared to Ketamine/Xylazine combinations. However, in rodents, Ketamine/Diazepam only provides light anesthesia so it may only be appropriate for chemical restraint. As a result, this is a relatively infrequently used anesthetic option in rodents. However, this combination provides rapid induction of anesthesia in cats with favorable duration.

**C) Tiletamine + Zolazepam (Telazol®):** Tiletamine is a similar drug as Ketamine and is available already formulated with Zolazepam under the trade name Telazol®. In combination, Telazol® is very similar to the anesthetic combination of Ketamine and Diazepam. Primarily used in larger species such as cats and pigs. The primary advantage is that a smaller injection volume is needed to induce sedation/anesthesia. However, this drug combination is not considered safe for use in rabbits. Once Telazol® has been reconstituted, discard after 4 days if stored at room temperature or after 14 days if stored refrigerated.

**Alpha-2 Agonists: Dexmedetomidine (Dexdomitor®), Xylazine (Rompun®)**

Alpha-2 agonists are used for their sedative and analgesic properties in a variety of species. Used as the sole agent, they do not produce an adequate level of anesthesia for even minor surgical procedures. However, in combination with Ketamine, $\alpha_2$-agonists become much more useful and effective as anesthetics for surgical procedures.

Advantages: Produces analgesia of short duration; can be combined with Ketamine to produce adequate surgical anesthesia in many species; effects can be reversed with a subcutaneous $\alpha_2$ antagonists injection such as Atipamezole; not a DEA controlled drug; not irritating when administered IM or IP.
Disadvantages: Cardiovascular depression (decreased heart rate, cardiac output, and hypotension); transient hyperglycemia following administration which may have research significance; causes vomiting in cats.

Additional Notes: Dexmedetomidine vs. Medetomidine. The first generation medetomidine (Domitor®) contained two isomers of the compound, one active and one inactive. Through drug refinement, the company created the second generation formulation called Dexmedetomidine (Dexdomitor®) which contains only the active isomer of the drug. Because only the active form is present, it is considered twice as potent. Medetomidine (Domitor®) should no longer be available commercially. It has been suggested to re-calculate drug dose combinations that used medetomidine by dividing the medetomidine dose in half to provide the dose of dexmedetomidine, as it is twice as potent. However,

published formulations of drug combinations have either not taken this advice or have reduced other drug dosages in these combinations to compensate for the increased potency of dexmedetomidine. We suggest using caution when re-tooling drug combinations with dexmedetomidine, starting with half the medetomidine dose when using dexmedetomidine, then working up if either anesthesia depth or duration are not adequate.

**Alpha-2 Antagonists: Atipamezole (Antisedan®), Yohimbine**

Alpha-2 antagonists are used as reversal agents for $\alpha_2$ agonists. Administration at the end of a procedure where the anesthetic combination included xylazine or medetomidine, an $\alpha_2$ antagonist will aid in reducing anesthesia time and prompting anesthetic recovery. Atipamezole is 200 - 300x more selective for the $\alpha_2$ receptor than Yohimbine. Thus, as a reversal agent, Atipamezole will provide a more rapid displacement of the $\alpha_2$ agonist, providing a more rapid reversal than Yohimbine.

Advantages: Can reduce duration of sedation and anesthesia caused by $\alpha_2$ agonist.
Disadvantage: Reverses any analgesic benefit of $\alpha_2$ agonist; can cause muscle tremors, increased respiratory rate, and hyperemic mucous membranes; has no use as a stand-alone drug.

Additional Notes: Reversal is not required when using an $\alpha_2$-agonist in an anesthetic combination but can be utilized in situations to reduce prolonged recovery times. Atipamezole ($\alpha_2$ antagonist), was developed in conjunction with Medetomidine ($\alpha_2$ agonist) so that 5 mg of Atipamezole is used to reverse 1 mg of Medetomidine (*12*). Due to the high specificity of Atipamezole for the $\alpha_2$ receptor as compared to Xylazine, only 1 mg of Atipamezole is administered to reverse every 10 mg of Xylazine administered (*13*). Yohimbine is also an $\alpha_2$ antagonist and can be used to reverse Xylazine at a standard dose of 0.2 mg/kg, independent of the Xylazine dose administered. While both are reversal agents for α2 agonists, the onset of reversal of Yohimbine is much longer than that of Atipamezole due to differences in selectivity of the $\alpha_2$ receptor between the two drugs.

Table of alpha-2 antagonist reversal agents as referenced on previous page.

| **Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine)** | | |
|---|---|---|
| Atipamezole (Dexmedetomidine Reversal) | 10 mg for every 1 mg of Dexmedetomidine | Reversal |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine | Reversal |
| Yohimbine (Xylazine Reversal) | 0.2 mg/kg | Reversal |

**Benzodiazepines: Diazepam (Valium®), Midazolam, Zolazepam**

This class of drug can provide marked sedation in a variety of species; however, there is no analgesic effect. Used alone, these drugs will not provide a true anesthetic state as awareness persists with relaxation even at high dosages. As a result, these drugs are primarily used as sedative, pre-anesthetics and the induction of anesthesia but are never used alone to provide or maintain anesthesia.

Additional Notes: Benzodiazepines are DEA Class IV controlled substances. Midazolam is favored over Diazepam because pharmaceutical grade preparations of Diazepam are formulated in a non-water soluble compounds that should only be administered intravenously. Midazolam is water-soluble and is provided in preparations where intramuscular injections are acceptable.

**Barbiturates: Sodium Pentobarbital (Nembutal®), Methohexital, Thiopental**

Barbiturates function as $GABA_A$ agonists and are considered to be good anesthetic agents but provide unreliable sedation at low dosages and inadequate analgesic effect at any dose. Pentobarbital, the most commonly used drug of this class, is considered a long acting anesthetic. Methohexital and Thiopental

are considered short and ultra-short acting anesthetics and were more commonly used as induction agents in large animal species.

Advantages: Rapid anesthetic onset; provides a prolonged duration of surgical anesthesia; decades of use has characterized many research side effects; Pentobarbital is the active drug in manufactured euthanasia solutions (Euthasol®, Fatal-Plus®).

Disadvantages: Prolonged recovery time; inadequate analgesic properties; extremely expensive; narrow margin of safety; produces respiratory depression at higher dosages; non-rodent species may experience a distressful anesthetic recovery; DEA License required for use as a Class II controlled substance.

Additional Notes: Sodium pentobarbital is the primary active ingredient in Fatal Plus®, Sleepaway®, Euthasol®, Beuthanasia®-D, and VetOne Euthanasia Solution which are manufactured euthanasia solutions. In addition to pentobarbital, Euthasol® Beuthanasia®-D and VetOne Euthanasia Solution also contains the active ingredient phenytoin sodium, which is an antiepileptic drug which suppresses brain activity. All products contain non-active ingredients include preservatives and coloring. The preservatives (benzyl alcohol, isopropyl or ethyl alcohol) are bacterial static, preventing bacterial growth. The added coloring (blue or pink [Rhodamine B]) aid in identifying the solution while in the syringe, preventing confusion and inadvertent euthanasia of animals.

Pentobarbital administration at euthanasia dosages (3-5x anesthetic dose) initiates a rapid and deep anesthesia causing a dramatic decrease in blood pressure and blocking the respiratory centers in the brain stopping respiration, followed by halting of cardiac function. While pentobarbital sodium is the active ingredient in these solutions, the intent of these solutions is euthanasia. These solutions are not to be diluted to provide deep anesthesia for recovery procedures or prolonged anesthesia for terminal procedures. They can be used at lower dosages if the procedure that is being performed is leading to death, such as in transcardial perfusion with fixation solution or tissue harvest (*14, 15*). No unintended consequences have been reported on research results with the use of euthanasia solutions for euthanasia of research rodents or larger species.

Pentobarbital is the lone active ingredient in Fatal Plus® and Sleepaway®. As a result, they are considered DEA class II (CII) drugs. The addition of phenytoin sodium to pentobarbital has an impact on the DEA classification, making Euthasol®, Beuthanasia®-D, and VetOne Euthanasia Solution each a DEA class III (CIII) drug. For the end user, this is important because the DEA license must cover the DEA classification of drugs that will be purchased and additional paperwork (DEA Form 222) is required to order class II drugs, but not class III drugs.

**Opioids: Buprenorphine (Buprenex®), Oxymorphone, Fentanyl, Morphine, Butorphanol**

Opioid drugs produce their effect by binding three different receptors [mu (μ), kappa (κ), and delta (δ)] as either agonists, partial agonists or antagonists. The location of these receptors vary, but in general, reside within the brain and spinal cord.

Advantages: Provide potent analgesia; concurrent administration can lower the dose of inhalant or barbiturate general anesthetic for surgery; mechanism mediated by receptor binding in the brain and spinal cord; long history of use in research; reversible with Naloxone.

Disadvantages: DEA Controlled Class II-IV drugs; high potential for human abuse and addiction; relatively short duration of action; repeated use may result in tolerance development.

Additional Notes: Duration of effect has continuously hampered the use of opioids in research animals. In general, opioids are short acting drugs. The longest duration of effect by an injectable administration route is Buprenorphine which can provide analgesia for up to 12 hrs in some species. Transdermal patches have also been developed to provide longer duration of action up to approximately 3 days. However, these patches are physically limited to use in species larger than rabbits due to the size of the patches. Most recently, liposomal encapsulated opioids have been developed which are showing promise in providing 48-72 hrs duration of analgesia with one injection with Buprenorphine SR/ER LAB™ and Ethiqa XR™ (*16, 17*).

**Non-steroidal Anti-Inflammatory Drugs (NSAIDs): Carprofen (Rimadyl®), Meloxicam (Metacam®), Flunixin meglumine (Banamine®), Ketoprofen (Ketofen®), Ibuprofen (Advil®), Acetaminophen (Tylenol®)***

Members of this group represent 13 different classes of drugs which share inhibitory activity of the cyclooxygenase (COX) enzyme. The COX enzyme facilitates the production of Prostoglandin $G_2$ ($PGG_2$) which then follows a variety of enzymatic processes in the production of several compounds that are involved in normal physiological processes and production of Prostoglandin $E_2$ ($PGE_2$). $PGE_2$ specifically plays a role in the perception of pain in the periphery and within the central nervous system. Thus, blockade of $PGE_2$ by COX inhibition is effective in control of discomfort at the site of insult and within the central nervous system. Two forms of the COX enzyme have been well characterized (COX-1 and COX-2). As a result, COX inhibitors are often referenced as non-selective COX inhibitors or selective COX-2 inhibitors. This distinction has been made because inhibition of COX-2 is believed to be the predominant method of NSAID function to provide analgesia and anti-inflammatory action even though this "consensus" is still under debate. Over the past 10 years, several NSAIDs have emerged for veterinary use that are COX-2 selective, such as Carprofen and Meloxicam which can be administered once every 12-24 hours in most species.

