Pig Anaesthesia

The intent of this Standard Operating Procedure (SOP) is to describe commonly used methods to anesthetize pigs within the Comparative Medicine (CM) program. This SOP is intended for use by CM staff and investigators who perform induction and maintenance of anesthesia of pigs. This procedure is approved by the NUS Institutional Animal Care and Use Committee (IACUC). Any deviation must be approved by the IACUC prior to its implementation.

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1. INTRODUCTION

This SOP covers common anesthetic regimen and procedures used to induce and maintain anesthesia in pigs in CM facility.

2. MATERIALS

a. Pre-anesthetic agents
   i. Atropine
   ii. Midazolam
   iii. Buprenorphine/Carpofen/Meloxicam (Used as pre-emptive analgesia and given as pre-medication)

b. Anesthetic agents
   i. Injectable anesthetics such as Ketamine, Xylazine, Telazol, Medetomidine, Fentanyl, Sufentanil and Thiopental
   ii. Inhalant anesthetics such as Isoflurane.
   iii. Local anesthetics such as Lignocaine and Bupivacaine

c. Medical Gasses
   i. Oxygen
   ii. Medical Air

d. Equipments and Instruments
   i. Weighing scale
   ii. Mobile cage
   iii. Preparation room with wash-down table
iv. Endotracheal tube
v. Laryngoscope
vi. Anesthesia Machine with ventilator
vii. Stretcher
viii. Portable pulse oximeter
ix. Anesthesia / Patient monitor (with ECG, Pulse, SPO2, etCO2, non-invasive blood pressure (NIBP), invasive blood pressure (IBP), Temperature)
x. Defibrillator
xi. Syringe pumps
xii. Infusion pumps
e. Miscellaneous drugs / Emergency Drugs / Supplies / Consumable
i. Ophthalmic / Eye Ointment
ii. Intravenous catheter
iii. Drip line
iv. Fluid replacement
v. Plasma replacement
vi. Bandage tape
vii. Gauze bandage
viii. ECG electrodes
ix. Invasive blood pressure transducers
x. Adrenaline
xi. Phenylephrine
xii. Amiodarone
xiii. Lignocaine
xiv. Atropine
xv. Fentanyl (infusion and patches)
xvi. Pancuronium
xvii. Needles and Syringes
xviii. Sodium Bicarbonate
iii. Magnesium Sulfate

3. PROCEDURES

a. Pre-surgical / Pre-anesthetic preparation.

i. All pig procedures performed at NUS must have prior approval by the IACUC.

ii. Researcher and investigators should liaise with CM in regard to pig ordering, quarantine, conditioning or acclimatization, and housing prior to the start of procedure. Pigs that are meant for non-survival procedures will require at least 48 hrs of acclimatization, and pigs that will undergo survival procedures have to be acclimatized for at least 5-7 days before the surgery.

iii. Examine the pig to make sure it is fit for anesthesia/surgery and that it does not exhibit any of the following signs such as coughing, diarrhea, emaciation, weakness / lethargy, paleness, severe skin lesions and any other signs that would deem the animal unfit for anesthesia or surgery.
Perform blood work such as complete blood count, liver function and kidney function tests depending on the veterinarian’s discretion or the requirement of the procedure.

iv. Fast the pig for 12 hrs prior to surgery for routine procedures. For procedures that require bowel prep, provide the pig with liquid food (instead of pellets) and laxatives at least 3 days prior to surgery.

v. Take the weight of the pig and calculate the required premedication, anesthetics and the emergency drugs prior to the procedure. Please refer to Table 1 and 2 for the dosages:

