Introduction.

This section will provide an overview of anaesthesia in African primates including highlighting various chemical restraint regimes and suggesting methods of anaesthesia for specific species. It aims to outline what is anaesthetic best practice, indicate instances and procedures where anaesthesia may not even be necessary, and also to investigate how each anaesthetic regime works. The section is divided into three parts. Part 1 outlines general anaesthetic principles and processes, including a brief section on manual restraint. Part 2 deals with anaesthetic emergency procedures when things go wrong. Part 3, discusses anaesthetic drug properties and provides anaesthetic suggestions by species.

Chemical immobilisation of wild primates is a difficult, risky and hazardous procedure. Besides the risks related directly to the capture itself, several authors have stressed the problem of behavioural disruption of a group following an anaesthetic event, resulting for example in a change in the social status of the darted individual (Chimpanzee *Pan troglodytes*; S. Unwin personal observations). This can also manifest as an altered response to the human observer (Karesh *et al.*, 1998). Procedures for darting small arboreal primates are described by Glander *et al.* (1991), Jones & Bush (1988) and Karesh *et al.* (1998); guidelines for chemical capture of large terrestrial NHPs can be found in Sapolsky & Share (1998) and Sleeman *et al.* (2000); practical tips for chemical restraint of mammals as well as a list of the necessary equipment for field anaesthesia may be found in Osofsky & Hirsch (2000) Readers are also directed to the primate anaesthetic chapters in West, Heard and Caulkett (2007) for a thorough overview of primate anaesthesia.

Part 1. The anaesthetic process – considerations for the field

**IS ANAESTHESIA NECESSARY?**

Anaesthesia can be physiologically stressful on any animal, and a decision to sedate or anaesthetise an animal must not be taken lightly. However, with the animal immobile, risk of disease transmission (from bites and scratches) is also reduced, and the quality of samples taken will be enhanced. Ethical and welfare considerations must also be taken into account. Consider:

- Could the process you are investigating be conducted with the animal unanaesthetised?
- Is the animal trainable to provide what is required in a non stressful way, such as presenting an arm for blood sampling?
- If manual restraint is to be considered, will the stress induced in the animal be more damaging than an anaesthetic? Have health and safety issues been considered for staff? Is there ease of access to the animal for sample collection? (a big problem if it is struggling inside a net). Is the process repeatable in the future without sedation?
• If anaesthesia is considered the best process, what regime will be employed? Will there be an effect of any anaesthetic regime on samples/ experimental parameters?

**MANUAL RESTRAINT**

As a general rule, Non Human Primates (NHP’s) are sensitive to stress, and, except for younger animals or smaller species, are very strong and able to inflict severe injuries on human handlers. Handling is a compromise between human and animal safety in a situation where stress levels must be kept as low as possible. Physical handling without tranquillisation is possible for smaller individuals, but chemical tranquillisation is necessary for larger individuals, or for major procedures.

NHPs weighing less than 3 kg can easily be handled and manipulated by one person. However, most of these species are agile and will not hesitate to bite if they feel threatened. Always handle primates with protective leather gloves. **Rapid capture is essential.** Chasing an animal around an enclosure is psychologically stressful to the animal. Physiological stress can also be induced, which can lead to hyperthermia, which can rapidly lead to death.

The smallest animals can be gripped around the neck with the thumb and forefinger, or by a fold of skin on the flank (especially prosimians). Larger prosimians can be held by the scruff of the neck with one hand, and by the feet or base of the tail with the other (FIGURE 1). Note however that most prosimians have an explosive flight reaction when disturbed in their nest or their captive box and considerable care should be taken when capturing individuals manually (Bearder & Pitts, 1987).

![Figure 1. Manual restraint of a Ring Tailed Lemur. Handler Chris Yarwood (Source Chester Zoo)](image)

Small monkeys should be grasped just under the arms, with the fingers encircling the upper chest. This position is convenient for intramuscular or intraperitoneal injection. However, for more effective immobilisation, the arms are held together behind the animal’s back in the same fashion as that used with larger primates (figure 2). A second person is always required to carry out procedures, and restraint should be kept to as short a time as possible to minimise stress. **Prolonged handling**
of small primates is extremely stressful, and we recommend considering the anaesthetic options below if the animal is going to be in hand for longer than a couple of minutes.

Animals weighing 3--10 kg can be caught in a heavy net (or blanket or piece of fabric) and held by pinning the arms back. The two arms are held together with one hand behind the primate’s back whilst the two feet are held together with the other hand (see figure 2). Never hold the animal by only one arm, as this could result in fracture or dislocation of the humerus. For obvious safety reasons, species weighing more than 10 kg need to be chemically restrained.

Figure 2. Correct monkey hold (Source; Limbe Wildlife Centre, Cameroon. Handler Jonathan Kang)

PRE-ANAESTHETIC ASSESSMENT AND PREPARATION

Preparation is essential so the animal can be immobilised efficiently and safely for the shortest period of time. EVERY MEMBER OF THE TEAM SHOULD BE BRIEFED BEFORE THE PROCEDURE AND JOBS ASSIGNED SO EVERYONE KNOWS WHAT TO EXPECT AND WHAT THEY SHOULD BE DOING DURING A PROCEDURE, BOTH IN GENERAL, AND IF PROBLEMS OCCUR.

Although modern drugs have a wide safety margin in primates, none are absolutely safe and the reaction of any individual primates to anaesthesia can be unpredictable. Therefore there is no such thing as "risk-free" anaesthesia and it follows that anaesthesia should never be undertaken lightly. Most drugs and drug combinations have advantages and disadvantages and it is important to use a technique with which the anaesthetist is familiar.

Many of the problems that can occur during anaesthesia are avoidable by careful pre-anaesthetic assessment of the patient and consideration of the conditions under which anaesthesia is to be performed. In emergencies such as the recovery of an escaped primate this is not always possible, but even in this situation thought should have been given to what will be needed in advance of the event. The following conditions increase the anaesthetic risks:

- old age
Prior to anaesthesia a primate's general condition should be assessed, its medical history considered and its weight determined, (often by estimation or from previous notes), in order to select the most appropriate drug and dose. It is also necessary to consider what type of anaesthesia is required - profound for surgical intervention, light for blood sampling or examination etc.

Consideration should be given to the possibility of dehydration, shock or the presence of disease, which may complicate the anaesthetic or require immediate attention once the primate is anaesthetised.

The physical assessment of a primate prior to anaesthesia can be difficult and may even require the use of binoculars. If any doubt exists, time spent quietly observing a primate prior to anaesthesia will be profitable. Poor water intake, diarrhoea, vomiting, sunken eyes or unusually frequent urination may suggest dehydration. Where there is a possibility of dehydration, equipment and materials should be prepared to allow aggressive fluid therapy during anaesthesia as primates rarely tolerate intravenous fluid administration when conscious.

Coughing or breathlessness may indicate a respiratory problem, and it is important to appreciate that respiratory disease is common in primates. This is especially true of the apes (and certain monkey species) which possess laryngeal air sacs. These air sacs are vulnerable to infection, and can complicate general anaesthesia if they are infected.

Weight is sometimes difficult to estimate and weighing the animal while anaesthetised is always useful.

All anaesthetic procedures should be recorded on anaesthetic data sheets. Included should be details on the initial effect and down time and the recovery times as well. The reason for the anaesthesia should be written and any treatments given. Any recommendations for changes to the anaesthetic regime should be noted. An example from Chester Zoo is presented below:
### Anaesthetic Record - Chester Zoo -

**Health Status:**
1. [ ] Normal
2. [ ] Abnormal

**Fasting Time:**
1. [ ] < 8 hours
2. [ ] 8 - 24 hours
3. [ ] 24 - 48 hours
4. [ ] > 48 hours

**Activity:**
1. [ ] calm
2. [ ] active
3. [ ] excited

**Demeanor:**
1. [ ] depressed
2. [ ] alert
3. [ ] aggressive
4. [ ] apprehensive

**Weight:**
__________ 1. [ ] Kg
1. [ ] actual
2. [ ] estimate
3. [ ] gm

**Environ. Temp:**
__________ 1. [ ] C
2. [ ] F

**Pressure/Dist:**
__________

---

### Physical Status:

1. [ ] Class I normal health
2. [ ] Class II minor health problem
3. [ ] Class III major health problem
4. [ ] Class IV serious or chronic prob.
5. [ ] Class V may not survive, with or without intervention