Advantages: Newer drugs (Carprofen, Meloxicam) include a long duration of analgesic activity; newer drugs demonstrate analgesic quality that rivals some opioids; not a DEA controlled substance; there are multi-route administration methods for several NSAIDs; relative safety when administered at prescribed dosages.
Disadvantages: Contraindicated for inflammation models, infectious disease, or coagulation research due to anti-inflammatory properties; COX-1 side effects such as: gastrointestinal complications, prolonged coagulation times, and changes in kidney function with non-COX-2 selective forms.

Additional Notes: Analgesic combinations that include NSAIDs *plus* opioids would be considered an ideal combination for the control and prevention of discomfort due to the demonstrated harmony and difference in mechanism of action. In contrast, it is discouraged to combine multiple NSAIDs in combination or use NSAIDs in combination with steroids (Prednisone, Prednisolone, and Dexamethasone) as the incidence of complications increase. Oral dosing of analgesics following anesthesia results in questionable consumption of the drug due to decreased water consumption following anesthesia, as demonstrated in rodents. *For simplicity, acetaminophen is included here in the NSAID class, but is not technically an NSAID and works independently of COX-1 and COX-2.

*NSAID Dilution for Small Mammals: Personal communication with Pfizer Animal Health indicates that dilution of Carprofen (Rimadyl®) with sterile water has been reported in veterinary medicine for product dilution. Once diluted, the solution can be stored at ambient temperature for 30 days prior to disposal.(18)*

*Example of Carprofen Dilution: Dilutions of Carprofen can be made in a 3-10 mL, empty sterile vial with injection stopper. Manufacturer stock concentration of small animal Carprofen is 50 mg/mL. The dose for rodents is typically 5 mg/kg. For mice, it is assumed that most will weigh approximately 25-30 grams. This can vary significantly between strains and with age. Dilute 0.1 mL of the manufacturer stock Carprofen (50 mg/mL) into 3.9 mL of sterile saline (0.9% NaCl). This will give you a diluted stock concentration of 1.25 mg/mL so that you would give approximately 0.1 mL per 25 g of body weight of each mouse.*

**Local Anesthetics: Lidocaine, Bupivacaine (Marcaine®), Ropivacaine (Naropin®), Proparacaine (Alcaine® Ophthalmic)**

Local anesthetics block nerve impulses by specifically binding the voltage-gated $Na^+$ channel in the nerve cell membrane at the site of insult. Reversible drug binding stabilizes the ion channel preventing the transmission of action potentials, thus preventing nerve information transmission to the spine and brain. Local anesthetic routes of administration include topical to mucus membranes (nose, eye, etc.) or injected directly into the tissue that will be incised/cut and around nerve bundles that provide sensation to the surgical site. Administration of local anesthetics prior to the painful stimulus (eg. incision) would be considered an adjunct analgesic to opioid and NSAID analgesics. Use as the primary analgesic is discouraged due to the short duration of effect (hours).

Advantages: Pre-operative and intra-operative administration directly on or at the incision site can provide a good adjunct in pain relief to general anesthesia and systemic analgesics administered after a procedure. Drugs of this class are not controlled substances.
Disadvantages: Avoid administering by intramuscular and intravenous injections as both routes reach systemic circulation very rapidly. Signs of overdose or systemic toxicity include seizures and death. Dilution of stock concentration is encouraged to provide more accurate dose administration.

Additional Notes: For rodent use, dilute 1-2% Lidocaine to 0.5%, and 0.5% Bupivacaine to 0.25%, to allow for more accurate dosing and realistic volume to infuse at the incision site. [Note: 1% solution is equal to 10 mg/mL]. Ropivacaine requires no dilution prior to use. Lidocaine is a fast acting, short duration local anesthetics. Bupivacaine is a slow onset, long acting local anesthetic. When used in combination (Lidocaine plus Bupivacaine in the same syringe) the benefits of both drugs can be achieved, namely rapid onset with long duration of local anesthesia. In addition, the duration of efficacy of local anesthetics can be extended by the addition of epinephrine to the injected solution. Epinephrine causes local vasoconstriction of blood vessels in the area of the injection resulting in decreased systemic absorption leading to prolonged duration of action. Preparations of Lidocaine and Bupivacaine can be purchased pre-combined with epinephrine (1:200,000).

## Veterinary Verification and Consultation:

Veterinary verification and consultation (VVC) is an option available to amend an approved IACUC protocol in consultation with a veterinarian.(*19*) To add or change pharmaceutical grade drugs to support animal welfare, the following common veterinary formularies are also recognized as extensions of the IACUC approved CU Denver Veterinary Formulary. They include: Plumb's Veterinary Drug Book, Carpenter's Exotic Animal Formulary, Hawk, Leary and Morris; Formulary for Laboratory Animals, American College of Laboratory Animal Medicine (ACLAM) e-Formulary, and the Merck Veterinary Manual.

# Mouse

Modified 7-6-2022

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Precision vaporizer. Open-drop method with IACUC approval (*20, 21*). |

| Injectable Sedation and Anesthetic Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Fentanyl | 0.8 mg/kg, IP | Sedation | (*22*) |
| Ketamine \| Medetomidine | 50 \| 0.5 mg/kg, IP | Sedation | (*23*) |
| Ketamine \| Xylazine | 50-65 \| 10-15 mg/kg, IP | Sedation | (*24, 25*) |
| Ketamine \| Xylazine | 80-100 \| 7.5-16 mg/kg, IP IM | Anesthesia | (*1, 26*) |
| Ketamine \| Xylazine \|Acepromazine | 100 \| 2.5 \| 2.5 mg/kg, IP IM | Anesthesia | (*1, 10*) |
| Ketamine \| Xylazine \|Acepromazine | 80 \| 8 \| 1 mg/kg, IP IM | Anesthesia | (*11*) |
| Ketamine \| Medetomidine | 75 \| 1.0 mg/kg, SC IP | Anesthesia | (*27*) |
| Dexmedetomidine \| Midazolam \| Fentanyl | 0.25-0.5 \| 5 \| 0.05 mg/kg, IP | Anesthesia | (*28, 29*) |
| Pentobarbital (Nembutal) | 50-90 mg/kg, IP | Anesthesia | (*1, 30*) |
| Propofol | 12-26 mg/kg, IV | Anesthesia | (*1*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg (max 7 mg/kg), SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*31*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg (max 8 mg/kg), SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31, 32*) |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg (max 8 mg/kg), SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31*) |
| Ice-cold Ethanol | Immerse distal tail, 10 seconds | Local Block | Tail biopsy, day 7-15 pups (*33*) |

| Reversal Agents | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IP | Reversal | (*27, 34, 35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IP | Reversal | (*13, 26, 34*) |
| Naloxone (Opioid Reversal) | 0.01-0.1 mg/kg, SC IP<br>1.2 mg/kg, SC IP | Reversal | (*12, 36*)<br>(*28, 29*) |
| Flumazenil (Midazolam Reversal) | 0.5 mg/kg, SC IP | Reversal | (*28, 29*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Buprenorphine (Buprenex®) | 0.1-0.5 mg/kg, SC IP | Yes | 4-6 hrs (*37-40*) |
| Buprenorphine SR/ER LAB™ | 1.0 mg/kg, SC | Yes | 48-72 hrs (*16, 41-43*) |
| Buprenorphine XR (Ethiqa XR™) | 3.25 mg/kg, SC | Yes | 72 hrs (*17, 44*) |
| Oxymorphone | 0.2-0.5 mg/kg, SC IP | Yes | 4-6 hrs (*34*) |
| Fentanyl | 0.05 mg/kg, IP | Yes | 4-6 hrs (*1*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Carprofen (Rimadyl®) | 5 mg/kg, SC IP PO | No | 24 hrs (*1, 37, 45*) |
| Meloxicam (Metacam®) | 1-2 mg/kg, SC IP PO | No | 24 hrs (*37, 45, 46*) |
| Meloxicam ER | 4 mg/kg, SC | No | 24-72 hrs (*41*) |
| Flunixin (Banamine®) | 1-2.5 mg/kg, SC | No | 12-24 hrs (*1, 37*) |
| Ketoprofen (Ketofen®) | 5 mg/kg, SC | No | 12-24 hrs (*1, 37*) |

# Mouse [Continued]

Modified 7-6-2022

| **NSAID (Food and Water Dosing)** | | | |
|---|---|---|---|
| Ibuprofen (Children's Advil® Elixir)* | 40 mg/kg or 0.2 mg/mL, PO | No | Start 48 hrs before sx. (*5, 37*) |
| Acetaminophen (Tylenol® Elixir)* | 300 mg/kg or 2-4.5 mg/mL, PO | No | Start 48 hrs before sx. (*30, 37*) |
| Acetaminophen/Codeine (Tylenol® III)* | 320 \| 32 mg/kg<br>1.6 \| 0.16 mg/mL, PO | Yes | Start 48 hrs before sx. (*47, 48*) |
| * Not appropriate as the only post-surgical analgesic due to reduction in water intake 24-48 hrs following surgery (*5-8*). | | | |