**Table 1. Premedication, analgesic, antibiotic and anesthetic drug dosages for pigs.**

<table>
<thead>
<tr>
<th>Drug Name</th>
<th>Dosage</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atropine</td>
<td>0.044mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Midazolam</td>
<td>0.5mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Ketamine</td>
<td>12mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Carprofen</td>
<td>4mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Ketamine + Medetomidine</td>
<td>1mg/kg + 0.1mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Telazol + Ketamine + Xylazine</td>
<td>Reconstitute Telazol® with 5ml large animal xylazine (100mg/ml) instead of water; add 5 ml ketamine(concentration of 100mg/ml), then administer 0.025ml/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Thiopental sodium</td>
<td>5mg/kg to effect</td>
<td>IV</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>50ug/kg bolus, 30-100ug/kg/hr infusion</td>
<td>IV</td>
</tr>
<tr>
<td>Sufentanil</td>
<td>7ug/kg bolus, 15ug/kg/hr infusion</td>
<td>IV</td>
</tr>
<tr>
<td>Buprenorphine</td>
<td>0.1mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Meloxicam</td>
<td>0.4mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>5mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Gentamycin</td>
<td>2mg/kg</td>
<td>IM/IV</td>
</tr>
<tr>
<td>Cephalexin</td>
<td>20mg/kg</td>
<td>IM</td>
</tr>
<tr>
<td>Isoflurane Induction</td>
<td>5%</td>
<td>Inhalation</td>
</tr>
<tr>
<td>Isoflurane Maintenance</td>
<td>2-3% (0.5%) as supplement to sufentanil infusion as required</td>
<td>Inhalation</td>
</tr>
<tr>
<td>Lignocaine</td>
<td>Up to 4mg/kg</td>
<td>Local infiltration</td>
</tr>
<tr>
<td>Bupivacaine</td>
<td>Up to 1-2mg/kg</td>
<td>Local infiltration</td>
</tr>
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</table>
Table 2. Emergency Drug Dosages

<table>
<thead>
<tr>
<th>Drug Name</th>
<th>Dosage</th>
<th>Indication</th>
<th>Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenaline (1:10,000)</td>
<td>0.5-2ml bolus&lt;br&gt;0.05-0.5ug/kg/min as infusion</td>
<td>Asystole/Cardiac Arrest&lt;br&gt;Low arterial blood pressure, decreased left ventricular function</td>
<td>IV, Intracardiac</td>
</tr>
<tr>
<td>Lidocaine</td>
<td>2-4mg/kg bolus, followed by 50ug/kg/min as infusion if needed</td>
<td>Arrhythmia, Fibrillation</td>
<td>IV</td>
</tr>
<tr>
<td>Phenylephrine</td>
<td>0.1-0.5mg bolus followed by .5ug/kg/min infusion</td>
<td>Low arterial blood pressure</td>
<td>IV</td>
</tr>
<tr>
<td>Magnesium Sulfate</td>
<td>1-2g bolus</td>
<td>Ventricular Tachycardia</td>
<td>IV</td>
</tr>
<tr>
<td>Sodium Bicarbonate</td>
<td>1 mmol/kg</td>
<td>Respiratory acidosis after cardiac arrest</td>
<td>IV</td>
</tr>
<tr>
<td>Atropine</td>
<td>0.02mg/kg</td>
<td>Bradycardia, Heart Block</td>
<td>IV</td>
</tr>
<tr>
<td>Gelofusine</td>
<td>Bolus equivalent to amount of blood lost due to hemorrhage</td>
<td>Hypovolemia</td>
<td>IV</td>
</tr>
<tr>
<td>Dantrolene</td>
<td>5mg/kg</td>
<td>Malignant Hyperthermia</td>
<td>IV</td>
</tr>
</tbody>
</table>

b. Premedication / Induction

i. Move the pig to the mobile cage prior to the injection of premedication drugs. Inject atropine and midazolam either in combination or separately intramuscularly over the neck, lumbar or thigh area using a 19G or 21G butterfly needle (with extension tubing) fitted to a syringe.

ii. Once pig is already partially sedated (5-10 min after midazolam injection), inject the analgesic of choice (buprenorphine / carprofen / meloxicam) intramuscularly.
iii. Wash / Spray / Shower the pig thoroughly with warm water while still in the holding room to remove fecal material on its skin. Dry thoroughly.