**Immobilizing Conditions:**
1. [ ] Free ranging
2. [ ] Large enclosure
3. [ ] Small enclosure
4. [ ] Squeeze cage
5. [ ] Manual restraint

(a) Drug administration

1. [ ] isolated
2. [ ] in group

**Body Condition:**
1. [ ] obese / fat
2. [ ] good
3. [ ] fair / thin
4. [ ] poor / emaciated

(b) Location

In enclosure [ ] inside [ ] outside[

Vetlab [ ] Leiahurst [ ]

Other [ ]

---

### Physiological Data:

**Temp [ ] C. [ ] F.**

**Heart (bpm)**

**Resp (bpm)**

---

**Method Used for Monitoring – Visual [ ] Pulse Ox [ ] Stethoscope**

---

**Initial Effect Time:**

____:____

**Recumbency Time:**

____:____

**Endotracheal Tube:**

__________

**Complications:**

---

### Anaesthetic Ratings:

**Induction:**

1. [ ] 2. [ ] 3. [ ] 4. [ ]

**Muscle Relaxation:**

1. [ ] 2. [ ] 3. [ ] 4. [ ]

**Overall:**

1. [ ] 2. [ ] 3. [ ] 4. [ ]

---

**Vet:**

1. [ ] SS 2. [ ] SU 3. [ ] JAC

---

### Recovery Data:

**Initial Time:**

____:____

**Effect:**

---

### Dose:

**Drug:**

**Amount**

**Route**

**Time**

**Delivery**

**Success**

**Max. Effect**

**Time Max. Effect**

**Batch / Trade Name**

---

**Premed**

**Maintenance**

**Antagonist**

**Supplemental**

**Other**

---

**Route:**

**Polesyringes**

**Facemask**

**Blowdart**

**Chamber**

**Metal Dart**

**Endotracheal Tube**

**Hand syringe**

**Venous catheter**

**Non-metal Dart**

**Oral**

---

**Meant muscular**

**Subcutaneous**

**V=intravenous**

**P=intraperitoneal**

---

**Del:**

**Complete**

**Partial**

---

**Effect:**

0 = no effect / fully recovered
1 = mild sedation
2 = heavy sedation
3 = light anaesthesia
4 = surgical anaesthesia
5 = excessively deep
6 = death

---

### Recovery:

1. [ ] Normal
2. [ ] Abnormal
3. [ ] Prolonged
4. [ ] Stormy
5. [ ] Renarcotized

---

**Accession:**

__________

**Date:**

____/____/09

---

**Species:**

__________

**Sex:**

__________

**Tattoo/Tag:**

__________

---

**House name:**

__________

**Birthdate/age:**

__________

---

**Transponder:**

__________

---

**Procedure:**

__________

---

**Drug:**

**Amount**

**Dose**

**Class**

**Name (generic)**

**Strength mg/ml**

**ml**

**mg or %**

**Route**

**Time**

**Given**

**Delay**

**Success**

**Max. Effect**

**Time Max. Effect**

**Batch / Trade Name**

---

**PHYSIOLOGICAL DATA:**

**Temp [ ] C. [ ] F. / Heart (bpm) / Resp (bpm)**

**METHOD USED FOR MONITORING – VISUAL / PULSE OX / STETHOSCOPE**

---

**Initial Effect Time:**

____:____

**Recumbency Time:**

____:____

**Endotracheal Tube:**

__________

---

**Complications:**

---
<table>
<thead>
<tr>
<th>Recorded by:</th>
<th>Recorded by:</th>
</tr>
</thead>
</table>

**Blood Sample Data:**

- Time: _____ : _____
- Collection Site: L / R _________________
- By: 1. [ ] SS  2. [ ] SU  3. [ ] JAC  4. [ ] KH  5. [ ] TC

**Haematology sample:**

1. [ ] EDTA
2. [ ] EDTA – liquid
3. [ ] EDTA – dry
4. [ ] Heparin
5. [ ] Heparin – liquid
6. [ ] Heparin – dry

**Chemistry sample:**

1. [ ] serum
2. [ ] plasma

**Comments:**

- __________________________________________________________________________
- __________________________________________________________________________
- __________________________________________________________________________

---

**Oxygen sat. %**

| TIME | 00 | 05 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 00 | 05 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 00 | 05 | 10 | 15 |
|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|      |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

**Temp C/F**

- __________________________________________________________________________

**ISO %**

- __________________________________________________________________________

**O2 (L)**

- __________________________________________________________________________

**NOTES**

---

**Oxy. Sat %**

| TIME | 00 | 05 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 00 | 05 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 00 | 05 | 10 | 15 |
|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|      |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

**Temp. C / F**

- __________________________________________________________________________
After the procedure, all equipment should be cleaned and returned to their allocated place.

A debrief of the procedure should always take place even if the procedure has gone well to make suggestions for improvements in the future.

Preparing the Animal.

(i) **Pre anaesthetic fasting.**
Primates being anaesthetised for elective procedures should be fasted to reduce the risk of vomiting and subsequent inhalation of vomitus. Except for small species, this should be for at least 12 hours (remove water 6 hours before hand). In smaller species such as guenons, 6 hours fasting is usually sufficient (2 hours for water). Care is needed in stressful situations and fasting might sometimes result in pica or coprophagy.

(ii) **Analgesia**
Analgesia should be considered for all procedures that would be considered painful in humans. Not only is this ethically sound, but the animal will recover a lot faster from an anaesthetic, with pain relief as part of the anaesthetic plan, after a painful procedure.

(iii) **Anaesthetic Doses**
Drug doses and regimes should be researched and/or previous anaesthetics on the same animal or species consulted from previous records.

(iv) **Emergency drugs and protocol.**
At every facility an emergency protocol must be in place as to what action needs to be taken if an anaesthetic does not go as planned. The standard **Airway Breathing Circulation Drug** therapy protocol can be employed, or a variant of it. Emergency drugs such as adrenaline and atropine should be readily available, either with doses already drawn up into labelled syringes for that animal, or with dose charts readily to hand. Each facility will need to adapt any emergency anaesthetic complication protocol to their own situation. An example of this protocol, including emergency drug dosages, is presented in the emergency medicine section 3.8 and in a cut down version at the end of this section.

(v) **Animal restraint while under anaesthetic.** Some method of physical restraint may be mandatory, especially in the larger monkey and ape species.

(vi) **Airway patency during anaesthesia**
Small monkeys should be masked with Oxygen (and suitable endotracheal tubes available). Larger monkey species, and the apes, should be intubated (Figure 3 and 4).
ROUTE AND METHOD OF ANAESTHETIC INDUCTION AND MAINTENANCE.

This will be based on the animals species, size, age, and state of health. No anaesthetic works immediately and consideration must be given to what may happen during the time between administering an anaesthetic and induction of anaesthesia. If the primate is contained in a carrying box or crush cage during this period the potential for problems is minimised. However, if anaesthesia has to be induced by darting in outside enclosures the weather should be considered, pools drained, the risk of falling from platforms, trees etc after induction taken into account and unnecessary personnel kept away. ALWAYS attempt to isolate the animal to anaesthetise it before anaesthetic induction is attempted WHEREVER POSSIBLE.
It is essential that primates are not excited prior to or during anaesthetic induction. An excited primate will require higher anaesthetic doses and take longer to become recumbent. Both these factors, plus the higher adrenaline levels circulating in excited primates increase the potential for complications during anaesthesia. Hearing is usually the last sense to be abolished by an anaesthetic, therefore it is also important to have quiet environment to avoid disturbance during induction.

In the case of primates that can be safely hand-held, anaesthetic agents can be delivered by direct intramuscular injection into the quadriceps, hamstrings or shoulder muscles. Crush cages also allow relatively safe intramuscular injection of anaesthetic agents. Oral use of medetomidine might allow hand injection. Remember that primates and especially apes recognize the person who anaesthetises them. In captivity operant conditioning can train some individuals to present a muscle mass for hand injection.

After an anaesthetic agent has been delivered, it is important to allow sufficient time for its full effect to be realised. Therefore a minimum of 10-15 minutes should be allowed to elapse before a primate is disturbed, irrespective of whether it is down, unless an emergency situation such as respiratory arrest develops during this period. Failure to allow such a period may result in partial arousal during the induction period leading to a lighter plane of anaesthesia than would normally be expected with a given anaesthetic dose rate, especially with a medetomidine/ ketamine mix.

Specific anaesthetics or anaesthetic combinations with appropriate dose rates are given in part 3.