# Rat

Modified 10-19-2020

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Precision vaporizer. Open-drop method with IACUC approval (*20, 21*). |

| Injectable Sedation Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Acepromazine | 0.5-1 mg/kg, IP IM | Sedation | (*36*) |

| Injectable Anesthetic Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Xylazine | 40-80 \| 5-10 mg/kg, IP IM | Anesthesia | (*1, 37*) |
| Ketamine \| Medetomidine | 60-90 \| 0.5 mg/kg, IP | Anesthesia | (*1, 37, 49*) |
| Pentobarbital (Nembutal) | 30-60 mg/kg, IP | Anesthesia | (*1, 37*) |
| Propofol | 10 mg/kg, IV | Anesthesia | (*1, 34, 50*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg (max 7mg/kg), SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*31*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg (max 8 mg/kg), SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31, 32*) |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg (max 8 mg/kg), SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31*) |

| Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IP | Reversal | (*34, 35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine, IP | Reversal | (*13, 26, 34*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Buprenorphine (Buprenex®) | 0.05-0.2 mg/kg, SC IP IV | Yes | 6-12 hrs (*1, 34, 37, 38, 51*) |
| Buprenorphine SR/ER LAB™ | 1-1.2 mg/kg, SC | Yes | 72 hrs (*16, 43, 52, 53*) |
| Buprenorphine XR (Ethiqa XR™) | 0.65 mg/kg, SC | Yes | 72 hrs (*17, 44*) |
| Oxymorphone | 0.2-0.5 mg/kg, SC IM | Yes | 4-6 hrs (*34*) |
| Fentanyl | 0.05 mg/kg, SC IP IM | Yes | 4-6 hrs (*1*) |
| **NSAID Anti-Inflammatory Agent** | | | |
| Carprofen (Rimadyl®) | 5 mg/kg, SC IP PO | No | 24 hrs (*1, 37, 54*) |
| Meloxicam (Metacam®) | 1-2 mg/kg, SC PO | No | 24 hrs (*37*) |
| Meloxicam ER | 2-4 mg/kg, SC | No | 48-72 hrs (*43, 54*) |
| Flunixin (Banamine®) | 1.1-2.5 mg/kg, SC | No | 12-24 hrs (*1, 37*) |
| Ketoprofen (Ketofen®) | 5 mg/kg, SC | No | 12-24 hrs (*37*) |
| **NSAID (Food and Water Dosing)** | | | |
| Ibuprofen (Children's Advil® Elixir)* | 10-30 mg/kg or 0.3 mg/mL, PO | No | Start 48 hrs before surgery. (*36, 37*) |
| Acetaminophen (Tylenol® Elixir)* | 300 mg/kg or 2-4.5 mg/mL, PO | No | Start 48 hrs before surgery. (*1, 30, 37*) |
| * Not appropriate as the only post-surgical analgesic to be administered due to the anticipated decreased water intake 24-48 hrs following surgery. | | | |

| **Inhaled Anesthetic Drugs** | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Administer via precision vaporizer and compressed $O_2$. (*1*) Open-drop method with IACUC approval (*20, 21*). |

| **Hypothermia** |
|---|
| Hypothermia Method: Mouse and rats pups, up to and including 10 days of age, may be anesthetized by hypothermia when inhalant anesthetic is not feasible.<br>• Hypothermia 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.<br>• 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.<br>• 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 smells on the pup then the litter returned to the dam. |
| **Comments (*Ref.*):** (*1, 55-61*) |

| **Injectable Anesthetic Drugs/Combinations** | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Xylazine | 40-80 \| 5-10 mg/kg, IP | Anesthesia | (*59*) |
| Pentobarbital | 30-40 mg/kg, IP | Anesthesia | (*56*) |
| **Comments:** Injectable anesthetics in neonatal rodents is unpredictable and has a >50% rate of mortality (*56*). Use of injectable anesthetics should only be considered in neonates >6 days of age and where gas anesthesia is not feasible. | | | |

| **Analgesics (Pain Relief)** | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Morphine | 5-10 mg/kg, SC | Yes | 6 hrs (*59*) |
| Buprenorphine (Buprenex®) | 0.1-0.5 mg/kg, SC IP | Yes | 4-6 hrs *No Citation* |
| Fentanyl | 0.05 mg/kg, IP | Yes | 4 hrs (*62*) |

# Hamster

Modified 8-25-2022

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Administer via precision vaporizer & compressed $O_2$. |

| Injectable Anesthetics Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Xylazine | 100 \| 5-10 mg/kg, IM IP | Anesthesia | (*36, 63*) |
| Ketamine \| Dexmedetomidine | 100 \| 0.25 mg/kg, IM IP | Anesthesia | (*64*) |
| Pentobarbital | 50-90 mg/kg, IP | Anesthesia | (*36*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*31*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31, 32*) |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31*) |

| Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*34, 35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM SC IP | Reversal | (*13, 34*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Buprenorphine (Buprenex®) | 0.05-0.1 mg/kg, SC IP | Yes | 6-12 hrs (*36*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Meloxicam (Metacam®) | 1-2 mg/kg, SC IP PO | No | 24 hrs (*64*) |
| Carprofen (Rimadyl®) | 5 mg/kg, SC | No | 24 hrs (*36*) |

# Gerbil

Modified 8/25/2022

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Administer via precision vaporizer & compressed $O_2$. |

| Injectable Sedation for Induction Drugs/Combinations | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Xylazine | 5-10 mg/kg, SC IM | Sedation | (*34*) |
| Medetomidine | 0.05-0.2 mg/kg, SC | Sedation | (*37*) |
| Diazepam | 3-5 mg/kg, SC IM | Sedation | (*34*) |
| Midazolam | 1-3 mg/kg, SC IM | Sedation | (*34, 37*) |
| Propofol | 100-200 mg/kg, IP | Sedation | (*65*) |

| Injectable Anesthetics Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Xylazine | 50-70 \| 2-5 mg/kg, SC IM IP | Anesthesia | (*34, 37*) |
| Ketamine \| Medetomidine | 75 \| 0.25-0.5, SC IM IP | Anesthesia | (*1*) |
| Telazol® | 50-80 mg/kg, IM IP | Anesthesia | (*1, 34*) |
| Pentobarbital | 60 mg/kg, IP<br>50-90 mg/kg | Anesthesia | (*34*)<br>(*36*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*31*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31, 32*) |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31*) |

| Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*34, 35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM SC IP | Reversal | (*13, 34*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Buprenorphine (Buprenex®) | 0.05-0.1 mg/kg, SC IM IP | Yes | 8-12 hrs (*34, 36, 37*) |
| Buprenorphine SR/ER LAB™ | 1.0 mg/kg, SC | Yes | 48-72 hrs *No Citation* |
| Oxymorphone | 0.2-0.5 mg/kg, SC IM IP | Yes | 6-12 hrs (*34, 37*) |
| Butorphanol | 1-5 mg/kg, SC IM IP | Yes | 2-4 hrs (*34, 37*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Meloxicam (Metacam®) | 1-2 mg/kg, SC | No | 24 hrs (*37*) |
| Carprofen (Rimadyl®) | 5 mg/kg, SC | No | 24 hrs (*37*) |
| Flunixin (Banamine®) | 2.5 mg/kg, SC | No | 12-24 hrs (*34, 37*) |
| Ketoprofen (Ketofen®) | 5 mg/kg, SC | No | 12-24 hrs (*37*) |
| **NSAID (Water Dosing)** | | | |
| Acetaminophen (Children's Tylenol Elixir)** | 7.5 mg/kg, PO | No | Given in water bottle (*34*) |
| ** Due to limited water consumption by this species, please seek veterinary consultation of administration of analgesics in the water to gerbils. | | | |

## Prairie Vole (*Microtus ochrogaster*)

Modified 1-10-2024

| **Inhaled Anesthetic Drugs** | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Administered via a precision vaporizer and compressed $O_2$. |

| **Injectable Anesthetic Drugs/Combinations** | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Xylazine | 67 \| 13.5 mg/kg, IM SC IV | Anesthesia | (*66*) |
| Pentobarbital | 50-65 mg/kg, IV | Anesthesia | (*67-69*) |

| **Local Anesthetics** | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr *No Citation* |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs *No Citation* |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs *No Citation* |

| **Alpha 2 Agonist Reversal (Xylazine)** | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM, SC | Reversal | (*13, 70*) |

| **Analgesics (Pain Relief)** | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Buprenorphine (Buprenex®) | 0.05-0.2 mg/kg, SC IP | Yes | 8-12 hrs *No Citation* |
| **NSAID Anti-Inflammatory Drug** | | | |
| Carprofen (Rimadyl®) | 5 mg/kg, PO SC IP | No | 24 hrs (*71*) |
| Meloxicam | 1-3.75 mg/kg, PO SC | No | 24 hrs (*72*) |
| Meloxicam ER | 2-4 mg/kg, SC | No | 24-72 hrs *No Citation, ref. Rat* |

## Naked Mole Rat (*Heterocephalus glaber*)

Modified 10-17-2018

| **Injectable Sedation and Anesthetic Drugs/Combinations** | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Xylazine | 35-50 \| 3-8 mg/kg, IP | Sedation | (*73, 74*) |
| Pentobarbital | 35-40 mg/kg, IP | Sedation | (*75, 76*) |
| Ketamine \| Xylazine | 50-100 \| 3-8 mg/kg, IP | Anesthesia | (*77, 78*) |
| Pentobarbital | 50 mg/kg, IP | Anesthesia | (*79*) |

# Guinea Pig

Modified 6-11-2020

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Administer via precision vaporizer & compressed $O_2$. |

| Injectable Sedation for Induction Drugs/Combinations | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Acepromazine | 0.5-1.5 mg/kg IM<br>2.5-5 mg/kg IP | Sedation | (*34, 37*)<br>(*1*) |
| Ketamine | 20-120 mg/kg IM | Sedation | Wide safety margin (*1, 37*) |
| Ketamine \| Xylazine | 20-40 \| 2 mg/kg, IM IP | Sedation | Non-surgical (*1, 37*) |

| Injectable Anesthetics Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Acepromazine | 20-40 \| 0.5 mg/kg, IM IP | Anesthesia | (*34, 37*) |
| Ketamine \| Xylazine | 87 \| 13 mg/kg, IM IP | Anesthesia | Surgical (*1*) |
| Ketamine \| Medetomidine | 40 \| 0.25-0.5 mg/kg, IM | Anesthesia | 20-30 min duration (*37*) |
| Ketamine \| Diazepam | 20-40 \| 2-3 mg/kg, IM IP | Anesthesia | (*34, 37*) |
| Fentanyl \| Diazepam | 1.0 mg/kg, IM \| 5 mg/kg, IP | Anesthesia | Minor surgical event (*1*) |
| Pentobarbital | 15-40 mg/kg, IP | Anesthesia | (*30, 34, 37*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*31*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31, 32*) |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31*) |

| Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM SC | Reversal | (*13*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Oxymorphone | 0.2-0.5 mg/kg, SC IM IP | Yes | 6-12 hrs (*34, 37*) |
| Buprenorphine (Buprenex®) | 0.05 mg/kg, SC IM IP | Yes | 8-12 hrs (*34, 37*) |
| Buprenorphine SR/ER LAB™ | 0.3-0.6 mg/kg, SC | Yes | 48 hrs (*80-82*) |
| Butorphanol | 0.4-2 mg/kg, SC IM IP | Yes | 4-12 hrs (*34, 37*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Meloxicam (Metacam®) | 0.5 mg/kg, PO, SC | No | 24 hrs (*1*) |
| Carprofen (Rimadyl®) | 1-4 mg/kg, PO SC | No | 24 hrs (*37*) |
| Flunixin (Banamine®) | 2.5 mg/kg, IM | No | 12-24 hrs (*34*) |
| Ketoprofen (Ketofen®) | 1 mg/kg, SC IM | No | 12-24 hrs (*37*) |
| **NSAID Agent (Water Dosing)** | | | |
| Ibuprofen (Children's Advil® Elixir) | 10 mg/kg, PO in water | No | 4 hrs (*37*) |

