

DCM Anesthetic and Analgesic Formulary

Reviewed by UCAR 7/17/24

This document contains recommendations for best practice use of sedatives/tranquilizers, anesthetics, and analgesics based on the current standard of care. While all of the drug combinations listed here are considered safe and effective, **the selections shaded in green represent the DCM best practice approach to anesthesia and analgesia in these species and should be followed whenever possible.** The drugs contained within this formulary are not exhaustive of all possible anesthetics and analgesics that can be used in laboratory animals, and investigators should consult with a DCM veterinarian if an alternative agent is desired to achieve the scientific goal. Veterinary staff continuously review outcomes of surgical and anesthetic procedures as well as the literature for refinements, and update their recommendations and clinical practice periodically to reflect the evolving standard of care.

Abbreviations	
IM	Intramuscular
IP	Intraperitoneal
IV	Intravenous
SQ	Subcutaneous
CRI	Constant rate infusion
PO	Per os (by mouth)

MULTIMODAL ANESTHESIA AND ANALGESIA

Multimodal anesthesia and analgesia, using multiple drugs that work by different mechanisms, are considered the gold standard and are strongly advised, unless there is scientific justification precluding a multimodal approach. This strategy harnesses the synergistic actions of different drugs to achieve balanced sedative, anesthetic and analgesic effects, achieving a better safety and efficacy profile with reduced drug doses to relieve moderate to severe pain. A multimodal analgesic approach may include administration of both opioids and NSAIDs, and/or performing a nerve block or local infiltration using a local anesthetic such as bupivacaine.

PRECAUTIONS REGARDING INJECTABLE ANESTHETICS

Rodents have a variable response to injectable anesthesia. This may vary based on strain, sex, and individual variation. Special attention is required to ensure that each animal under injectable anesthesia achieves the desired depth of anesthesia for the intended procedure. In addition, it is highly recommended to conduct pilot experiments with new anesthetic protocols to assess efficacy. This should be done in consultation with DCM veterinarian.

MOUSE FORMULARY

DRUG NAME and DOSE	ROUTE & FREQUENCY	NOTES
Anesthetics		
Isoflurane Induction 4-5% Maintenance 1-3%	Inhalation	Generally, first choice agent in rodents because it can be easily titrated to deliver dose required for anesthesia and allows for rapid recovery. Induce rodent in a chamber at 4-5%, then reduce to 1-3%. Adjust as needed based on patient assessment.
Ketamine 80-120 mg/kg + Xylazine 5-10 mg/kg	IP Once ^a	30-45 min of general anesthesia ^b
Ketamine 80-100 mg/kg + Xylazine 8-20 mg/kg + Acepromazine 1-3 mg/kg	IP Once ^a	45-60 minutes surgical anesthesia, immobilization time up to 75-135 minutes ^b
Ketamine 50-75mg/kg + Dexmedetomidine 0.5- 1.0mg/kg	IP Once ^a	Surgical anesthesia 20-30 min ^b
Ketamine 100-200 mg/kg + Diazepam OR Midazolam 5mg/kg	IP Once ^a	20-30 minutes immobilization anesthesia, prolonged 60-120 min sleep time
Local Anesthetics		
Bupivacaine 2 mg/kg max	SQ	Local infiltration
Analgesics- Non-steroidal anti-inflammatory (NSAID)		
Meloxicam 1-5mg/kg	PO ^c , SQ q12- 24h	NSAIDs are useful in addition to an opioid to provide multimodal analgesia for moderate to severe pain. May be used as a sole agent for mild pain.
Carprofen (Rimadyl) 5 mg/kg	PO ^c , SQ q12- 24 hours	
Analgesics- Opioid		
Ethiqa XR 3.25 mg/kg	SQ q72 hours	Extended release formulation administered SQ between the shoulder blades (base of the neck). Onset of analgesia is 30 minutes. Ordered through SMD Pharmacy.
Buprenorphine ER 0.5 – 1.0 mg/kg	SQ q48-72h	Extended release formulation administered SQ between the shoulder blades (base of the neck). Available for purchase through DCM.
Buprenorphine HCl (Bup HCl) 0.1 mg/kg	SQ, IP q4 hours	Short-acting formulation May be given prior to surgery followed by BupER or EthiqaXR 4h later.