iv. Induce the pig with ketamine 10 min after premedication was given and wait for another 5 min for the anesthetic to take effect before moving the pig into the preparation room.

v. Once pig is in the preparation room, mask with 5% isoflurane until complete relaxation of the jaw muscles has been attained. Alternatively, induction can also be achieved by intravenous injection of thiopental sodium (if available).

c. Intubation

i. Prepare the required materials and instruments such us endotracheal (ET) tube, laryngoscope, lidocaine spray and gauze bandage. Use cuffed ET tube size 2-6 mm for pigs between 1 to 10 kg, cuffed ET tube size 6 – 15 mm can be used for 10 to 200 kg pigs.

ii. Connect a portable pulse oximeter to the pig’s ear or lips. Ensure that heart rate and oxygen saturation is within acceptable range (refer to Appendix 1). If pig is not breathing spontaneously (apnea) flush with oxygen using mask and intubate immediately.

iii. Position the pig on the prep table based on preference. If one person is intubating, the best position would be right lateral recumbency, and if there is another person assisting the best position would be supine.

iv. Confirm that jaw is fully relaxed.

v. Open the jaw and spray the larynx with 1% lidocaine.

vi. Use appropriate size laryngoscope (size 1-4 Soper or Wisconsin) to expose and visualize the epiglottis before inserting the endotracheal tube.

vii. Ensure proper placement of the tube by presence of condensation in the tube, or by compressing chest and ensuring air blows out thru the tube. Alternatively, tube can be connected to the anesthesia circuit and ensure that rebreathing bag inflates during expiration and deflates during inspiration.

viii. Inflate endotracheal tube cuff slowly with 5-10 mls of air until it is fully inflated. Care has to be taken not to over-inflate the cuff as this will interfere with assisted ventilation.

ix. Use gauze bandage to secure the endotracheal tube and tie it behind the head.
d. Surgical Preparation, Anesthesia Maintenance, Ventilation and Anesthesia Monitoring (using volatile anesthetic and gas delivery)

i. Use either a rebreathing or non-rebreathing circuit depending on the nature of the procedure. Short duration procedures and procedures that do not require ventilation can use non-rebreathing circuit. For long duration procedures and procedures that require ventilation, a rebreathing circuit is preferred, especially for thoracic surgeries.

ii. Adjust isoflurane dose to 2-3% depending on depth of anesthesia.

iii. If using a non-rebreathing circuit set the oxygen flow rate to at least 2-3 liters/min, if using a rebreathing circuit set the oxygen flow rate to 1-2 liters/min.

iv. Note that the above anesthesia preparation and induction is the standard regimen practiced at CM. Other alternative anesthetic combinations are also available and investigators have to discuss it with veterinarian prior to use and under an approved IACUC protocol.

v. Apply eye ointment to lubricate the cornea.

vi. Prepare the surgical site by clipping the hair and scrubbing it with chlorhexidine soap to remove dirt and oils/sebum.

vii. Once surgical site prep is done, disconnect pig from the anesthesia circuit and move the pig to the operating theater. Position the pig on the surgery table accordingly. Use gauze bandage to tie down the pig on the table. Ensure that the warmers are turned on and preheated.

viii. Reconnect the pig to the anesthesia circuit and adjust isoflurane and oxygen flow rate accordingly.

ix. If mechanical ventilation is required set the following parameters based on Table 3.

<table>
<thead>
<tr>
<th>Table 3. Ventilation Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume</td>
</tr>
<tr>
<td>Ventilation pressure</td>
</tr>
<tr>
<td>Breaths per minute</td>
</tr>
<tr>
<td>Inspiratory to expiratory ratio</td>
</tr>
</tbody>
</table>