# Chinchilla

Modified 8-5-2018

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Administer via precision vaporizer & compressed $O_2$. |

| Injectable Sedation for Induction Drugs/Combinations | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Acepromazine | 0.5-1.0 mg/kg IM | Sedation | (*30, 37*) |
| Ketamine | 20-40 mg/kg IM | Sedation | (*37*) |

| Injectable Anesthetics Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Acepromazine | 20-40 \| 0.5 mg/kg, IM IP | Anesthesia | (*34, 37*) |
| Ketamine \| Xylazine | 35-40 \| 4-8 mg/kg, IM IP<br>40 \| 2 mg/kg, IM | Anesthesia | (*37*)<br>(*83*) |
| Ketamine \| Dexmedetomidine | 4-5 \| 0.015 mg/kg IM | Anesthesia | (*83-85*) |
| Ketamine \| Diazepam | 20-40 \| 2-3 mg/kg, IM IP | Anesthesia | (*34, 37*) |
| Midazolam \| Medetomidine \| Fentanyl | 1.0 \| 0.05 \| 0.02 mg/kg, IM | Anesthesia | (*1*) |
| Telazol® | 20-40 mg/kg, IM IP | Anesthesia | (*34*) |
| Pentobarbital | 35-40 mg/kg, IP | Anesthesia | (*34, 37*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*31*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31, 32*) |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31*) |

| Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*35, 84, 85*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM, SC | Reversal | (*13*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Oxymorphone | 0.2-0.5 mg/kg, SC IM IP | Yes | 6-12 hrs (*34, 37*) |
| Buprenorphine (Buprenex®) | 0.05 mg/kg, SC IM IP | Yes | 8-12 hrs (*34, 37*) |
| Butorphanol | 0.2-2 mg/kg, SC IM IP | Yes | 4 hrs (*34, 37*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Meloxicam (Metacam®) | 1-2 mg/kg PO SC | No | 24 hrs *No Citation* |
| Carprofen (Rimadyl®) | 4 mg/kg, PO SC | No | 24 hrs (*37*) |
| Flunixin (Banamine®) | 2.5 mg/kg, IM | No | 12-24 hrs (*34*) |
| Ketoprofen (Ketofen®) | 1 mg/kg, SC IM | No | 12-24 hrs (*37*) |

# Rabbit

Modified 8-6-2018

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>±Nose Cone<br>±Intubation | Administer via precision vaporizer & compressed $O_2$. |

| Injectable Sedation for Induction Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Acepromazine | 0.25-1.0 mg/kg, IM | Pre-med | (*1, 34, 37*) |
| Xylazine | 1-5 mg/kg, IM SC | Pre-med | (*34*) |
| Medetomidine | 0.25 mg/kg, IM | Pre-med | (*37*) |
| Diazepam | 1-5 mg/kg, IV | Pre-med | (*34*) |
| Midazolam | 1-2 mg/kg, IM | Pre-med | (*34*) |
| Propofol | 5-8 mg/kg, IV | Induction | (*34*) |

| Injectable Anesthetics Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Ketamine \| Xylazine | 25-35 \| 3-5 mg/kg, IM SC | Anesthesia | (*1, 34, 37*) |
| Ketamine \| Medetomidine | 15-35 \| 0.25-0.5 mg/kg, IM SC | Anesthesia | (*1, 34, 86, 87*) |
| Ketamine \| Diazepam | 20-40 \| 1-5 mg/kg, IM SC | Anesthesia | (*34*) |
| Pentobarbital | 20-40 mg/kg IV | Anesthesia | (*1, 34*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*31*) |
| Bupivacaine (0.5% Marcaine) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31, 32, 88*) |
| Ropivacaine (0.2% Naropin) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*31*) |

| Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine) | | | |
|---|---|---|---|
| Yohimbine (Xylazine Reversal) | 0.2 mg/kg, IM SC | Reversal | (*34*) |
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*34, 35, 86*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM, SC | Reversal | (*13, 34*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Fentanyl Trans-Dermal Patch | 12.5 mcg/hr per 3 kg body wt. | Yes | 72 hrs. Apply patch 24 hrs prior to surgery. (*12, 37, 89*) |
| Oxymorphone | 0.05-0.2 mg/kg, IM SC | Yes | 8-12 hrs (*34*) |
| Fentanyl | 0.005-0.02 mg/kg, IV | Yes | 0.5-1 hrs (*12, 37*) |
| Buprenorphine (Buprenex®) | 0.01-0.05 mg/kg, IM SC IV | Yes | 8-12 hrs (*1, 34, 37*) |
| Buprenorphine SR/ER LAB™ | 0.12-0.15 mg/kg, SC | Yes | 72 hrs (*90*) |
| Butorphanol | 0.1-0.5 mg/kg, IM SC IV | Yes | 4-6 hrs (*1, 37*) |
| Morphine | 2-10 mg/kg, IM SC | Yes | 2-4 hrs (*36*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Meloxicam (Metacam®) | 0.3 mg/kg, PO SC | No | 24 hrs (*1, 91*) |
| Carprofen (Rimadyl®) | 4 mg/kg, SC<br>1-2.2 mg/kg, PO | No | 24 hrs (*37*)<br>12 hrs (*37*) |
| Flunixin (Banamine®) | 1.0 mg/kg, IM SC | No | 12-24 hrs. Do not administer for longer than 3 days (*1, 34*) |
| **NSAID Agent (Water Dosing)** | | | |
| Ibuprofen (Children's Advil® Elixir) | 7.5 mg/kg PO | No | Given in water bottle (*34*) |

# Ferret

Modified 2-10-2024

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Intubation | Induction with Iso should only be performed after sedation. Administered via a precision vaporizer and compressed $O_2$. (*92*) |

| Injectable Sedation for Induction Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Acepromazine | 0.2-0.5 mg/kg, IM SC | Sedation | (*82*) |
| Dexmedetomidine | 0.04-0.1 mg/kg, IM SC | Sedation | (*93, 94*) |
| Diazepam | 0.5-3 mg/kg, IV IM | Sedation | (*93, 95, 96*) |
| Ketamine | 5-20 mg/kg, IM | Sedation | (*82*) |
| Midazolam | 0.25-1 mg/kg, IV IM SC | Sedation | (*93, 95, 96*) |
| Ketamine \| Dexmedetomidine | 5 \| 0.03-0.04 mg/kg, IM SC | Sedation | (*36, 37, 94, 97, 98*) |
| Ketamine \| Xylazine | 5-20 \| 0.1-0.5 mg/kg, IM SC | Sedation | (*93*) |
| Ketamine \| Xylazine | 10-25 \| 0.25-2.0 mg/kg, IM SC | Anesthesia | (*36*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg max, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*99*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg max, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*99*) |

| Alpha 2 Agonist Reversal (Dexmedetomidine) | | | |
|---|---|---|---|
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM, SC | Reversal | (*13, 34*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Buprenorphine XR (Ethiqa XR™) | 0.6 mg/kg, SC | Yes | 72 hrs (*44*) |
| Buprenorphine (Buprenex®) | 0.01-0.03 mg/kg, IV IM SC | Yes | 6-12 hrs (*34, 36, 100*) |
| Butorphanol (Torbogesic®) | 0.1-0.5 mg/kg, IV IM SC | Yes | 4-6 hrs (*34, 36*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Meloxicam (Metacam®) | 0.2 mg/kg, loading IV IM SC PO | No | 24 hrs (*36, 100*) |
| Carprofen | 2-5 mg/kg, IV IM SC PO | No | 24 hrs (*36, 100*) |

# Cat

Modified 8-5-2018

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Intubation | Induction with Iso should only be performed after sedation. Administered via a precision vaporizer and compressed $O_2$. |

| Injectable Sedation for Induction Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Acepromazine | 0.025 – 0.1 mg/kg IV IM SQ | Sedation | Max total dose 1 mg at time of injection (*12, 101*) |
| Butorphanol | 0.1-0.2 mg/kg, IV IM<br>0.4-0.8 mg/kg, SQ | Sedation | 1-3 hrs (*12*)<br>(*102*) |
| Midazolam | 0.1 mg/kg, IV IM | Sedation | (*12*) |
| Ketamine \| Diazepam | 10 \| 0.5 mg/kg, IV | Induce/Sedate | (*102*) |
| Propofol | 4-6 mg/kg, IV | Induction | (*12*) |
| Dexmedetomidine \| Ketamine \| Buprenorphine | 0.015 \| 5 \| 0.01 mg/kg, IM | Anesthesia | (*103*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg max, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*99*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg max, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*99*) |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg max, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs |

| Alpha 2 Agonist Reversal (Dexmedetomidine) | | | |
|---|---|---|---|
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*35*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Fentanyl Trans-Dermal Patch | 2.5 mcg/hr per kg body weight | Yes | 72 hrs. Apply 24 hrs prior to surgery. (*12*) |
| Oxymorphone | 0.05-0.1 mg/kg, IV IM SC | Yes | 3-4 hrs (*99*) |
| Buprenorphine (Buprenex®) | 0.02-0.04 mg/kg IV IM<br>SC or PO if necessary | Yes | 8-12 hrs (*104, 105*)<br>(*104, 106, 107*) |
| Buprenorphine SR/ER LAB | 0.12 mg/kg, SQ | Yes | 72 hrs (*106*) |
| Butorphanol (Torbogesic®) | 0.4 mg/kg, IV IM SC | Yes | 1-3 hrs (*99*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Meloxicam (Metacam®) | 0.2 mg/kg loading, PO IV SC<br>0.05 mg/kg PO IV SC | No | 24 hrs (*101, 108-110*) |
| Ketoprofen (Ketofen®) | 1 mg/kg, IV IM SC | No | 24 hrs (*101*) |