^a Re-dosing injectable anesthetics to extend the surgical plane of anesthesia is not recommended due to the risk of severe adverse effects and may not reliably extend the surgical plane. The use of isoflurane is required for longer procedures unless there is justification for the use of injectable anesthetics only. Consult with a DCM veterinarian if your experimental procedures necessitate the use of injectable anesthetics for long procedures.

^b To speed recovery from cocktails using dexmedetomidine or xylazine, atipamezole 0.1-1 mg/kg SQ or IP may be used AFTER systemic analgesics have been given.

^c It is recommended to offer oral medications (in drinking water, MediGel, or other oral formulations) 24-48h prior to the planned procedure to ensure consumption and allow the drug to reach therapeutic levels by the time of surgery.

RAT FORMULARY

DRUG NAME and DOSE	ROUTE & FREQUENCY	NOTES
Anesthetics		
Isoflurane, Induction 4-5% Maintenance 1-3%	Inhalation	First choice agent in rodents because it can be easily titrated to deliver the dose required to achieve a surgical plane of anesthesia. Induce rodent in a chamber at 4-5%, then reduce to 1-3% for procedure. Adjust as needed based on patient assessment.
Ketamine 75mg/kg + Dexmedetomidine 0.25- 1mg/kg	IP Once ^a	Surgical anesthesia up to 120min. ^b Recommended starting dose for dexmedetomidine is 0.25 mg/kg. Higher doses may be used if appropriate to achieve reliable surgical anesthesia for certain strains or procedures.
Ketamine 40-90mg/kg + Xylazine 5-10mg/kg	IP once ^a	Surgical anesthesia 45-90min. ^b Most reliable when used with pre-emptive analgesia and/or local anesthetics.
Ketamine 40-60 mg/kg + Xylazine 2.5-6.25 mg/kg + Acepromazine 1-1.5 mg/kg	IP, SQ once ^a	Surgical anesthesia ^b
Ketamine 75mg/kg + Diazepam OR Midazolam 5mg/kg	IP once ^a	Light anesthesia 20-30min
Local Anesthetics		
Bupivacaine 2 mg/kg max	SQ	Local infiltration
Bupivacaine Liposomal (Exparel) 1 mg/kg	SQ	Local infiltration pre-op provides up to 4d pain relief

Analgesics – NSAID		
Carprofen 5 mg/kg	SQ, PO ^c q24h	NSAIDs are useful in addition to an opioid to provide multimodal analgesia for moderate to severe pain. May be used as a sole agent for mild pain.
Meloxicam 1-2mg/kg	SQ, PO ^c q12-24h	
Ketoprofen 5 mg/kg	SQ q24h	
Analgesics – Opioid		
Ethiq XR 0.65 mg/kg	SQ q72h	Extended release formulation administered SQ between the shoulder blades (base of the neck). Onset of analgesia is 30 minutes. Ordered through SMD Pharmacy.
Buprenorphine ER 1.2 mg/kg	SQ q48-72h	Extended release formulation administered SQ between the shoulder blades (base of the neck). Available for purchase through DCM.
Buprenorphine HCl 0.05 mg/kg	SQ q6-8h	Short-acting formulation May be given prior to surgery followed by BupER or EthiqXR 6h later.

^a Redosing injectable anesthetics to extend the surgical plane of anesthesia is not recommended due to the risk of severe adverse effects and may not reliably extend the surgical plane. The use of isoflurane is required for longer procedures unless there is justification for the use of injectable anesthetics only. Consult with a DCM veterinarian if your experimental procedures necessitate the use of injectable anesthetics for long procedures.

^b To speed recovery from cocktails using dexmedetomidine or xylazine, atipamezole 0.1-1 mg/kg SQ or IP may be used AFTER systemic analgesics have been given.

^c It is recommended to offer oral medications (in drinking water, MediGel, or other oral formulations) 24-48h prior to the planned procedure to ensure consumption and allow the drug to reach therapeutic levels by the time of surgery.