Ensure that there is no gas leakage and that the actual tidal volume delivered to the patient is within +/- 10% range of the actual setting. Make the necessary adjustments to the ventilation settings and anesthesia dose depending on dept of anesthesia and oxygen saturation. Alternatively, take a base line blood gas reading to ensure that pig is getting sufficient ventilation.
x. Catheterize the ear vein or any other accessible vein (cephalic/saphenous) with either a 20G or 22G cannula (catheter) and connect the pig to a fluid drip (0.9% NaCl or Hartmann’s solution). Adjust the fluid drip rate to 3 to 6 mls/kg/hr. Use infusion pump whenever possible.

xi. Administer antibiotics if pig will undergo survival surgery (with veterinary consultation or as written in an approved IACUC protocol).

xii. Connect the patient to the multi-physiological parameter patient monitor and monitor the following:

A. Minor surgeries/Non-survival surgeries:

1) Pulse/ECG
2) SPO2
3) ETCO2
4) NIBP
5) Temperature

B. Major Surgeries:

1) Pulse
2) ECG
3) SPO2
4) ETCO2
5) Arterial Blood Pressure (IBP)
6) Venous Pressure (CVP for Cardiac Surgeries)
7) Temperature

Please refer to Appendix 1 for the normal range of physiological parameters.

xiii. Ensure that physiological parameters are stable and that depth of anesthesia is sufficient all throughout the procedure. Assess dept of anesthesia by checking the jaw tone. Absence of jaw tone is an indication that animal is deeply anesthetized but make sure animal does not receive any muscle relaxant before assessing muscle tone. Monitor patient continuously and record vital signs every 15 min in the anesthesia record form (see Appendix 2).

xiv. Discuss emergency protocol with the veterinarian prior to the procedure. Anesthesia and surgery complications such as bradycardia, tachycardia, arrhythmia, ventricular fibrillation, hypotension, heart block, hypovolemia, cardiac arrest/asystole, malignant hyperthermia, etc. must be addressed appropriately using the available emergency drugs in CM. Please refer to the list of emergency drugs and the corresponding dosage in Table 2.
**e. Recovery**

i. At the end of the procedure, gradually wean the pig the anesthesia and ventilation. Deflate the cuff of endotracheal tube and remove once pig is already able to swallow.

ii. Ensure that local anesthetic and second dose of analgesic is administered whenever required.

iii. Refer to SOP # 204 for the post-operative recovery and care of the pig.

**f. Infusion Anesthesia**

For procedures that cannot use isoflurane for maintenance of anesthesia, infusion anesthesia can be used as an alternative. Please see some of the recommended infusion anesthesia regimen below.

i. **Infusion anesthesia for non-survival ventilation procedures.**

   1) Induce the anesthesia with ketamine and midazolam and mask animal with 5% isoflurane to achieve full relaxation of the jaw muscles. Intubate the pig as described in the previous sections of this SOP. Administer analgesic of choice.

   2) Mix 200 mg ketamine, 5 mg midazolam, and 12 mg pancuronium bromide in 50 ml saline and infuse at a rate of 0.5 ml/kg/hr. Adjust the flow rate in reference to the depth of anesthesia, heart rate and blood pressure to ensure animal is maintained at stable plane of anesthesia.

   3) Pancuronium bromide infusion can be given separately and not together with the above mixture to be more flexible with infusion flow rate and also to allow spontaneous breathing whenever it is required by the procedure. Alternatively it can be given as repeated bolus every 30-40 min at a dose of 0.06 mg/kg.

ii. **Infusion anesthesia for general surgeries.**

   **Fentanyl Infusion**

   1) Induce the anesthesia with ketamine and midazolam and mask pig with 5% isoflurane to achieve full relaxation of the jaw muscles. If procedure permits, intubate the pig as described in the previous sections of this SOP. Administer either meloxicam or carprofen as analgesic. Avoid using buprenorphine as opioids cause severe cardiopulmonary depression if in combination with midazolam.

   2) Once pig has been intubated and vein cannulated, inject bolus of fentanyl 50 ug/kg IV and infuse 30-100 ug/kg/hr IV as maintenance. Care has to be taken when loading the patient with
fentanyl due risk of cardiopulmonary depression. Adjust the flow rate in reference to depth of anesthesia, heart rate and blood pressure to ensure animal is maintained at a stable plane of anesthesia. Check whether level of anesthesia is sufficient by jaw tone and deep pain reflex.