# Dog

Modified 8-5-2018

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Intubation | Induction with Iso should only be performed after sedation. Administered via a precision vaporizer and compressed $O_2$. |

| Injectable Sedation for Induction Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Acepromazine | 0.05 mg/kg, IV SC<br>0.1-0.25 mg/kg IM | Sedation | Max total dose 3 mg at time of injection (*12, 101*) |
| Medetomidine | 5-10 mcg/kg, IM | Sedation | (*101*) |
| Xylazine | 1.1-2.2 mg/kg, IV IM | Sedation | (*101*) |
| Diazepam | 0.3-0.5 mg/kg, IV | Sedation | (*101*) |
| Acepromazine \| Butorphenol | 0.05 \| 0.2 mg/kg, IM SC | Pre-Med | (*101*) |
| Acepromazine \| Morphine | 0.05-0.2 \| 0.25-2, mg/kg IM SC | Pre-Med | (*30*) |
| Acepromazine \| Hydromorphone | 0.1-0.25 \| 0.05-0.1 mg/kg IM | Pre-Med | Will induce vomiting (*101*) |
| Propofol | 4-6 mg/kg, IV | Induction | (*101*) |

| Injectable Anesthetic | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Pentobarbital | 20-30 mg/kg, IV | Anesthetic | Rarely Indicated (*30*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg max, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*111*) |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg max, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*99, 111*) |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg max, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs (*111*) |

| Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine) | | | |
|---|---|---|---|
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM, SC | Reversal | (*35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM, SC | Reversal | (*13*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Fentanyl Trans-Dermal Patch | 2.5 mcg/hr per kg body weight | Yes | 72 hrs. Apply 24 hrs prior to surgery. (*1, 12, 112*) |
| Oxymorphone | 0.05-0.2 mg/kg, IV IM SC | Yes | 1-2 hrs (*12, 101*) |
| Fentanyl | 0.01 mg/kg, IV IM SC | Yes | 2 hrs (*101*) |
| Buprenorphine (Buprenex®) | 0.01-0.02 mg/kg, IV IM SC | Yes | 6 hrs (*1, 101*) |
| Butorphanol | 0.1-1 mg/kg, IV SC | Yes | 2-4 hrs (*12, 101*) |
| Tramadol | 1-4 mg/kg, PO | No | 6 hrs *No Citation* |
| **NSAID Anti-Inflammatory Drug** | | | |
| Meloxicam (Metacam®) | 0.2 mg/kg loading, PO IV SC<br>0.1 mg/kg PO IV SC | No | 24 hrs (*1, 12*) |
| Carprofen (Rimadyl®) | 4 mg/kg once loading, PO IV<br>2.2 mg/kg PO IV IM SC | No | 12 hrs (*1, 12*) |
| Ketoprofen (Ketofen®) | 2 mg/kg once loading, IV IM SC<br>1 mg/kg, PO IM | No | 24 hrs (*12*) |

# Pig

Modified 2-8-2022

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Intubation | Induction with Iso after sedation. Administered via a precision vaporizer and $O_2$. |

| Injectable Sedation, Induction, and Anesthesia Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Acepromazine | 0.5-1.1 mg/kg, IM | Sedation | (*12, 36*) |
| Alfaxalone | 2-5 mg/kg, IM | Sedation | (*113, 114*) |
| Dexmedetomidine | 0.01-0.1 mg/kg, IM | Sedation | (*115*) |
| Ketamine | 10-20 mg/kg, IM | Sedation | (*12*) |
| Telazol® | 2-4 mg/kg, IM | Sedation | (*116, 117*) |
| Telazol® \| Xylazine | 2-4.4 \| 1-2.2 mg/kg, IM | Sedation | (*118, 119*) |
| Fentanyl CRI | 0.03-0.1 mg/kg/hr IV | Sedation | (*120*) |
| Ketamine \| Xylazine \|Acepromazine | 20 \| 2 \| 0.2 mg/kg, IM SC | Induction | Non-survival Surgery (*30*) |
| Ketamine \| Xylazine \|Acepromazine | 10-15 \| 2 \| 0.2 mg/kg, IM SC | Induction | Survival Surgery (*30*) |
| Ketamine \| Acepromazine | 30-35 \| 1.1 mg/kg, IM SC | Induction | (*30, 121*) |
| Ketamine \| Xylazine | 10-20 \| 2 mg/kg, IM SC IV | Induction | (*1, 122*) |
| Ketamine \| Midazolam | 15-20 \| 0.1-1.0 mg/kg, IM SC IV | Induction | (*1, 121, 123*) |
| Midazolam | 0.1-0.5 mg/kg, IM SC IV | Induction | (*1, 70*) |
| Propofol | 0.8-1.6 mg/kg, IV | Induction | (*1, 70*) |
| Alfaxalone | 1.5-2 mg/kg, IV | Induction | (*124*) |
| Propofol \| Fentanyl CRI | 3.2-4.4 mg/kg/hr \| 3.5-5 mcg/kg/hr, IV | Anesthesia | (*30*) |
| Propofol CRI | 12-20 mg/kg/hr | Anesthesia | (*124, 125*) |
| Alfaxalone CRI | 12-15 mg/kg/hr | Anesthesia | (*123, 124*) |
| Pentobarbital | 20-40 mg/kg, IV | Anesthesia | (*1*) |
| Telazol® | 4-8 mg/kg, IM SC | Anesthesia | (*1, 70*) |
| Telazol® \| Xylazine | 4.4 \| 2.2 mg/kg, IM SC | Anesthesia | (*126*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs |
| Liposomal Bupivacaine | 266-300 mg/animal, SC | Local Block | Duration 12 hrs (*127*) |

| Reversal Drugs | | | |
|---|---|---|---|
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM SC | Reversal | (*13*) |
| Tolazoline (Xylazine Reversal) | 2-4 mg/kg, IV | Reversal | (*128*) |
| Flumazenil (Telazol® Reversal) | 0.015-0.1 mg/kg, IM SC | Reversal | (*118, 129*) |

## Pig [Continued]

Modified 1-2-2022

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Fentanyl Trans-Dermal Patch | 2.5 mcg/hr/kg | Yes | 72 hrs. Apply 24 hrs prior to surgery. (*1, 12, 70, 130*) |
| Buprenorphine (Buprenex®) | 0.05-0.1 mg/kg, IM SC | Yes | 8-12 hrs (*1, 70*) |
| Buprenorphine SR/ER LAB | 0.12-0.24 mg/kg, SC | Yes | 72-96 hrs (*125, 131, 132*) |
| Hydromorphone | 0.08-0.2 mg/kg, IV<br>0.2 mg/kg, IM SC | Yes | 2 hrs (*12, 36*)<br>4-6 hrs (*36*) |
| Oxymorphone | 0.15 mg/kg, IM SC | Yes | 4 hrs (*1, 70*) |
| Fentanyl | 0.05 mg/kg, IM SC | Yes | 2 hrs (*1*) |
| Butorphanol | 0.1-0.3 mg/kg, IM SC | Yes | 4-6 hrs (*1, 70*) |
| Tramadol | 1-5 mg/kg, IM, PO | Yes | 4-8 hrs (*125, 133, 134*) |
| Oxycodone (OxyContin®) | 0.075-0.125 mg/kg, PO | Yes | 6 hrs *No Citation* |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **NSAID Anti-Inflammatory Drug** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Carprofen (Rimadyl®)*** | 2 mg/kg, PO SC<br>4 mg/kg, PO SC | No | 12 hrs (*120, 122*)<br>24 hrs (*36, 120, 122*) |
| Meloxicam (Metacam®)*** | 0.1-0.4 mg/kg, PO IM SC | No | 24 hrs (*120, 122*) |
| Flunixin (Banamine®)*** | 1-4 mg/kg, IM SC | No | 12-24 hrs (*120, 122*) |
| Acetaminophen (Tylenol® Elixir) | 10 mg/kg, PO | No | 8 hrs (*135*) |
| **Other Analgesics** | | | |
| Gabapentin | 5-20 mg/kg, PO | No | 8-12 hrs Start minimum 2 hrs prior to surgery. *No Citation* |
| *** Longterm (> 3 days) use of NSAIDs has the potential to induce gastrointestinal ulceration and decreased appetite. Famotidine (Pepcid AC) 0.5-1 mg/kg should be considered in these situations. | | | |

# Sheep

Modified 8-5-2018

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Intubation | Induction with Iso after sedation. Administered via a precision vaporizer and compressed $O_2$. |

| Injectable Sedation for Induction Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Diazepam | 0.1-0.3 mg/kg, IV | Sedation | (*1, 136*) |
| Acepromazine | 0.5 mg/kg, SC IM IV | Sedation | (*1*) |
| Butorphanol | 0.5 mg/kg, SC | Sedation | (*1*) |
| Xylazine | 0.03-0.2 mg/kg IM IV | Sedation | (*1*) |
| Medetomidine | 0.006-0.15 mg/kg, IM IV | Sedation | (*1*) |
| Ketamine \| Diazepam | 10-25 \| 0.1-0.3 mg/kg, IV<br>17.5 \| 0.2 mg/kg, IV<br>4.0 \| 0.4 mg/kg, IV | Induction | (*30, 137, 138*)<br>(*30*)<br>(*1, 137*) |
| Ketamine \| Midazolam | 10-25 \| 0.1-0.3 mg/kg, IV | Induction | (*30*) |
| Propofol | 3-5 mg/kg, 0.4-0.5 mg/kg/min, IV | Induction | (*1, 139, 140*) |
| Pentobarbital | 20-25 mg/kg, IV | Induction | (*1*) |
| Food/Water Restriction: food restriction for 24 hrs and water restriction 12 hrs prior to surgery is considered a standard veterinary practice in the preparation of ruminants (sheep, goats, cows, etc.) for anesthesia. | | | |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs |

| Alpha 2 Agonist Reversal (Xylazine and Dexmedetomidine) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Yohimbine (Xylazine Reversal) | 0.0125-0.2 mg/kg, IM SC | Reversal | (*1*) |
| Atipamezole (Antisedan®) | 10 mg for every 1 mg of Dexmedetomidine, IM SC | Reversal | (*35*) |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM, SC | Reversal | (*13, 70*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Opioid** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Fentanyl Trans-Dermal Patch | 100 mcg/hr per 60 kg | Yes | 72 hrs. Apply 12 hrs prior to surgery. (*141-143*) |
| Buprenorphine (Buprenex®) | 0.005-0.01 mg/kg, IM IV SC | Yes | 4-6 hrs (*30, 70, 136*) |
| Butorphanol | 0.1-0.5 mg/kg, IM IV | Yes | 1-3 hrs (*1*) |
| Morphine | 0.2-0.5 mg/kg, IM SC | Yes | 4 hrs (*1*) |
| Fentanyl | 0.01 mg/kg, IV | Yes | 1 hr (*1, 136*) |
| **NSAID Anti-Inflammatory Drug** | | | |
| Flunixin (Banamine®) | 2.2 mg/kg, IM IV<br>1.1 mg/kg, IM IV | No | 12-24 hrs (*1, 12, 70, 136*)<br>8-12 hrs (*1, 12, 70, 136*) |
| Ketoprofen (Ketofen®) | 2-3 mg/kg, IV PO | No | 24 hrs (*12*) |
| Carprofen (Rimadyl®) | 2-4 mg/kg, SC IM | No | 24 hrs (*70*) |
| Phenylbutazone | 2-6 mg/kg, IV PO | No | 24 hrs (*70, 136*) |
| **Other Analgesics** | | | |
| Xylazine | 0.05 mg/kg, IV | No | 1-2 hr (*1, 12, 136*) |