OTHER RODENTS FORMULARY

Anesthetics			
Drug & Dose Range	Species	Route	Notes
Isoflurane Induce 3-5%; Maintenance 2-3%	All	Inhalation	

Ketamine 50-70mg/kg + Xylazine 2-3mg/kg	Gerbil	SC	Higher dose induces surgical plane of anesthesia
Ketamine 27mg/kg + Xylazine 0.6mg/kg	Blind mole rat	IM	
100mg/kg ketamine + 5mg/kg diazepam	Gerbil	SC, IP	
Ketamine/Dexmedetomidine Ketamine 50-75 mg/kg + Dexmedetomidine 0.5-1.0 mg/kg	Gerbil	IP	Anesthesia for <1h. Do not re-dose. Use isoflurane for procedures >1h.
Analgesics- NSAID			
Meloxicam 2mg/kg loading dose, followed by 1mg/kg	Mole Rat	PO, SC; SID	
Analgesics- Opioid			
Buprenorphine, consult vet for dose	All other rodents	SC, PO; q8-12 h	

BIRD FORMULARY

DRUG NAME and DOSE	ROUTE & FREQUENCY	NOTES
Anesthesia		
Isoflurane, Induce 3-5%; Maintenance 2-3%	Inhalation	Bird can be placed in a chamber or induced via mask. Intubation in birds is relatively easy.
Ketamine 1.5-6 mg/kg + Dexmedetomidine 40- 160mcg/kg	SQ	Can be used to maintain anesthesia delivered continuously SQ diluted in LRS Reverse dexmedetomidine with atipamezole 0.5mg/kg SQ
Ketamine 10-50mg/kg + Diazepam 0.5-2mg/kg	IM	

Analgesics		
Meloxicam 0.1mg/kg	IM q24h	NSAID
0.5mg/kg	PO q12h	
Carprofen 1mg/kg	SQ q12-24h	NSAID
Buprenorphine 0.01- 0.05mg/kg	IM q8-12h	Opioid agonist-antagonist
Butorphanol 0.5-2mg/kg	IM q6h	Opioid agonist-antagonist

RABBIT FORMULARY

DRUG NAME and DOSE	ROUTE & FREQUENCY	NOTES
Sedation		
Acepromazine 0.75mg/kg	IM	Produces a peripheral vasodilation useful for venipuncture
Dexmedetomidine 0.05mg/kg	SQ	Produces moderate sedation, useful for minimally invasive procedures less than 30 minutes
Induction		
Ketamine 10-20mg/kg + Dexmedetomidine 0.1mg/kg	SQ	IM administration of ketamine may cause myonecrosis, vasculitis, and axonal degeneration with resultant self-trauma Dermal ulcers may occur even with SQ administration, so 1ml saline can be injected at the same site following administration
Ketamine 44mg/kg + Xylazine 5mg/kg	SQ	
Maintenance		
Isoflurane	1-2% (MAC = 2%)	Laryngeal masks may be utilized in place of endotracheal tubes as rabbits are difficult to intubate
Analgesics		
Meloxicam 0.3-0.5mg/kg	SQ or PO q24h	NSAID – useful for mild to moderate pain
Buprenorphine SR 0.12mg/kg	SQ q 72hr	Sustained release formulation that eliminates frequent dosing requirement
Buprenorphine 0.02-0.05mg/kg	SQ or IV q6- 12h	Opioid