**Sufentanil Infusion**

a) Administer ketamine, midazolam and atropine combination to tranquilize the pig. To induce anesthesia, administer thiopental at 5 mg/kg or mask with 5% isoflurane until full relaxation of jaw muscles is achieved. Intubate pig with appropriate size endotracheal tube and connect to a ventilator whenever possible. Start sufentanil infusion at a rate of 0.015 mg/kg/hr then administer bolus of 0.007 mg/kg 5 min after infusion has started.

b) Maintain the anesthesia with sufentanil infusion at a rate of 0.015 to 0.030 mg/kg/hr. Supplement with 0.5% isoflurane if required for major surgeries. Muscle relaxants can be used if needed but utmost care has to be taken to ensure that animals are deeply anesthetized prior to its use.

4. **PERSONNEL SAFETY**

   a. Wear safety shoes and other required PPE when working with pigs.
   b. Ensure anesthesia machines are checked and maintained regularly.
   c. Ensure that there is no gas leakage and that waste gas is scavenged properly.
   d. Switch off vaporizer when refilling with isoflurane.
   e. Handle and dispose sharps in to the designated containers.
   f. Do not recap needles.
   g. Observe proper hygiene, and be aware of allergy, zoonosis, and injury risks.
   h. Seek assistance when handling pigs that are more than 20kg. Use appropriate equipments for handling; avoid lifting the pig as much as possible.

5. **ANIMAL RELATED CONTINGENCIES**

   a. Please call the Emergency veterinary phone 90013073 for veterinary related contingencies after office hours or the duty veterinarian during office hours.
6. REFERENCES


d. Swindle, M., Smith, A. *Swine Anesthesia and Analgesia (Revision).*

<table>
<thead>
<tr>
<th>Revision #</th>
<th>Author</th>
<th>Effective Date/IACUC Approval Date</th>
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<td>Jonnathan Peneyra</td>
<td>16 May 2013</td>
<td>102.01</td>
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7. APPENDICES

Appendix 1. Normal Physiological Values

<table>
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<tr>
<th>Parameter</th>
<th>Normal Range</th>
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<tbody>
<tr>
<td>Oxygen Saturation (SPO2)</td>
<td>95-98 %</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>70-120 bpm</td>
</tr>
<tr>
<td>End Tidal CO2 (ETCO2)</td>
<td>35-45 mmHg</td>
</tr>
<tr>
<td>Temperature</td>
<td>39 °C</td>
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<tr>
<td>Arterial Blood Pressure</td>
<td>60-80 mmHg mean BP</td>
</tr>
<tr>
<td>Central Venous pressure</td>
<td>8-15 mmHg</td>
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Appendix 2. Anesthesia Record Form.

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<tr>
<th>Investigator</th>
<th>National University of Singapore</th>
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<tr>
<td></td>
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<table>
<thead>
<tr>
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| 2 |

**PRE-ANESTHETIC DRUGS:**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dose</th>
<th>Route</th>
<th>Time</th>
<th>Drug</th>
<th>Dose</th>
<th>Route</th>
<th>Time</th>
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</table>

**POST-OP TREATMENTS**

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<table>
<thead>
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**ANESTHETIC INDUCTION**

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<th>Drug</th>
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<th>Route</th>
<th>Time</th>
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**REMARKS**

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<th>45</th>
<th>60</th>
<th>15</th>
<th>30</th>
<th>45</th>
<th>60</th>
</tr>
</thead>
</table>

**CODE:**

- Puls
- Resp.
- SaO2
- Mean B.P.
- ETCO2

**TIMES:**

- Start area:
- Start proc. 1:
- Start proc. 2:
- End surgery:
- End anes.

**TOTAL FLUIDS (MLS):**

<table>
<thead>
<tr>
<th>Fluids</th>
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