# Cow

Modified 11-30-2018

| Inhaled Anesthetic Drugs | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Isoflurane | Induction: 3-5%<br>Maintenance: 1.5-3% | Inhaled<br>Nose Cone | Induction with Iso after sedation. Administered via a precision vaporizer and compressed $O_2$. |

| Injectable Sedation or Anesthetic Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Butorphanol \| Ketamine \| Xylazine | 0.0375 \| 3.75 \| 0.375 mg/kg, IM SC IV | Anesthesia | 20-30 min anesthesia (*144*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Lidocaine (1-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr |
| Bupivacaine (0.5% Marcaine®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs |
| Ropivacaine (0.2% Naropin®) | 1-2 mg/kg, SC | Local Block | Onset 15-30 min, Duration 4-8 hrs |

| Alpha 2 Agonist Reversal (Xylazine) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Atipamezole (Xylazine Reversal) | 1 mg for every 10 mg of Xylazine IM SC | Reversal | (*35*) |

## Zebrafish (*Danio rerio*)

Modified 1-24-2020

| Anesthetic Drug | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Tricaine (MS-222) | 0.01-0.03% or 100-300 mg/L, buffered | Immersion | (*145*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Lidocaine | 5 mg/L, immersion for 40-45 min prior to insult | No | (*146-148*) |

## Goldfish (*Carassius auratus*)

Modified 10-17-2018

| Anesthetic Drug | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Tricaine (MS-222) | 0.01-0.022% or 100-220 mg/L, buffered | Immersion | (*149, 150*) |

## African Clawed Frog (*Xenopus laevis* and *X. tropicalis*)

Modified 6-20-2019

| Anesthetic Drug | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Tricaine (MS-222) | 0.05-0.2% or 0.5-2 g/L, buffered | Immersion | (*47, 151-153*) |
| Pentobarbital | 60 mg/kg, dorsal lymph sac inj. | Injection | (*47*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Flunixin (Banamine®) | 25 mg/kg, intracoelomic inj., dorsal lymph sac inj. | No | 24 hrs (*151, 154*) |
| Xylazine | 10 mg/kg, intracoelomic inj., dorsal lymph sac inj. | No | 12-24 hrs (*154*) |

## Anoles (*Anolis sagrei*)

Modified 9-30-2024

| Injectable Sedation or Anesthetic Drugs/Combinations | | | |
|---|---|---|---|
| **Agent(s)** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Alfaxalone \| Dexmedetomidine | 30 \| 0.1 mg/kg, SC cervical area | Anesthesia | (*155*) |

| Local Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Route** | **Comments (*Ref.*)** |
| Lidocaine (0.5-2%) | 2-4 mg/kg, SC | Local Block | Onset 5-10 min, Duration 0.5-1 hr (*82*) |

| Analgesics (Pain Relief) | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **DEA** | **Dosing Frequency (*Ref.*)** |
| Meloxicam (Metacam®) | 0.2-0.5 mg/kg, SC | No | 24 hrs (*82, 156*) |

## Non-Pharmaceutical Grade Anesthetics †

[Use Requires Scientific Justification and IACUC Approval]

Modified 8-1-2019

### Mouse

| Non-Pharmaceutical Grade Injectable Anesthetics | | | |
|---|---|---|---|
| **Agent** | **Dosage** | **Use** | **Comments (*Ref.*)** |
| Tribromoethanol (TBE) †† | 300 mg/kg, IP | Anesthesia | (*1, 30*) |
| Pentobarbital ††† | 50-90 mg/kg, IP | Anesthesia | (*14*) |
| Chloral Hydrate | 370-400 mg/kg, IP | Anesthesia | (*1, 30*) |
| Chloral hydrate \| Pyrazole | 400 \| 400 mg/kg, IP | Anesthesia | (*157*) |
| Alpha Chloralose | 114 mg/kg, IP | Anesthesia | 5% solution (*1, 30*) |
| EMTU (Inactin) | 80 mg/kg, IP | Anesthesia | (*30*) |
| Ethyl Carbamate (Urethane) | 1.25-2.5 g/kg, IP | Anesthesia | Carcinogen. Not to be used for survival surgical procedures (*24*) |

### Rat

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Tribromoethanol (TBE) †† | 300 mg/kg, IP | Anesthesia | (*30*) |
| Pentobarbital ††† | 30-60 mg/kg, IP | Anesthesia | (*14*) |
| Chloral Hydrate | 300-450 mg/kg, IP | Anesthesia | 4-5% solution (*1, 30, 158*) |
| Alpha Chloralose | 55-65 mg/kg, IP | Anesthesia | (*1, 30, 158*) |
| EMTU (Inactin) | 80-100 mg/kg, IP | Anesthesia | (*30, 158*) |
| Ethyl Carbamate (Urethane) | 1-1.5 g/kg, IP | Anesthesia | Carcinogen. Not to be used for survival surgical procedures (*1, 30*) |

### Guinea Pig

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Ethyl Carbamate (Urethane) | 1.5 g/kg, IP | Anesthesia | Carcinogen. Not to be used for survival surgical procedures (*159*) |

### Cat

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Alpha Chloralose | 75 mg/kg, IV | Anesthesia | (*30*) |
| Chloral Hydrate | 300 mg/kg, IV | Anesthesia | (*30*) |

### Dog

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Alpha Chloralose | 80-100 mg/kg, IV | Anesthesia | (*30, 70*) |

### Pig

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Alpha Chloralose<br>Alpha Chloralose \| Midazolam | 60-100 mg/kg, IV<br>20-30 \| 0.35 mg/kg/hr, CRI | Induction<br>Maintenance | Not to be used as the sole agent for anesthesia (*1, 160*) |

### Zebrafish

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Eugenol (Clove Oil) | 60-100 mg/L, Immersion<br>200 uL/L, Immersion | Anesthesia | (*161*) |

## Non-Pharmaceutical Grade Anesthetics [Continued]

[Use Requires Scientific Justification and IACUC Approval]

Modified 6-21-2019

**African Clawed Frog (*Xenopus laevis*)**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Eugenol (Clove Oil) | 350 uL/L, Immersion<br>350 mg/L, Immersion | Anesthesia | (*162*)<br>(*163*) |

Please review the CU Denver IACUC Policy for "Use of Non-Pharmaceutical Grade Chemicals and Compounded Pharmaceutical Grade Drugs."
http://www.ucdenver.edu/research/OLAR/Pages/Policies.aspx

† The use of a compounding pharmacist to produce a drug from raw reagents, to administer to research animals, is highly encouraged if the drug is not commercially available. Obtaining unavailable drugs through a compounding pharmacy effectively makes the compounded drug pharmaceutical grade from the perspective of the IACUC. This section on non-pharmaceutical grade anesthetics refers to the purchase of reagent grade raw materials for the production of stock solution in the laboratory by researchers.

†† The use of Tribromoethanol (TBE) is restricted by the CU Denver IACUC because a pharmaceutical grade preparation of the drug is no longer available where other pharmaceutical anesthetics do exist that can fulfill the same purpose. Please refer to the IACUC approved procedure for the preparation, storage, use and disposal of TBE in the CU Denver IACUC Policies.

††† Recent exorbitant cost increases of pharmaceutical grade pentobarbital have placed it logistically into the unavailable category. However, pharmaceutical grade Nembutal® may still be found and purchased at times. The use of a compounding pharmacist to generate a drug that is administered to research animals, including injectable pentobarbital, from raw reagents is highly encouraged.

# Euthanasia Drug Dosages by Species

Modified 3-8-2024

The AVMA Guidelines for the Euthanasia of Animals indicates that the euthanasia dose is typically 3-5 times the anesthetic dose in mammals (pg. 35, 60).(*61*) For the dosages provides below, approximately 3x the highest-end of the anesthetic dose has been used to calculate the anesthetic overdose for euthanasia. For euthanasia solutions, the product instructions have been used, at a minimum, for dose determination. Other drugs used for euthanasia are based on literature or the AVMA Guidelines for the Euthanasia of Animals.

**Mice**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥270 mg/kg, IP | Euthanasia | |
| Ketamine \| Xylazine | ≥300 \| ≥48 mg/kg, IP | Euthanasia | |
| Isoflurane | ≥30% in air | Euthanasia | Do not use an isoflurane vaporizer. Prevent direct contact to isoflurane liquid. |

**Rat**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥ 180 mg/kg, IP | Euthanasia | |
| Ketamine \| Xylazine | ≥ 240 \| ≥ 30 mg/kg, IP | Euthanasia | |
| Ketamine \| Xylazine \|Acepromazine | ≥ 240 \| ≥ 30 \| ≥ 3.5 mg/kg, IP | Euthanasia | |
| Isoflurane | ≥ 30% in air | Euthanasia | Do not use an isoflurane vaporizer. Prevent direct contact to isoflurane liquid. |

**Gerbil, Hamster**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥ 270 mg/kg, IP | Euthanasia | |
| Ketamine \| Xylazine | ≥ 210 \| ≥ 30 mg/kg, IP | Euthanasia | |
| Isoflurane | ≥ 30% in air | Euthanasia | Do not use an isoflurane vaporizer. Prevent direct contact to isoflurane liquid. |

**Naked Mole Rat**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥ 150 mg/kg, IP | Euthanasia | (*164*) |
| Ketamine \| Xylazine | ≥ 150 \| ≥ 24 mg/kg, IP | Euthanasia | |

**Vole**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥ 200 mg/kg, IP | Euthanasia | |
| Ketamine \| Xylazine | ≥ 200 \| ≥ 40 mg/kg, IP | Euthanasia | |
| Isoflurane | ≥ 30% in air | Euthanasia | Do not use an isoflurane vaporizer. Prevent direct contact to isoflurane liquid. |

**Ferret**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥ 1 mL / 10 lbs. (4.5 kg), IP IV | Euthanasia | |
| Ketamine \| Xylazine | ≥ 125 \| ≥ 10 mg/kg, IP IM | Euthanasia | |