NONHUMAN PRIMATE FORMULARY

DRUG NAME and DOSE	ROUTE & FREQUENCY	NOTES
Sedation/Tranquilization		
Ketamine 8-10mg/kg + Midazolam 0.25mg/kg ± Glycopyrrolate 0.004mg/kg	IM	Diazepam causes pain on intramuscular injection and is not tissue soluble, so midazolam is preferred over diazepam for IM injections. Since midazolam is tissue soluble, it produces more reliable sedation that may allow intubation at this dose.
Ketamine 2-5 mg/kg + Dexmedetomidine 0.01-0.02 mg/kg	IM	Brief, reversible sedation for exams and minimally invasive procedures. To reverse, administer atipamezole in an equal volume (ml) to dexmedetomidine.
Ketamine 5-15mg/kg	IM	To be used only for chemical restraint, any invasive procedures require additional drugs
Ketamine 1-3mg/kg + Medetomidine 0.15mg/kg	IM	Medetomidine is alpha-2 agonists that are associated with bradycardia that should not be treated with atropine <ul style="list-style-type: none"> • Reversible with atipamezole at 0.22mg/kg IM Dexmedetomidine can be used as an alternative to medetomidine at 0.02-0.05mg/kg IM
Induction		
Propofol 2-4mg/kg	IV	Recommended as an alternative to masking with isoflurane to allow intubation following one of the above pre-medications
Maintenance		
Isoflurane	1-3% (MAC = 1.3%)	Dose-dependent hypotension due to a reduction systemic vascular resistance especially pronounced when >2%

Analgesics		
Meloxicam 0.2mg/kg followed by 0.1mg/kg	IM or SQ q24h	A COX-2 specific NSAID with fewer side effects than other less specific NSAIDs. The oral formulation does not last 24hrs in macaques, so the parenteral formulation should be used
Meloxicam SR 0.6mg/kg	SQ q72h	Sustained release formulation of meloxicam
Buprenorphine SR 0.12-0.2mg/kg	SQ q 72hrs	Sustained release formulation of buprenorphine that lasts for 72hrs
Buprenorphine 0.01-0.04 mg/kg	IM or SC q8-12h	An opioid useful as an adjunctive agent to NSAIDs; required for major invasive surgeries If the lowest dose (0.01mg/kg) is chosen, it must be given every 6-8hrs. Higher doses (0.03mg/kg) may be administered every 12hrs.
Fentanyl 7-10mcg/kg/hr	IV CRI	Opioid – useful intra-operatively for balanced anesthesia in procedures associated with moderate to severe pain

SWINE FORMULARY

DRUG NAME and DOSE	ROUTE & FREQUENCY	NOTES
Pre-Medication / Induction		
Telazol 4-6 mg/kg + Xylazine 2-3 mg/kg	IM	Prepared by reconstituting a 500mg bottle of Telazol with 2.5ml xylazine + 2.5ml saline and administered at 0.04-0.06 ml/kg body weight. For large pigs, a double-strength cocktail may be prepared by eliminating the saline and given at 0.02-0.03ml/kg.
Ketamine 10mg/kg + Medetomidine 0.2mg/kg	SQ	Sufficient for intubation. Medetomidine reversible with same volume of atipamezole (Antisedan) IM
Ketamine 33mg/kg + Acepromazine 1.1mg/kg + Atropine 0.05mg/kg	SQ	A butterfly catheter attached to a syringe can be used to avoid stress associated with restraining pigs. Behind the ears is the most easily accessible site for SQ injections in swine. This combination will not be adequate for intubation

Propofol 2-4mg/kg	IV	Used to induce general anesthesia for intubation; administer slowly to effect
Maintenance		
Isoflurane	1-2%	
Amiodarone 10mg/kg + 0.5mg/kg/hr	IV	Amiodarone is an anti-arrhythmic drug useful to prevent arrhythmias common in anesthetized swine especially during cardiac manipulation
Lidocaine 2-4mg/kg , then 0.3mg/kg/hr CRI	IV	Indicated for ventricular arrhythmias
Analgesics		
Carprofen 3-4mg/kg	PO q12h SQ or IM q24h	An NSAID, can be administered IM prior to procedure, then continued orally afterwards.
Meloxicam 0.4mg/kg	PO or SQ q24h	Can increase bleeding time in swine
Buprenorphine 0.02-0.05 mg/kg	IV, IM or SC q8-12h	Useful for breakthrough pain
Buprenorphine SR 0.18mg/kg	SQ q72hrs	Sustained release formulation eliminates need for frequent dosing