(i) Induction using an Injectable agent:
Most anaesthetic induction agents are given via intramuscular or intravenous injection. Care is needed to ensure that primates do not injure themselves following the administration of injectable anaesthetics or during the recovery phase (see below). If an animal is remotely injected with anaesthetic (such as with a blowpipe or dart gun), they should be on the ground when darted so they are not injured if they fall. Preferably, all monkeys should be induced in crush cages. This process is quick and accurate. Enclosure design should accommodate the use of various sized crush cages. When animals are released after dosing with an injectable anaesthetic for example, they invariably sit high up on a perch or cling high up on the sides of the cage or pen, and in a large cage may fall heavily when they lose consciousness. This can be prevented by using a small cage for anaesthetic induction, or by supporting the animal as it succumbs. Note however that this last may actually increase the animals stress, and make anaesthetic induction less smooth. The decision must be based on an individual assessment.

(ii) Induction using Inhalation agent:
In small species such as guenons, and in juvenile larger monkeys, either manual restraint or an induction box can be employed and the animals masked down with inhalation agent. Handling can be very stressful to the individual concerned, particularly with an agent such as isoflurane which has an unpleasant odour and is a respiratory irritant. Sevoflurane does not have these negative aspects and should be considered in animals too sick for an injectable agent, or those more amenable to handling. Little is yet published on the use of this anaesthetic in non human primates.
Use of an induction box can often be a better alternative to manual restraint. For example you can create an induction box by placing a small holding cage or carrier inside an airtight plastic bag, and provide a hole to pump in gaseous anaesthetic and oxygen.

(iii) Anaesthetic Maintenance:

When it is necessary to prolong anaesthesia beyond the time allowed by a single dose of the injectable induction agent, maintenance with gaseous anaesthetic agents such as isoflurane or sevoflurane administered with oxygen via an endotracheal tube is the best option.

Great apes are best intubated in dorsal recumbency (figure 4) with the head extended off the edge of the table.

However, certain injectable anaesthetic drugs (e.g.: ketamine) can be given in incremental intravenous doses. If supplementary anaesthetics are given in intramuscular increments the total recovery time may be significantly prolonged. The IV route allows lower quantities of drugs, but as the elimination is faster, it might be necessary to top up frequently. It is therefore not recommended to EXTEND an anaesthetic by injectables alone for longer than 60 to 80 minutes.

Whatever the method of induction, placement of an endotracheal tube, to maintain a patent airway, is recommended in nearly all general anaesthetic cases, even if inhalation anaesthetics are not to be administered. As intubation does not present any particular problems in primates, a well fitting face mask can alternatively be employed by experienced anaesthetists. Endotracheal intubation allows precise delivery of inhaled anaesthetic agents. Intubation in small non-human primates (less than 1 kg), is straightforward, using commercially available equipment and careful positioning of the animal (Morris et al., 1997).

In all primates, tracheal length is relatively short, so endotracheal tubes should only be inserted to just past the larynx, to prevent bronchiole intubation and consequent over inflation of one or other lung.

In chimpanzees and gorillas, laryngeal masks could be used to minimise tracheal irritation.

The larynx can be sprayed with local anaesthetic such as lignocaine before intubation to reduce the risk of laryngospasm, particularly following induction with ketamine alone, as the laryngeal reflexes will still be functioning.

Very young or very sick primates can be induced using gas anaesthesia, or intravenous propafol.
ASSESSMENT AND MONITORING OF PRIMATES DURING ANAESTHESIA

The primary purpose of anaesthesia monitoring is to maximize the safety of an anaesthetic procedure, particularly by avoiding excessive anaesthetic depth. Physiological parameters of guenons, baboons and chimpanzees are presented in Table 1. These physiological reference ranges are altered by anaesthesia or restraint.

<table>
<thead>
<tr>
<th></th>
<th>Guenon</th>
<th>Baboon</th>
<th>Chimpanzee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body temperature</td>
<td>39°C</td>
<td>39°C</td>
<td>37°C</td>
</tr>
<tr>
<td>Heart rate</td>
<td>2-300/min</td>
<td>150/min</td>
<td>60-80/min</td>
</tr>
<tr>
<td>Respiratory rate</td>
<td>20-50/min</td>
<td>35/min</td>
<td>20-50/min</td>
</tr>
<tr>
<td>Tidal volume</td>
<td>50 ml</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 1: Physiologic parameters of Non human primates

Following apparent immobilisation it is necessary to assess the effectiveness of anaesthesia before any procedures (including moving the primates) are carried out. This is especially important with large individuals which could be dangerous if incompletely immobilised. It is also necessary to constantly assess the well-being of a primate during anaesthesia as problems are easier to correct if detected early. Of the five senses, hearing is the last to go, and the first to return. Noise MUST be kept to a minimum throughout induction and anaesthetic maintenance.

Responses to stimuli such as pinching between the toes, respiration rate, colour of mucous membranes (e.g. the lining of the mouth), pulse rate and quality, and muscle tone should all be assessed without delay after apparent immobilisation, and at regular intervals (every 5 minutes) thereafter. Wherever possible, this anaesthetic monitoring should be undertaken by a dedicated person.

During intubation, the mouth should be checked thoroughly and any food material, excess saliva or even pieces of dart or dart needles removed. Body temperature should be monitored and hypo- or hyper-thermia corrected. Hyperthermia can result from pre-anaesthetic excitement, high ambient temperatures or direct sunlight during anaesthesia, or convulsions at any stage.

A member of the team should be holding the hand of the primate throughout the procedure. The grip reflex is one of the first to return after an anaesthetic, and can be used as another indicator of an anaesthetic getting too light.

Once a primate is immobilised, place a small amount of an ophthalmic ointment onto the surface of the eyes to prevent drying of the cornea. Do not allow the sun to shine directly into the eyes of a primate at any stage during anaesthesia - irreversible damage may be done to the retina, especially if the pupils are dilated. Whilst monitoring anaesthesia, detailed notes or charts should be kept of all measured physiological parameters, including respiratory, heart rates, body temperature, pulse quality, muscle tone and mucous membrane colour.

- pink mucous membrane is normal
- red mucous membrane might be a sign of hyperthermia
- white or pale mucous membrane might be a sign low blood pressure, vascular problem
- blue might mucous membrane be a sign respiratory problem
Capillary refill time should be less than 2 seconds, time exceeding 2 seconds is a sign of low blood pressure. Where possible, use a pulse oximeter to measure blood oxygenation levels.

Respiratory rates decrease during anaesthesia and increase during recovery. Access to a capnograph is useful to assess carbon dioxide levels in the expelled air (C02 should be maintained between 3.5 and 5.5% of end tidal volume – above 5.5% is an indication that increased oxygen/ IPPV is required). This in conjunction with a pulse oximeter will provide an excellent early warning system of pending anaesthetic issues.

With keeping detailed notes of physiological parameters, changes in the vital signs - even subtle ones - can be easily appreciated and reference may be made to a particular primate’s response to anaesthesia at a later date (see an example of an anaesthetic form provided above).

Always record a primate’s weight during anaesthesia so that accurate dose rates of anaesthetic agents can be calculated retrospectively.

The palpebral and pedal reflexes may also be used, depending on the anaesthetic used. While these can all be useful in determining if the animal is ‘too light’, they provide little information about an animal that is ‘too deep’ (Horne 2001). Hypoxia and hypothermia, common side effects with increasing depth of anaesthesia, are the two main causes of anaesthetic emergencies. Continuous monitoring, with pulse oximetry, of oxygen-haemoglobin to maintain above 85% saturation and temperature, to detect hypoxia and hypothermia, represent a bare minimum that must be undertaken. Anaesthetic emergencies can also occur because of hypoventilation (measure end tidal CO2 via capnography), hypotension (measure blood pressure) and cardiac arrhythmias (measure cardiac electrical activity via ECG). Careful monitoring of all these parameters allows for continuous assessment of cardiopulmonary function and provides early warning, should problems arise (Horne, 2001).

Important for long-term anaesthesia is the placement of an indwelling catheter that allows for administration of fluids and emergency drugs. Sterile technique for catheter placement is imperative (Hrapkiewicz et al., 1998).