**Guinea Pig, Chinchilla, Rabbit, Ferret, Cat, Dog, Pig, Sheep, Cow**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥ 1 mL / 10 lbs. (4.5 kg), IV | Euthanasia | |

**All Mammals**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Potassium chloride (KCl) | 1-2 mmol/kg, IV IC<br>1-2 mEq $K^+$/kg, IV IC<br>75-150 mg/kg, IV IC | Euthanasia | (*61*) Requires unconsciousness or general anesthesia for administration. |

**Zebrafish Adults**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| MS-222 | 250-400 mg/L | Euthanasia | Buffered, immersion for 30 min. past last opercular movement (*61, 165*) |
| Benzocaine | ≥ 250 mg/L | Euthanasia | Buffered, immersion for 30 min. past last opercular movement (*1, 61*) |
| Eugenol (Clove Oil) | ≥ 400 mg/L | Euthanasia | Immersion for 10 min. past last opercular movement. (*61, 166*) |
| Ice Bath | 36-39°F (2-4°C) | Euthanasia | Immersion for 10 min. past last opercular movement (*61*) |

**Zebrafish Larvae (< 8 dpf)**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| MS-222 [1st Method Only] | ≥ 1000 mg/L | Euthanasia | Buffered, immersion for minimum of 20-30 min (*61, 145*) |
| Ice Bath [1st Method Only] | 36-39°F (2-4°C) | Euthanasia | Immersion for 20-30 min. (*61, 145*) |
| Eugenol (Clove Oil) [1st Method Only] | ≥ 400 mg/L | Euthanasia | Immersion for 10 min. (*167*) |
| Bleach Solution [2nd Method Only] | 500 mg/L or<br>6.15% bleach diluted 1:5 in $H_2O$ | Euthanasia | Immersion (*61*)<br>Immersion for 5 min. (*168*) |
| Freezing [2nd Method Only] | < 32°F (0°C) | Euthanasia | (*61*) |
| Note: To ensure Zebrafish embryo and larva lethality, a 2-step method is required where secondary methods cannot be substituted for primary methods. (*61*) | | | |

**Goldfish**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| MS-222 [1st Method Only] | 500-1000 mg/L | Euthanasia | Immersion for 15-30 min. [2nd Method] decapitation required. (*169*) |

**Amphibian (Frogs and Salamanders)**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥ 1100 mg/kg, intracoelomic inj. | Euthanasia | (*61, 170*) |
| MS-222 | ≥ 5 g/L | Euthanasia | Immersion for minimum of 1 hour (*61, 170*) |
| Benzocaine | ≥ 250 mg/L<br>20% gel topically over 2 $cm^2$ skin | Euthanasia | Immersion (*61, 170*) |

**Lizard**

| Agent | Dosage | Use | Comments (*Ref.*) |
|---|---|---|---|
| Pentobarbital Euthanasia Solution | ≥ 1000 mg/kg, intracoelomic inj. | Euthanasia | Dilute solution 1:10 in saline (*171*) |
| MS-222 | Two steps: 1% buffered solution, 250-500 mg/kg intracoelomic injection. Following loss of pain response, injection 35-50% unbuffered solution with a volume for 0.1-1.0 mL intracardiac or intracoelomic | Euthanasia | (*61, 172*) |

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**V. Edition Changes**

Modified: 9-30-2024
Edition 4.11

1. Lizard euthanasia: Within the two-step euthanasia method for lizards with MS222, the dose of the second injection has been changed to 50% MS222 solution to coincide with the 2020 AVMA Guidelines on Euthanasia of Animals.
2. Anoles: Added analgesics including Meloxicam and Lidocaine based on contemporary literature and formularies for dosing.

Modified: 3-8-2024
Edition 4.10

1. Zebrafish: The duration of exposure of adult zebrafish to high dose MS222 for euthanasia was updated to 30 minutes contact time to coincide with the 2020 AVMA Guidelines on Euthanasia of Animals.
2. Zebrafish: Added euthanasia by ice water bath for adult zebrafish and zebrafish fry which is consistent with the 2020 AVMA Guidelines on Euthanasia of Animals.
3. Zebrafish: Clarification on the duration of immersion for euthanasia with Benzocaine and Clove oil to be consistent with the 2020 AVMA Guidelines on Euthanasia of Animals.

Modified: 2-10-2024
Edition 4.9.1

1. Hamster and Gerbil: Changed the dose range of buprenorphine HCl for these species from 0.01-0.05 mg/kg to 0.05-0.1 mg/kg. There is limited data to support any buprenorphine HCl dose for these species. However this adjustment makes the dose align more closely with mice and rats. (Carpenter et al 2013, 4$^{th}$ Ed)
2. Ferrets: Added sedation medications of Acepromazine and Ketamine, each as sole agents for sedation. (Carpenter et al 2023, 6$^{th}$ Ed) Added Buprenorphine XR (Ethiqa XR$^{TM}$) for extended release opioid analgesia for ferrets.
3. Mice: Updated to provide a dose range for Buprenorphine ER (0.5-1.0 mg/kg) to stay consistent with the recommendations of the manufacturer (Wedgewood Pharmacy).
4. Neonatal Rodents: Changed the Buprenorphine HCl dose and frequency of administration to coincide with the dose and duration for mice. No citation is provided because there is little literature on the topic.
5. Guinea Pig: Updated to provide a dose range for Buprenorphine ER (0.3-0.6 mg/kg) to stay consistent doses recommended by current literature (Zametti et al 2017) and Carpenter et al 2023, 6$^{th}$ Ed.
6. Prairie Voles: The dose of Meloxicam ER (2-4.0 mg/kg), is extrapolated from the rat, without pharmacokinetic or pharmacodynamics studies. Despite this, the dose was updated to include the full range to stay consistent with the rat dose range.

Modified: 8-1-2022
Edition 4.8

1. Mouse: For Buprenorphine HCl, adjusted the dose to 0.1-0.5 mg/kg and duration of efficacy 4-6 hr based on re-evaluation of the literature (Foley et al 2019).
2. Ferrets: Added pre-medications of Diazepam and Midazolam in the event of ketamine induced seizure activity.

3. Buprenorphine SR LAB: Beginning July 1, 2022, the manufacturer has formally changed the name of this drug to Buprenorphine ER LAB. To provide longitudinal memory that they are the same product, all references to this drug have been updated to indicate “SR/ER”.

Modified: 2-8-2022
Edition 4.7

1. Pigs: Extended the drug administration interval of Buprenorphine SR in swine to a range of 72-96 hrs to be consistent with current literature (Hanks et al. 2013)
2. Pigs: Added fentanyl CRI dose as an adjunct to surgical anesthesia (Swindle 2013).
3. Ferrets: Added the subcutaneous route of administration to injectable anesthetics. While this will result in longer induction times, anesthesia is still obtained and there is no adverse effect.

Modified: 10-12-2021
Edition 4.6

1. NSAIDs (pg. 9). Removed reference to a sterile blood vial for diluting injectable drugs and replaced the recommendation with “an empty sterile vial with injection stopper.”

Modified: 3-23-2021
Edition 4.5

1. Gerbil: Added propofol, by intraperitoneal injection for sedation with limited effect on neurophysiology.
2. Pigs: Extended the dose range of flumazenil lower to 0.015 mg/kg. This reflects our experience and considers volume of administration with a low concentration of drug stock (0.1 mg/mL).
3. Pigs: Added doses for Telazol and Telazol + xylazine combination for sedation of pigs with appropriate references.
4. Pigs: Added the α2 adrenergic antagonist Tolazoline as an off label reversal agent for xylazine for pigs (Malavasi, L.M., 2015).
5. Euthanasia Solutions: Updated the language to made the distinction clearer between DEA class II and class III euthanasia solutions as it relates to the impact on the end user.
6. Rats: Added an additional citation for the use of propofol IV for sedation/anesthesia in rats (Lee et al 1998).
7. Ferrets: Added ferrets to the formulary, including basic anesthetics, analgesics, and euthanasia as appropriate with applicable references.
8. Mice: Increased the range of ketamine and xylazine for mouse sedation for non-invasive procedures like molecular imaging (Janssen et al 2004).
9. Rabbits: Lowered the lower end of the range of xylazine, used in ketamine-xylazine anesthesia based on clinical assessment and reference material (Hillary and Quesenberry, 1997).

Modified: 6-15-2020
Edition 4.4

1. Mice: Added the anesthetic combination of dexmedetomidine, midazolam, and fentanyl and the appropriate reversal agents of atipamezole, flumazenil and naloxone (Thal et al 2007, Fleischmann et al 2016). A range was provided for dexmedetomidine to correlate with the increased activity of dexmedetomidine as compared to medetomidine.
2. Anoles: Added the anesthetic combination of alfaxalone and dexmedetomidine for surgical anesthesia (Rasys et al 2019).
3. Pigs: Added Flumazenil for the reversal of benzodiazepines such as zolazepam, which is present in Telazol and midazolam (Lu et al 2011, Lee et al 2012).

4. Pigs: Added Alfaxalone as a single agent, IM injection, sedative (Santos et al 2013) or in combination with other drugs (Santos et al 2016). Alfaxalone has also been included as a maintenance anesthetic by CRI infusion as the sole agent (Baumgarter et al 2015) or in combination with other drugs (Lervik et al 2020).
5. Neonatal Rodent: Increased the age for which hypothermia can be used as a method of systemic anesthesia up to and to include 10 days of age for mouse and rat neonates to be consistent with the 2020 AVMA Guidelines for the Euthanasia of Animals.
6. Guinea Pigs: Added Buprenorphine SR LAB to the list of analgesics for guinea pigs due to recent literature (Smith et al 2016, Zanetti et al 2017).
7. AVMA Guidelines for the Euthanasia of Animals: Cross referenced and then removed reference to the 2013 edition and replaced with the reference for the 2020 edition.
8. Euthanasia Solutions (pg. 7): Updated to include Beuthanasia®-D which contains both pentobarbital and phenytoin, as compared to pentobarbital alone.

Modified: 1-24-2020
Edition 4.3

1. Mice and Rats: Added the new formulation of extended release buprenorphine now referred to in the formulary as "Buprenorphine XR" or Ethiqa XR™ . Dose determination based on the product website.
2. Zebrafish: Added lidocaine immersion as an analgesic for treatment prior to procedures (Deakin et al 2019, Schroeder et al 2017, Lopex-Luna et al 2017).