RUMINANT FORMULARY

DRUG NAME and DOSE	ROUTE & FREQUENCY	NOTES
Sedation		
Midazolam 0.3mg/kg + Fentanyl 0.0025mg/kg	IV	Sedation resulting in sternal recumbency for 20-30 minutes (adequate for quick minimally invasive procedures)
Pre-Medication		
Midazolam 0.5mg/kg + Fentanyl 0.005mg/kg	IV	Excellent sedation resulting in lateral recumbency for 30-45 minutes
Ketamine 7.5mg/kg + Midazolam 0.4mg/kg + Glycopyrrolate 0.004mg/kg	IV	Useful for IV sedation to produce lateral recumbency for animal transport and catheter placement
Induction		
Propofol 2-4mg/kg	IV	Administer slowly to effect for intubation Causes apnea with rapid administration
Maintenance		
Isoflurane	1-2%	

Fentanyl 5-20mcg/kg/hr	IV CRI	Short-acting opioid useful for intra-operative pain management during major invasive procedures; Required as balanced anesthesia for procedures such as sternotomies that are expected to cause severe pain
Analgesics		
Meloxicam 1mg/kg	IM or PO	NSAID – generally no more than 3-5 days, may provide analgesia for up to 72hrs
Flunixin (Banamine) 1.1mg/kg	IM or IV q12-24h	NSAID – generally no more than 3-5 days
Buprenorphine 0.005-0.01mg/kg	IV or IM q8h	Opioid

AMPHIBIAN FORMULARY

Drug and Dose Range	Route	Comments
Anesthetics		
Isoflurane 3-5% induction to effect; 2-3% maintenance	Inhalation	
Tricaine methane sulfonate (MS-222) 50-200 mg/kg ----- 0.5-2.0 g/l (frogs/salamanders)	Intracoelomic ----- Water bath to effect	Buffer to a pH of 6-7 with sodium bicarbonate
Ketamine 50-150 mg/kg	SQ, IM, IV or dorsal lymph sac	
Analgesics		
Drug and Dose Range	ROUTE and FREQUENCY	Notes
Buprenorphine 38-75 mg/kg	Dorsal lymph sac; Not less than every four hours	
Carprofen 2-4 mg/kg 1 st dose 1-2 mg/kg 2 nd dose	PO, SQ or IM; Every 24-72 hours	
Meloxicam 0.1-1.0 mg/kg	PO, SQ or intracoelomic; Every 24 hours	
Morphine 38-42 mg/kg	SQ; No less than every few hours	
Bupivacaine <2 mg/kg	Infiltrate or apply topically; Re-dose as needed	not to exceed a total dose of 2 mg/kg)

Lidocaine/Bupivacaine <2 mg/kg	Infiltrate or apply topically; Lasts 1-4 hours; Re-dose as needed	(not to exceed a total dose of 2 mg/kg)
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APPENDIX

LOCAL ANESTHETICS

Local anesthetics can be used in all species at similar doses, with the exception of cats. Nerve blocks should be considered prior to surgery whenever possible. Alternatively, infiltration of the surgical site with a local anesthetic at closing can significantly reduce pain in the post-operative period. Bupivacaine is the local anesthetic of choice due to its relatively long duration of action (6-8hrs compared to 2-4 hours of analgesia from lidocaine).

In all species, a maximum of 2mg/kg bupivacaine or 6mg/kg lidocaine should be administered. Although these drugs have relatively short half-lives, a variety of studies have shown that they reduce post-operative pain long after the drug has been metabolized and eliminated, demonstrating the power of prevention of nociceptor wind-up in controlling pain.

For animals experiencing a craniotomy, a regional scalp block with 2mg/kg bupivacaine is recommended. The supraorbital nerves are blocked as they emerge from each orbit by palpating the supraorbital notch, inserting the needle along the upper orbital margin, perpendicular to the skin, just medial to the supraorbital foramen. The occipital nerve is then blocked as it exits the skull near the occipital protuberance. The occipital artery on the back of the skull is palpated, and bupivacaine is injected medially after careful aspiration to avoid intra-arterial injection. These three injections are sufficient to regionally block the scalp for the region of most head post and chamber placements.