A note on Body Temperature
Hypothermia may be a significant problem during surgery on primates unless care is taken to keep animals warm during anaesthetic induction and the surgical preparation time. For example, Ketamine has been shown to produce a fall in rectal temperature to 35°C within 10 minutes at an ambient temperature of 30°C. Induction in the home cage means that the animal is lying on metal mesh or bars when it loses consciousness. Any drop in temperature may then be exacerbated by clipping extensive areas of hair and by the application of large volumes of rapidly evaporating skin preparation solutions (Baskerville 1999). Intraoperatively, monkeys should have their body temperature monitored and maintained by use of a circulating heating blanket, heat pads and/or heat lamps. Warm intravenous fluids are also helpful in preventing hypothermia. Latex gloves can be filled with hot water to provide short term hot water bottles. These however must be removed and replaced regularly, and
removed totally before recovery. Hypothermia is indicated at temperatures below 36°C.  
The stress of handling may also result in a rise in body temperature to, at MOST, 39.5°C. Any temperature above this, or one which doesn’t reduce, usually indicates an underlying disease process.

Two commonly used anaesthetic combinations, ketamine and acepromazine or tiletamine-zolazepam (Zolitel®), were compared to identify their effects upon body temperature in cynomolgus macaques (Lopez et al., 2002). Thirty cynomolgus macaques previously implanted with subcutaneous telemetry devices were allocated into two groups of 15 animals. Baseline temperature data were collected for 3 days before administering anaesthesia to establish normal diurnal temperature patterns for each monkey. Each group was then anaesthetized with either ketamine-acepromazine or tiletamine-zolazepam, and their body temperatures were recorded at 15-min intervals. Both groups had marked decreases in body temperature, with the greatest decreases in the tiletamine-zolazepam group. In addition, both groups had notable post-anaesthesia elevations in body temperature that often lasted for more than 24 h post-induction.

ANAESTHETIC RECOVERY

Recovery must be conducted in as calm and quiet environment as possible. Keep the animal warm and away from drafts. Extubation of the endotracheal tube should not occur until the animal can swallow. A string can be tied to the tube so it can be removed remotely, as many primates don’t provide a clue as to when they are about to awaken, and extubation is often reliant on the anaesthetists experience. Providing a favourite toy for the animal may be appropriate to help keep it calm until it is sure of its surroundings. During recovery, primates try to climb upwards as soon as they recover consciousness. Fortunately, they rapidly regain the ability to cling with their hands and feet, and support their own weight. They usually then stay quietly clinging onto something until they have fully recovered.

In hot weather, recovery areas should be cooled. Before leaving a primate to recover, the mouth and pharynx (back of throat) should be checked for saliva, food material, foreign bodies etc. The latter must be removed. Be particularly careful after dental extractions as post-extraction haemorrhage can be significant. Monitoring of pulse, respiration and temperature should continue until it is no longer safe to do so or until such interference disturbs the primate.

The primate should be left in lateral recumbency with head and neck extended and the tongue protruding from the mouth if possible. This should allow any saliva to drain from the mouth. Protect the eyes from direct sunlight. Be aware of potential hazards (water, falling from heights etc) to the primates in its immediate environment - most primates will stagger somewhat as they attempt to move away following awakening. Do not feed or provide water until recovery is complete and the primate can walk without ataxia. Recovery will take longer in fat individuals.
ANAESTHETIC INDUCTION VIA DARTING

The most common approach to capturing wild NHPs is remote injection using blowguns or capture rifles (Figure 5). Darting can also be used to dispense medications such as antibiotics or vaccines.

![Darting System](image)

Description of various darting systems, their advantages and disadvantages can be found in Sapolsky & Share (1998) and Karesh et al. (1998). A brief review of using air powered darts is given below. Remote delivery systems should be used only by experienced people owing to the high risks of injury to the animal from a badly located dart, and hazards related to the pre-anaesthetic stage (e.g. falling from a tree or into water, aggression from a conspecific or a predator). NHPs also often remove the dart following impact, before the full dosage has been injected, and only a mild tranquilisation stage is achieved. In this case, the animal must be monitored until completely recovered.

Ideally primates should not be darted when another is present in the cage or enclosure.

**NB: NEVER DART A PRIMATE IN AN ENCLOSURE WHERE AN ELECTRIC FENCE IS ACTIVE.**

When using a blowpipe care should be taken to ensure that the anaesthetic agent is delivered intramuscularly and not subcutaneously, as the latter route may prolong the induction time or may fail to produce complete immobilisation.

**Particular attention should be taken with chimps who can return darts with surprising force. All primates can remove the dart very quickly so small volumes should be used.** Be careful not to inadvertently dart genital swellings in females as the risk of haemorrhage is high.
Dan-inject™/ Telinject™ example - Loading the dart:

Always wear latex gloves when loading a dart. Many anaesthetics are absorbable through skin, and further precautions to prevent operator contamination may be required. CHECK THE MANUFACTURERS RECOMMENDATIONS FOR EACH DRUG.

Before attaching the needle to the dart, block the hole of the dart needle with the silicon sealing sleeve (colour depends on the size), so 1/3rd of the sleeve is above the hole(s) and 2/3rds is below it. The silicon sleeve should be used only once.

Remove the stabilizer (see figure 6) and release any air retained from the syringe air chamber.

Position the black plunger at the rear of the chamber (needle side) while holding the dart with the air chamber uppermost.

Reverse the position of the dart to put the drug chamber uppermost. Slowly inject the anaesthetic to prevent dribbling out of the top of the dart.

Mount the dart needle onto the dart syringe boss using pliers and locate it firmly by rotating it.

Apply a safety cap over the needle before pressurizing the dart.

Pressurising the dart:

This is best done as soon after the anaesthetic is placed in the dart as is possible. Hold the dart vertically. **Place a protective covering over the needle in case of leaks.**

Mount the coupling adapter onto a syringe. Introduce air into the syringe:

- 10 - 15 ml air for 1.5 ml dart
- 15 - 20 ml air for 3.0 ml dart
- 20 ml air for 5.0 ml dart
- 30 ml air for 10.0 ml dart
Connect the syringe to the air chamber of the dart and, with a smooth continuous action, inject the air into the dart air chamber. The red plunger will act as a non-return valve and retain the air within the dart. The dart is now pressurized and must be handled very carefully. Place the red stabiliser firmly on the rear of the dart. The stabiliser must not be wet (the syringe would be unstable in flight). THE ONLY SAFE PLACE FOR A CHARGED DART IS INSIDE THE DART GUN OR BLOWPIPE. MOST GOOD DARTS WILL HOLD THEIR PRESSURE IN THE GUN FOR QUITE A WHILE BUT THE CHANCE OF MISFIRE INCREASES THE LONGER THE DART REMAINS PRESSURISED. IF YOU HAVE A LOADED DART IN THE GUN FOR LONGER THAN AN HOUR BEFORE DARTING WE RECOMMEND DEPRESSURISING AND REPEATING.

After use
Make sure someone (usually the anaesthetist) is tasked with retrieving all darts used as soon after anaesthetic induction as it is safe to do so. They must be depressurised immediately and placed in a safe container (e.g a plastic tube) so they are stored safely until after the procedure. Always clean and dry the dart and needle as soon after use as possible. Do not store drugs or water in the dart syringes for prolonged periods, it will adversely affect the plunger and dart barrel.
INHALATION ANAESTHETIC MACHINES AND THEIR MAINTENANCE

Standard to-fro systems of inhalation anaesthesia can be used in sanctuaries (Figure 7).

Special inhalation anaesthetic field kits are available, (e.g Lewis 2004, Figures 8 and 9), and provide an excellent option for the field researcher for anaesthetic maintenance.
The maintenance of the anaesthetic machines is a critical part of successful anaesthesia.
Human anaesthetic equipment is well adapted to apes.

Regular checks should be made to make sure the anaesthetic machine is ready for use:
Check oxygen level, change if low/needle in the red.
Ensure oxygen tap is closed and any remaining pressure in the system has been released.
Remove regulator and exchange bottles.
Oxygen cylinders should be stored so they can not fall over (either lying down or chained in position), as they could explode if dropped.
Top up Isoflurane according to level gauge. AVOID breathing vapours and skin contact. Vapourisers should be recalibrated annually if at all possible.
Check for leaks: Connect circuit, close ‘pop-off’ valve, fill re-breathing bag and gently squeeze. Identify any leaks and rectify where possible.
Soda lime – should be replaced when changes colour or every 1-2 months depending on use. Amount of absorber should be 1.5 x the tidal volume ie 1000ml absorber will do 50kg animal
Circuit and re-breathing bags should be cleaned regularly (once a month), more regularly after excessive use (long procedures).