Modified: 8-1-2019
Edition: 4.2

1. Xenopus: Added drugs for anesthesia, analgesia, and non-pharmaceutical grade anesthetics.
2. Hamster: Added drugs for anesthesia and analgesia.
3. Non-pharmaceutical grade drugs: Updated the URL for the CU Denver IACUC policy page (pg. 27) and reverted language about non-pharmaceutical drugs back to the same text that was present in Edition 4.0 due to spacing.
4. Non-pharmaceutical grade drugs: Added clarification (pg. 27) to differentiate between drugs created by a licensed compounding pharmacist and those created by researcher in the laboratory.
5. Euthanasia drugs: Added comments to potassium chloride to require unconsciousness or general anesthesia for administration as required by the 2013 AVMA Guidelines for Euthanasia.
6. Change: Removed the MediGel CPF (DietGel impregnated with carprofen by Clear$H_2O$™) from the mouse and rat sections as the product has been discontinued by the manufacturer.

Modified: 3-26-2019
Edition: 4.1

1. Organization: Added species and changed the order of the mammals to correspond to relative physical size, followed by aquatic species. Updated internal hyperlinks.
2. Mouse: Added the use of ice-cold ethanol immersion for tail biopsy of mice 7-15 days old (Dudley et al 2016).
3. Pigs: Added tramadol and gabapentin as analgesics. Added the oral route of administration of carprofen for daily treatment. Added a dose for a propofol, single agent CRI anesthetic option. Added liposomal bupivicaine as a long acting local anesthetic. See references in section.

4. Voles: Added drugs for anesthesia, analgesia and euthanasia. References provided support the dose determination as an indication of “adequate response” to administration. However, systematic determination of dose or response to the dose was not investigated.
5. Naked Mole Rats: Added drugs for sedation, anesthesia, and euthanasia. References provided support the dose determination as an indication of “adequate response” to administration. However, systematic determination of dose or response to the dose was not investigated.
6. Cow: Added isoflurane, injectable anesthetic cocktail, local anesthetic and alpha-2 reversal agents. See references in section.
7. Goldfish: Added Tricaine (MS-222) anesthesia and euthanasia (Posner et al 2013).
8. Zebrafish: Added Clove oil (Eugenol) to the list of non-pharmaceutical grade anesthetics (Grush et al 2004).

Modified: 8-13-2018
Edition: 4.0

1. Change: Updated the dose of atipamezole for the reversal of dexmedetomidine for all species based on atipamezole product website.
2. Change: Selected ketamine-dexmedetomidine as the recommended chinchilla injectable aesthetic instead of ketamine-xylazine from new literature reference (Parkinson et al. 2017).
3. Change: Recommendations for Rimadyl® (carprofen) dilution stability, for use in small mammals, was updated based on new literature (Simonek et al 2017).
4. Mouse: Removed yohimbine as an effective option for reversal of alpha 2 agonists. Changed the route of administration of atipamezole based on new literature (Janssen et al 2017). Increase the range of Ket/Xyl sedation dose based on literature. Added acetaminophen/codeine as an oral analgesic option in mice. Added chloral hydrate + pyrazole as a non-pharmaceutical grade anesthetic combination (Radek et al 2012).
5. Rat: Removed yohimbine as an effective option for reversal of alpha 2 agonists. Changed the route of administration of atipamezole based on new literature (Janssen et al 2017). Changed the dose and solution of concentration of ibuprofen based on reference and normal water consumption of ~10 mL/100 g BW. Added acepromazine for sedation of rats.
6. Gerbil: Deleted ibuprofen as an analgesic in gerbils due to lack of literature demonstrating use and efficacy, and difficulty in extrapolating dose of administration based water consumption.
7. Guinea Pig: Removed yohimbine as an effective option for reversal of alpha 2 agonists. Removed Telazol for surgical anesthesia as it is extremely uncommon at our institution. Added urethane as a non-pharmaceutical grade anesthetic combination (Peterson et al 1989).
8. Pigs: Added the analgesics acetaminophen, Buprenorphine SR LAB, hydromorphone and oxycodone. Added acepromazine and dexmedetomidine for sedation. Added the anesthetic induction agents Telazole + xylazine, ketamine + midazolam, ketamine + xylazine. Changed the dose of Propofol + fentanyl to more accurately represent a dose range, rather than a specific dose. Removed yohimbine as an effective option for reversal of alpha 2 agonists.
9. Sheep: Added the induction anesthetic cocktail ketamine + midazolam based on the dose of ketamine + diazepam. Changed the dose of ketamine + diazepam to a dose range to more accurately represent the dose administered when a flat volume per sheep is used. Retained the target doses as an alternative to the range. Corrected the dose provided for morphine and provides routes of administration.
10. Addition: Added language to support the use of alternative formularies approved by the IACUC on 11-13-2017 for use with the mechanism of veterinary verification and consultation (VVC).
11. Addition: Euthanasia drug dosages for a variety of agents and species with applicable references.

12. Change: Updated the title to the CU Denver Veterinary Formulary as it now include dosages for euthanasia agents.
13. Addition: Added additional citations for the use of low dose euthanasia solution administration for anesthesia, leading euthanasia for procedures like pericardial perfusion and tissue harvest. (NABR Webinar, 7-24-2018)

Modified: 6-9-2017
Version/Edition: 3.12

1. Addition: Added MediGel CPF (DietGel impregnated with carprofen by Clear$H_2O$™) to mouse and rats sections with associated references (Ingrao et al 2013, Seymour et al 2016).
2. Addition: Clarified the start-time before surgery to begin administering oral analgesics in mice and rats.
3. Addition: Added Meloxicam SR for mice.
4. Change: Deleted Buprenorphine ER (Animalgesic) as it is no longer made.
5. Change: Modified the Ketamine and Medetomidine does for injectable anesthesia in chinchillas to account for Dexmedetomidine use and reversal with Atipamezole based on current literature (Fox et al 2016).
6. Change: Narrowed the dose to 1 mg/kg and widened the range for the duration of effect of Buprenorphine SR LAB in mice to 48-72 hrs. based on current literature (Kendall et al 2014 and Healy et al 2014).
7. Addition: Updated the references for Buprenorphine SR LAB in rats based on current literature (Seymour et al 2016, Johnson et al 2016).
8. Addition: Updated the reference for Buprenorphine SR LAB in rabbits based on current literature (DiVincenti et al 2016).
9. Change: Clarified the dose and duration of action for carprofen in pigs and updated meloxicam and flunixine based on current literature (Swindle M.M. and Smith A.C., 3rd Ed. 2016).
10. Change: Removed Telazol® from the anesthetic formulary for both mice and rats as it is not commonly used as compared to other injectable anesthetic combinations.

Modified: 6-8-2016
Version/Edition: 3.11

1. Addition: Highlighted Ketamine, Xylazine, and Acepromazine anesthetic cocktail in mice as a commonly used injectable anesthetic regimen.
2. Addition: Added information about VetOne Euthanasia solution to the list of other common euthanasia solutions.
3. Addition: Added Buprenorphine SR Lab to the list of analgesics for rabbits.
4. Change: Removed Ketoprofen as a recommended NSAID for rabbits due to the availability of less COX-1 modulating NSAIDs.
5. Change: Updated the university designation to CU Denver to stay consistent with university branding.

Modified: 6-10-2015
Version/Edition: 3.10

1. Change: Altered language about dexmedetomidine and medetomidine under alpha-2 agonists description to reflect conversions between the two drugs in combined drug formulations.
2. Change: Buprenorphine and meloxicam dosing and route information for cats
3. Change: Altered language about ketamine + xylazine ± acepromazine injectable anesthetic in rodents based on current literature (Jader et al 2014).

4. Addition: Combination ketamine + xylazine + acepromazine cocktail with published anesthesia and recovery times (Jader et al 2014).
5. Change: Updated the reference for the use of non-pharmaceutical grade drugs in research animals with OLAW webinar 6-4-2015.

Modified: 10-31-2014
Version/Edition: 3.9

1. Addition: Reference for decrease food consumption in mice for 24-48 hours after surgical procedure (Ratsep et al 2013).
2. Addition: Reference for pharmacokinetics of Meloxicam in the rabbit (Turner et al 2006).
3. Addition: Updated the induction dose of Ketamine | Acepromazine for the pig to 30-35 mg/kg | 1.1 mg/kg based on relevant literature (Linkerhoker et al 2010).
4. Addition: Added non-pharmaceutical grade alpha chloralose anesthesia for pigs (Huang et al 2013).
5. Change: Un-highlighted Buprenoprhine and a commonly used analgesic in sheep at CU Denver.
6. Addition: Anesthetics and analgesics commonly used in cats.
7. Addition: Animalgesic (sustained release buprenorphine) dose for rats.
8. Addition: Route of administration to Buprenorphine SR in rats.
9. Change: Ibuprofen medicated water concentration for rats to 0.4 mg/mL. This is based on a dose of 40 mg/kg/day and a water consumption of 10 mL/100g body weight.

Modified: 2-26-2014
Version/Edition: 3.8.1

1. Change: Removed hyperlinks to veterinary formularies for Stanford School of Medicine and University of Pittsburgh due to lack of open access.
2. Change: Corrected the duration of action for Animalgesic use in mice to correctly indicate hours.

Modified: 2-25-2014
Version/Edition: 3.8

1. Change: Removed the “letter” designation to indicate the version of the document to now indicate a number. 3rd Edition, Version H = Edition 3.8. Number designation will be used from this point forward.
2. Change: Increase the minimum dose of Buprenorphine HCL for mice and rats to 0.05 mg/kg from 0.01 mg/kg.
3. Addition: Buprenorphine ER (Animalgesic), dose, and duration of action were added to the mouse section of the formulary.
4. Addition: Buprenorphine SR™, dose, and duration of action were added to the mouse section of the formulary. It already was present in the rat section.
5. Change: Pentobarbital no longer be considered a “most common” injectable anesthetic for rodents.
6. Change: Dilution of carprofen with saline, Not Water as previously indicated.
7. Change: Extended the length of time a diluted drug (ex. carprofen) can be used once diluted and maintained sterilely from 7 to 30 days.
8. Addition: Pentobarbital to the list of Non-Pharmaceutical Grade Anesthetics. Reference to the 2012 OLAW Webinar series also added. “Recent exorbitant cost increases of pentobarbital have placed it logistically into the unavailable category. Pentobarbital from a reagent or analytical-grade powder, properly prepared by a pharmacist or other knowledgeable individual (e.g., chemist, veterinarian, researcher), with assurance of appropriate storage and handling, and

approval by the IACUC is acceptable. IACUC approval can be institution-wide for the drug prepared in this fashion for all approved users."

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