Just prior to an anaesthetic ensure all equipment is ready for use and is functional:
• Correct anaesthetic system
• Sufficient oxygen –turn on
• Sufficient anaesthetic – refill
• Masks and endotracheal tubes
• Gauze bandage or tape to hold mouth open and/or to tie tube in,
• Cuff syringe and clamp,
• K-Y Jelly,
• Lignocaine spray
• Emergency drugs are all available with dose rates and protocols.
• **Remember to regularly check for Leaks**
  o Breathing bag and or breathing circuit
  o Breathing circuit point o connection to machine
  o Breathing valves
  o CO₂ absorber gasket
  o Pressure relief valve
Vapouriser inlet and outlet connections – filler cap
Fresh gas delivery hose and connection to machine

ANAESTHETIC MACHINE SET-UP

See Anaesthetic machine manual and instructions.

Animals under 5kgs should use semi open system - an Ayres T piece system or Bains circuit that doesn’t involve the soda-lime (figure 7).

Animals over 5kg to 100kg should use semi closed system - the circle system through the soda lime and exhaust pipe.

<table>
<thead>
<tr>
<th>Semi open flow rates should be</th>
<th>200ml/kg/min</th>
<th>200ml/kg/min</th>
<th>1L/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1.5kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal 30 breaths/min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal &gt;50 breaths/min</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Flow Rates for semi open systems

Semi closed flow rates should be

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>IND</th>
<th>MAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>25kg</td>
<td>1L/min</td>
<td>500ml/min</td>
</tr>
<tr>
<td>40kg</td>
<td>1.6L/min</td>
<td>800ml/min</td>
</tr>
<tr>
<td>75kg</td>
<td>3L/min</td>
<td>1.5L/min</td>
</tr>
</tbody>
</table>

Table 3. Flow rates for semi closed systems.

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>Size of Rebreathing bag</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5kg</td>
<td>500mL</td>
</tr>
<tr>
<td>7.5 – 15kg</td>
<td>1L</td>
</tr>
<tr>
<td>15 - 30kg</td>
<td>2L</td>
</tr>
<tr>
<td>30 – 60kg</td>
<td>3L</td>
</tr>
<tr>
<td>50kg +</td>
<td>5L</td>
</tr>
</tbody>
</table>

Table 4. Rebreathing bag recommendations

A NOTE ON EUTHANASIA

Although euthanasia is never a palatable option, it is sometimes necessary for the animals welfare. For this and staff safety reasons, primate euthanasia must ALWAYS be conducted when the animal is fully anaesthetised. A phenobarbitone overdose intravenously (femoral vein) is the most common regime. This substance is extremely irritating for the animal when injected perivascularly as it causes rapid onset tissue necrosis.

Introduction - The Vital Signs of Life

A practical knowledge of a primate's vital signs and the physiological processes giving rise to them is essential. In simple terms, vital signs are the clinical indicators of the existence and stability of life. Every opportunity should be taken with healthy primates to observe such signs.

Life in all cells of the body depends on a good supply of oxygen and nutrients so that cellular metabolism can be fuelled. The waste products of this metabolism must be removed from the cells' immediate environment to avoid them being poisoned. Cellular metabolism, which is basically a series of highly complex chemical reactions, can only occur within a limited temperature range.

The circulatory or cardiovascular system (the heart, blood vessels and the blood flowing through them) provides the means by which oxygen and nutrients can be distributed to every cell in the body and the waste products, such as carbon dioxide (CO2) and lactic acid, removed. It is only in the extensive network of tiny capillaries that this delivery and removal service occurs, therefore normal function in the capillary network is vital for the life of any tissue.

Breathing (respiration in its narrowest sense) is the mechanism by which oxygen is taken into the lung and delivered to the red blood cells in the lungs' capillaries for distribution throughout the body. Simultaneously waste CO2 is released from the blood and voided as the primate breathes out.

A primate's vital signs provide information about the functional state of the cardiovascular and respiratory systems, thereby revealing the condition of the crucial life support mechanisms. If any component of these systems is compromised, life itself is at risk.

The vital signs of life include:
- Heart rate
- Pulse rate and strength
- Quality, rate, and gross sounds of breathing
- Mucous membranes colour
- Capillary refill time (2-3 seconds is normal)
- Core body temperature
- Volume and specific gravity of urine

Given that few serious emergencies are sudden in onset, monitoring of a patient's vital signs is the key to appropriate action during an anaesthetic. The same applies for a collapsed primate. Most monitoring procedures are directed towards assessing the oxygen carrying ability of the blood and the effectiveness of the circulatory system in carrying this blood to and from the tissues. Carried out correctly and with sufficient frequency, appropriate monitoring will allow you to avoid a number of deaths.
Resuscitation is not generally about dramatic rescues - prevention is always better than cure. In all anaesthetic emergency situations demanding resuscitation the actions required should follow a disciplined pattern or ABCD approach. Further comment will be made on this below, and also in section 3.8 (Emergency Medicine). Once faced with complete respiratory and circulatory failure (cardiopulmonary failure) restoring life is exceedingly difficult. It is good to practice these techniques so the process becomes almost automatic in an actual emergency situation.

The most significant life-threatening anaesthetic complications that are likely to be met are respiratory failure, and/or circulatory failure (including shock) and hyperthermia.

**Respiratory Failure**

Respiratory failure (lack of or ineffective breathing) can occur during anaesthesia or in any severely injured, shocked or diseased primates at any time, especially in cases of severe respiratory infections. During anaesthesia respiratory failure is often caused by the administration of too much anaesthetic agent, or administration of opiate drugs. It can also be caused by obstruction of the airway, or even by severe pain.

The monitoring of respiration is achieved by observing the depth and rate of breathing, by checking the colour of the mucous membranes and by ensuring that no obstructions develop within the oral cavity or pharynx. Signs of impending respiratory failure include a fall in the rate of breathing to less than 50% of normal, a progressive fall in the depth of breathing, and pallor or a blue appearance of the mucous membranes. Obstruction of the airway in unanaesthetised primates may be indicated by violent and frequent attempts by the primates to draw in breath. During profound anaesthesia, obstruction can cause inadequate ventilation without the dramatic inspiratory attempts.

As a rough "rule of thumb" complete respiratory failure in an adult primate may be considered as having occurred if there is a lack of breathing for 1 minute, with continued beating of the heart. On diagnosing this condition the following action should be taken (following an ABCD code):-

**A is for Airway** Check that the passage of air into the lung is unobstructed

An endotracheal tube of the correct size should be available at all times. Remove any vomit, mucous, blood clots or foreign bodies from the mouth. If an endotracheal tube has been fitted, check that it is not blocked or kinked. If no endotracheal tube is in place, put the animal in dorsal recumbency extend the head and neck and pull the tongue out of the way. A laryngoscope can be useful in this situation, not only as a light source, but also to keep the tongue and epiglottis out of the way. Don’t forget to inflate the cuff!

**B is for Breathing** Establish and then maintain breathing

Establish an effective pattern of breathing. This is best done forcibly using an anaesthetic circuit and "positive pressure ventilation" with oxygen or an ambubag. However, blowing intermittently through an endotracheal tube positioned in the
trachea can be extremely effective. One respiratory movement should be established every 3-5 seconds. Intermittent pressure on the chest wall can be used to establish an airflow in and out of the lungs but is extremely inefficient for anything more than a couple of minutes. Refer to the Emergency Medicine section for more details.

C is for Circulation

Respiratory and circulatory failure often occur together and therefore it is essential to ensure that the primate's heart is still beating and that an effective pulse is present.

D is for Drugs:

The supply of gaseous anaesthetic agents should be discontinued and where reversible anaesthetic agents have been used the antidote should be administered. (The consequences of recovery to consciousness must be considered - especially where a primates is undergoing an operation).

Give atropine at 0.05mg/kg to dilate bronchioles and stabilise the heart rate.

If breathing is re-established and stabilised an anaesthetic can be continued, but monitor the primates closely and try to lighten the anaesthesia. In the case of a collapsed primates, if the respiration is restored, the cause will have to be identified and addressed. In either event close monitoring will be required for a prolonged period following the failure.

Cardiovascular or Circulatory Failure

Failure of the circulation can occur in many circumstances, but is seen particularly in severely shocked primates or those undergoing anaesthesia. It is important to realise that most anaesthetic agents have a depressant effect on cardiovascular function and anaesthetic overdoses are the commonest cause of cardiac failure during anaesthesia. The early diagnosis and treatment of cardiovascular failure is complex. For the sake of clarity and practicality only a simplified account will be given here.
1. **Heart failure**

"Heart failure" means no effective output from the heart. Therefore the term includes not only complete absence of a heart beat (cardiac arrest), but also uncoordinated beating of different parts of the heart (such as ventricular fibrillation) and inefficient heart beats caused by (egg) fluid overload.

**Signs**
- Absence of previously palpable pulse.
- Rapid cyanosis (blue coloration) or pallor of mucous membranes.
- No heart sound (use stethoscope).
- These signs are rapidly followed by wide dilatation of pupils, and cessation of breathing or agonal gasping.

**Action**
Look at watch, set stopwatch. Brain cells are particularly at risk from hypoxia and irreversible brain damage is likely unless cerebral circulation is restored within 3 minutes.
- **Airway** - check as above.
- **Breathing** - Establish and maintain breathing. Provide oxygen if possible.
- **Circulation** - Apply external cardiac massage: Intermittent pressure on chest wall over heart - 1 per second.
- **Drugs** - Turn off or reverse reversible anaesthetics.
  - If cardiac arrest
    - **Adrenaline:** 0.01mg/kg IV every 3-4 minutes (1ml of 1/10,000 adrenaline per 10 kgs)
    - **Atropine:** 0.05mg/kg IV
      - If ventricular fibrillation
    - **Lignocaine:** 1-2 mg/kg IV

If cardiac function is restored consider giving IV fluid to correct hypovolaemia and monitor very closely. Cerebral oedema often follows circulatory failure - give 1mg/kg methyl-prednisolone every 6 hours x 4, plus diuretics.

**NB:** The restoration of effective cardiovascular function after cardiac failure is difficult, and prevention is infinitely better than attempting a cure. A common situation during anaesthesia where too much anaesthetic has been given is the weakening of pulse strength and slowing of the heart. The timely administration of subcutaneous or very slow intravenous atropine at this point can restore both and prevent heart failure developing.
2. Shock

Shock is failure of the microcirculation (basically the capillary network) to provide adequate perfusion of the tissues with blood. Thus cells are deprived of oxygen and nutrients, and waste products are not removed. Local cellular death will eventually occur, followed by death of the animal. Various categories of shock can be recognised, but of most practical importance is hypovolaemic shock ("low blood volume shock") - due to loss of blood, plasma, or just water and electrolytes. Common causes include haemorrhage, severe and prolonged diarrhoea or vomiting, or simply the inability to drink whilst injured. Whatever the cause, the main effect is insufficient liquid in the blood vessels to keep capillaries open and functioning.

Primates suffering from lesser degrees of fluid or blood loss may not actually be in shock as various adjustments in the body's fluid distribution will have been made to compensate for these losses, hence maintaining the microcirculation. However, they are heading towards shock and such losses should be replaced. Thus the best way to deal with shock is to prevent it occurring.

Signs include:
- Weak and rapid pulse
- Pale or cyanotic mucous membranes
- Rapid heartbeat
- Hyperventilation
- Mental depression.

If the delay in treating shock is too long, damage to cells will be irreversible.

Action
- Correct any obvious cause - anaesthetic off or reversed, stop haemorrhage
- Give intravenous fluids rapidly. Give 40ml/kg of crystalloid solution such as lactated Ringers solution. Hypertonic saline (7 - 7.5% sodium chloride) can be given as an alternative. 5mls/kg. If dehydration is severe, <100mls/kg can be given.
- Give broad spectrum antibiotics and high dose corticosteroids (E.G: dexamethasone at <5mg/kg IV)
- Provide oxygen if available
- Monitor vital signs very closely. Especially capillary refill time and pulse rate and quality.

3. **Hyperthermia**

Untreated, hyperthermia can lead to brain damage and death from pulmonary oedema. Even in less extreme cases a prolonged recovery from anaesthesia can be expected.

**Mild cases:** Externally applied water and increased air cooling.

**Severe cases:** Cold water immersion, cold water enemas, IV fluids and corticosteroids plus antibiotics.
Respiratory Arrest In Brief (Print this section and have on hand during every anaesthetic)

Causes

- Anaesthetic medullary depression = too much anaesthetic agent
- CO₂ washout in hyperventilation = too much oxygen
- Respiratory muscle paralysis

Management

- Check heart and pulse rate
- Ensure airway patency and intubate ASAP.
- Ventilate with 100% oxygen (no anaesthetic agent)
  - Small mammals every 10-15 seconds
  - Large mammals every 30-45 seconds

Treatment

- Intravenous (or intramuscular) reversal agents (dependent on type of anaesthetic agent used)
- Provide supportive therapy - bicarbonate to correct acidosis

Summary

- Check presence of heart and pulse rate
- Ensure that airway is clear and intubated
- Ventilate with 100% oxygen
- Reverse the anaesthetic as much as possible
Cardiac Arrest In Brief (Means The Heart Is Not Beating). Print this section and have on hand during every anaesthetic

Causes

- Anaesthetic overdose
- Hypoxia / hypercapnaea
- Vagal reflex mechanisms causing bradycardia / asystole
- Blood loss
- Electrolyte changes, in particular potassium and calcium
- Cardiac disease

Clinical Signs

- Absence of respiration
- Absence of pulse
- Dilation of pupils
- Cyanosis of the mucous membrane and non-pigmented skin
- Lack of a capillary refill
- Colour and degree of haemorrhage from a surgical wound
- Absence of heart sounds

Treatment

- Stop anaesthesia
- Intubate and ensure patent airway: check the patient, the tube and the machine
- Administer ventilation (IPPV) immediately by bagging and check chest expands
- Begin cardiac massage
- Ventilation: cardiac compression ratio 1:5 if team available 3:15 if sole operator
- Assess effectiveness of resuscitation by checking pupils, pulse, mucous membranes, capillary refill
- Place intravenous catheter (by direct venipuncture or by cut down with scalpel blade)
- Administer anaesthetic reversal agent
- Draw up adrenaline 1-5 ml 1:10,000 adrenaline
- Draw up bicarbonate
- Draw up short acting corticosteroids: 2-mg/kg

Summary

A - Airway → Intubate and ensure there is a patent airway
B - Breathing → Begin IPPV by bagging
C - Circulation → Begin cardiac massage
D - Drugs → Reversal agent
              Adrenaline
### Anaesthetic Emergency Drug Doses (also refer to the emergency Medicine section 3.8)

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adrenaline</td>
<td>Requires to be diluted before use because in most cases it comes packaged as 1:1,000 and we require 1:10,000. Draw up 0.1 - 0.5 ml in a 1 ml or 5 ml syringe and then fill syringe to 1 ml or 5 ml with water for injection. This will give you 1-5 ml of 1:10,000 adrenaline. 0.01mg/kg IV every 3-4 minutes (i.e. 1ml of 1/10,000 adrenaline/10 kg). IV effect is immediate, IM effect within 8 minutes.</td>
</tr>
<tr>
<td>Atropine</td>
<td>0.05mg/kg IV</td>
</tr>
<tr>
<td>Lignocaine</td>
<td>1-2 mg/kg IV</td>
</tr>
<tr>
<td>Doxapram</td>
<td>20mg/ml Lge animals 0.5 mg/kg = 0.025 ml/kg. 2.5 ml / 100 kg Sm animals 5-10 mg/kg = 0.25 - 0.5 ml/kg. 2.5 ml / 10 kg</td>
</tr>
</tbody>
</table>

**Reversal Agents**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yohimbine</td>
<td>10mg/ml 0.125 – 0.25mg/kg</td>
</tr>
<tr>
<td>Atipamezole</td>
<td>5mg/ml 4 – 5mg per mg medetomidine 1mg per 10 mg xylazine</td>
</tr>
<tr>
<td>Naltrexone</td>
<td>100mg per mg carfentanil 20mg per mg etorphine</td>
</tr>
</tbody>
</table>

*Table 5. Anaesthetic emergency drug dosages including reversal agents (also refer to section 3.8)*
PART 3. Anaesthesia Agents and Suggestions by Species

Summarised anaesthetic information and dose rates are presented on tables 6, 7 and 8 at the end of this section. Suggested analgesic dose rates are presented in table 9. With all anaesthetic agents, dose rates given are only guidelines. Variations in response to these standardised dose rates will be seen in individual primates. Such variations depend on a host of factors such as general health status, pre-anaesthetic state of excitement, concurrent disease, biological variations etc.

How do you choose which Anaesthetic is best for your situation?

The choice of substance and dosage is always a compromise between safety and efficiency, and depends on the delivery system, skill and preparation of the human team, ecological conditions (e.g temperature), and the biological features of the primate itself. The equivalent dosage of anaesthetic will have a variable effect, depending on the metabolic size of the individual. There are also wide differences in physiological characteristics (body temperature, heat depredation, heart rate, etc.) between species. Several other biological features (age, body condition, pregnancy, lactation) must also be considered.

The first priority when choosing an anaesthetic is to maximise the safety margin of the drug (the difference between an efficacious and a lethal dose), since in field conditions, the exact weight of the animal to be caught is rarely known.

a. Preanaesthetic Medications.

Analgesics, (table 8), should be given for invasive procedures that are known to cause pain in other mammals. Buprenorphine (Temgesic) is recommended for control of acute or chronic visceral pain but can cause sedation. Butorphanol (Torbugesic) is recommended for mild postoperative discomfort. Both these drugs are opiate based preparations. Note however that primates have more of an agonist effect at the Mu receptor (compared to other mammals) which may cause severe respiratory depression when using butorphanol, especially in combination with anaesthetic agents, (Ligouri et al., 1996).

The respiratory depressant effects of opiates and benzodiazepines (such as diazepam and medazolam) are synergistic in humans. Benzodiazepines alone have minimal respiratory depressant effects but, combined with even small doses of opiates, have been shown to cause respiratory collapse in some humans. Thus, these two classes of drug should not be mixed in non human primates.

Oral diazepam, used as a pre-induction agent at 1mg/kg at about one hour pre induction provides amnesia. However, clinical sedation when using this drug is highly variable between individuals, as well as species. Note that diazepam can also be given intravenously, to reduce seizuring but is not effective in primates when given intramuscularly (Horne 2001). Benzodiazepines have minimal effects on cardiopulmonary function and are generally considered very safe compounds to use in primates.
b. Injectable anaesthetics

**Ketamine:** Ketamine used alone as an injectable anaesthesia agent has long been a mainstay of primate anaesthetics. Ketamine would be the induction agent of choice if preanaesthetic fasting is not possible (for example if an animal has a fight wound requiring immediate attention), as gagging reflexes are maintained.

Ketamine belongs to the cyclohexamine class of drug and, is a non-competitive NMDA receptor antagonist, which is short acting and has been used as a dissociative anaesthetic as well as a research tool in psychosis (Shiigi and Casey 1999). As a dissociative agent, very high doses produce a state of catalepsy and profound analgesia. Cardiovascular function is slightly stimulated rather than depressed when ketamine is used, and there is respiratory depression only at high doses (Baskerville 1999). The pharyngeal and laryngeal reflexes are well maintained, except at very high doses, which is an advantage since primates often have to be anaesthetised when food has not been withheld beforehand (thus increasing the risk of emesis and reflux, possibly leading to aspiration). The drug may also be given on repeated occasions, though some tolerance may develop. As ketamine is frequently used for restraint for taking blood samples it should be noted that high doses decrease the leucocyte and erythrocyte values.

Animals given ketamine are often adequately anaesthetised for placement of an endotracheal tube and can then be maintained by inhalation anaesthesia. If a monkey is too light to be intubated on the initial dose of ketamine, a small intravenous bolus of ketamine (at ¼ the original dose) can be given to achieve intubation for gaseous anaesthesia, or administration of oxygen alone.

Ketamine alone is not satisfactory for major surgery since at anaesthetic doses it would require potentiation to provide adequate analgesia. Muscle tone is also increased during ketamine anaesthesia, making it unsuitable for use alone for invasive surgery. It can be mixed with other anaesthetic drugs to improve the rating of anaesthetic. The most common combination is with medetomidine (table 7).
Anaesthetic Research Box – Effect of ketamine on neural conductivity and visual processing.

Ghaly et al. (2001) examined the effect of incrementally increasing ketamine dosages on somatosensory and neural motor volleys, recorded epidurally in response to transcranial magnetic stimulation. Their findings reflected the maintenance of a state of neural excitability under Ketamine induced anaesthesia. This helps to explain the lack of muscle relaxation and the anecdotal tolerance to this drug in a number of species.

Leopold et al. (2002) used optokinetic responses and functional magnetic resonance imaging (fMRI) to examine visual processing in monkeys whose conscious state was modulated by low doses (1-2 mg/kg) of ketamine. They found that, despite the animal's dissociated state and despite specific influences of ketamine on the oculomotor system, optokinetic nystagmus (OKN) could be reliably elicited with large, moving visual patterns. Responses were horizontally bidirectional for monocular stimulation, indicating that ketamine did not eliminate cortical processing of the motion stimulus. Also, results from fMRI directly demonstrated that the cortical blood oxygenation level-dependent response to visual patterns was preserved at the same ketamine doses used to elicit OKN. Finally, in the ketamine-anesthetized state, perceptually bistable motion stimuli produced patterns of spontaneously alternating OKN that normally would be tightly coupled to perceptual changes. Taken together, these results demonstrate that, after ketamine administration, cortical circuits continue to process visual patterns in a dose-dependent manner, despite the animal's behavioural dissociation. While perceptual experience is difficult to evaluate under these conditions, oculomotor patterns revealed that the brain not only registers, but also acts upon, its sensory input, employing it to drive a sensor motor loop and even responding to a sensory conflict by engaging in spontaneous perception-related state changes. This is an important finding, as ketamine alone does not provide amnesia, thus creating increased stress in the individual in future anaesthetics.

Ketamine: Medetomidine (or medetomidine equivalent) combination: This combination is also a common induction regime of non human primates. They provide an ideal injectable combination in primates for minor short term procedures (30-45 mins). Medetomidine can be reversed using atipamezole (table 7). However, anaesthetic maintenance becomes unpredictable after 30 to 40 minutes without the addition of another agent, for example, Isoflurane via intubation. When using ketamine and medetomidine, it is recommended to wait 30 minutes before the reversal administration. If the medetomidine is reversed earlier, the individual will likely wake up still under some ketamine effects and may have a turbulent and disoriented recovery.

Medetomidine is an α-2 agonist, thus produces profound sedation and analgesia by virtue of its’ ability to modulate neurotransmitter release in noradrenergic and serotonergic pathways of the spinal cord and brain (Horne, 2001). There is slight hypotension on administration of this drug, and this can readily be controlled by IV fluid administration. Note however that it is unsafe to use medetomidine alone, particularly in great apes, because they can readily be roused, even from a very deep sedation (see transmucosal use of medetomidine in the chimpanzee section below). Thus, a medetomidine/ ketamine combination is used (table 7).

A recent study, in a laboratory setting, compared ketamine alone with ketamine plus medetomidine for balanced anaesthesia and assessed the repeated intramuscular use of ketamine and its potential for tissue damage (Sun et al., 2003). The combination of ketamine and medetomidine was tested in newly arrived macaques undergoing a period of quarantine in an animal facility. Results indicated that the medetomidine and ketamine combination induced a deeper, more level plane of anaesthesia of longer duration than did ketamine alone. Furthermore, use of the medetomidine-reversing agent, atipamezole, permitted more rapid recovery.
A preliminary study in adult rats was undertaken to assess tissue damage induced by intramuscular injection of ketamine versus the combination of ketamine and medetomidine (Sun et al. 2003). Histological evaluation of tissue inflammation and muscle necrosis in rats indicated that the lower dose of ketamine, afforded by combination with medetomidine, caused markedly less damage to muscle tissue at injection sites.

A major advantage with medetomidine, is that its effects are reversible with atipamezole. Takako et al. (2001) evaluated the sedative effects of medetomidine, and a medetomidine-midazolam combination, in Japanese macaques and the antagonism of medetomidine-midazolam with atipamezole. Behavioural changes and responses to external stimuli were assessed. Animals given medetomidine became sedated but could be aroused by external stimuli. Despite the lower (25%) dose of medetomidine involved, the effects of medetomidine-midazolam were more marked. Macaques given this combination became sedated in 4 ± 2 minutes (mean ± SD) and remained unresponsive to external stimuli for at least 60 minutes. Five out of six macaques became laterally recumbent for 74 ± 37 minutes. Intramuscular atipamezole effectively reversed sedation, shortening the arousal and total recovery time. The recovery from sedation was rapid and smooth, being completed 19 ± 11 minutes after antagonism. It was concluded that the medetomidine-midazolam combination provided useful chemical restraint and may prove useful in macaques undergoing some experimental, diagnostic or therapeutic procedures.

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**Anaesthetic Research Box. The cardiorespiratory effects, effectiveness, and reversibility of two injectable anaesthetic combinations in captive Patas Monkeys (Erythrocebus patas)**

(Kalema-Zikusoka et al., 2003).

Seven patas monkeys were hand-injected with medetomidine (40 microg/kg IM.), butorphanol (0.4 mg/kg IM.), and ketamine (3.0 mg/kg IM), and seven were injected with the same dosages of medetomidine and butorphanol plus midazolam (0.3 mg/kg IM). Heart rates decreased in monkeys in both treatment groups and were lower than those previously recorded in patas monkeys anaesthetized with either ketamine or ketamine and isoflurane. Mean arterial pressures were highest in ketamine-treated monkeys but remained within normal limits for both groups. End tidal CO$_2$ values increased gradually over time in both groups and were above physiologic norms after 20 min. Respiratory rates were similar between groups and remained constant throughout the procedures. Despite adequate ventilation parameters, initial low percent oxygen-haemoglobin saturation (SpO$_2$) values were suggestive of severe hypoxemia. It was not clear whether these were accurate readings or an artefact of medetomidine-induced peripheral vasoconstriction. Oxygen supplementation restored SpO$_2$ values to normal (>94%) in both groups. Both combinations effectively produced a state of light anaesthesia, although spontaneous recoveries occurred after 30 min in three ketamine-treated monkeys. All monkeys were given IM atipamezole (0.2 mg/kg) and naloxone (0.02 mg/kg), whereas midazolam-treated monkeys also received flumazenil (0.02 mg/kg, i.v.), which resulted in faster (median recovery time = 5 min) and more complete recoveries in this group. Both combinations were considered safe to use when supplemented with oxygen, although the midazolam combination provided a longer anesthetic period and was more fully reversible.

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**Tiletamine-zolazapam (Telazol®/ Zoletil®)** is a 1:1 combination of the cyclohexamine, tiletamine, and the benzodiazepine, zolazapam. It has been widely used in primate medicine, particularly in field situations, either alone or combined with an α-2 agonist (table 7). It is a good combination for anaesthetic novices, as side effects are minimal, and the therapeutic index is wide, so potential overdosing is unlikely to cause long term problems. Tiletamine is more potent than ketamine and thus small volumes of Zoletil are required for injection. For example, in the authors experience, zoletil at 3-4mg/kg provides excellent immobilisation in chimpanzees for
60 minutes, but full recovery can take a couple of hours. Zoletil immobilised primates tend to maintain stable cardiopulmonary parameters (Horne, 2001)

Propafol (table 6 and 7), given intravenously through an indwelling catheter provides a smooth, rapid (less than 30 seconds) induction of anaesthesia and can be used to maintain anaesthesia by intermittent bolus administration – which would be required every 5-10 minutes. Primates maintained on propafol should be intubated, as propofol may induce a short period of apnoea. Monkeys recover from propofol smoothly and rapidly (Hrapkiewicz et al., 1998).

c. Inhalation anaesthetics
All of the common inhalation agents have been used in primates, with isoflurane currently being the most popular. Although generally acknowledged as being much safer than halothane, isoflurane does have potent vasodilatory properties that can cause severe hypotension if not used carefully (Horne, 2001). Sevoflurane (widely used in humans, but to date only rarely in non human primates) is not as soluble in the blood as isoflurane, while maintaining a 50% greater alveolar concentration, translating clinically to much faster induction and recovery times. In a calm patient, mask induction and intubation can be achieved in as little as 5 minutes (compared to 10 minutes for isoflurane). Whatever inhalation agent is used, they all cause cardiovascular depression, although, unlike halothane, this is very minimal with sevoflurane and isoflurane. All depress the respiratory system.

<table>
<thead>
<tr>
<th>Anaesthetic research box. Sevoflurane use in Rhesus Macaques.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The effects of sevoflurane on cerebral metabolism and haemodynamics have been studied in rhesus monkeys (Yoshikawa et al., 1997). At 3.0% sevoflurane, regional cerebral blood flow (CBF) increased significantly in response to the increase in the mean arterial pressure, suggesting the inhibition of autoregulation of CBF. However, regional CBF/CMR O2 ratio was not significantly different among the cerebral regions with each condition. It could be concluded that CBF, during sevoflurane anaesthesia levels of up to 3%, might become dependent on the cerebral perfusion pressure and the changes in regional CBFs varied among the regions. On the other hand, the ratio of oxygen consumption and delivery was well maintained throughout the brain regions.</td>
</tr>
<tr>
<td>Anaesthetic Agent</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Ketamine</td>
</tr>
<tr>
<td>Medetomidine</td>
</tr>
<tr>
<td>Zolazepam/Tiletamine</td>
</tr>
<tr>
<td>Propofol</td>
</tr>
<tr>
<td>Diazepam</td>
</tr>
<tr>
<td>Isoflurane</td>
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<tr>
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<td></td>
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</tbody>
</table>

Table 6 (After Plumb 1999). Pharmacological information for several anaesthetics used in Non Human Primates
<table>
<thead>
<tr>
<th>Indication and Drugs</th>
<th>Dosage and Route of Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium Pentobarbital, C-II</td>
<td>20-30 mg/kg</td>
</tr>
<tr>
<td>Sodium Thiopental, C-III (2.5%)</td>
<td>15-20 mg/kg</td>
</tr>
<tr>
<td>Thiamylal Sodium, C-III (2.5%) (Surital®, Bio-Tal®)</td>
<td>25 mg/kg</td>
</tr>
<tr>
<td>Ketamine (Ketaset®, Vetalar®)</td>
<td>5-20mg/kg</td>
</tr>
<tr>
<td>Ketamine/Diazepam: Ketamine</td>
<td>5-25 mg/kg; 10mg/kg</td>
</tr>
<tr>
<td>Diazepam (Valium®)</td>
<td>0.5 mg/kg; 7.5mg/kg</td>
</tr>
<tr>
<td>Ketamine/Xylazine: Ketamine</td>
<td>7 mg/kg</td>
</tr>
<tr>
<td>Xylazine (Rompun®)</td>
<td>0.6-1.0 mg/kg</td>
</tr>
<tr>
<td>Ketamine/medetomidine: Ketamine</td>
<td>5-7.5mg/kg</td>
</tr>
<tr>
<td>Medetomidine (Domitor/Zalapine®)</td>
<td>0.033-0.075mg/kg</td>
</tr>
<tr>
<td>Propofol</td>
<td>2-4 mg/kg; baboons for induction</td>
</tr>
<tr>
<td></td>
<td>2.5-5 mg/kg; macaques</td>
</tr>
<tr>
<td>Tiletamine + zolazapam (Zolitel/Telazol®)</td>
<td>5-10 mg/kg</td>
</tr>
<tr>
<td></td>
<td>1-15 mg/kg (higher dose rate for smaller species)</td>
</tr>
<tr>
<td>Tiletamine + zolazapam/medetomidine: Tiletamine + zolazapam</td>
<td>1.25 mg/kg (Apes)</td>
</tr>
<tr>
<td>Medetomidine:</td>
<td>2mg/kg (chimps)</td>
</tr>
<tr>
<td></td>
<td>0.03-0.04 mg/kg (Apes)</td>
</tr>
<tr>
<td>Methoxyflurane (Metofane®)</td>
<td>0.02mg/kg (chimps)</td>
</tr>
<tr>
<td>Halothane (Fluothane®)</td>
<td>To effect</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>To effect</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>To effect</td>
</tr>
<tr>
<td>Halothane/Nitrous Oxide (50% O₂ + 50% N₂O)</td>
<td>To effect</td>
</tr>
</tbody>
</table>

**TABLE 7: General Anesthesia regimes used in Non human Primates - those in bold recommended by the authors (see text)**

Reverse Medetomidine with Atipamizole at 0.1-0.25 mg/kg (equal volume to medetomidine 1mg/mL)

NB. Erythrocebus patas may require a higher dose of xylazine. Cercopithecus sp require a much lower dose of barbiturates.
<table>
<thead>
<tr>
<th>Indication and Drugs</th>
<th>Dosage and Route of Administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morphine, C-II</td>
<td>0.5-2.0 mg/kg q4h SC IM IV</td>
</tr>
<tr>
<td>Oxymorphone, C-II</td>
<td></td>
</tr>
<tr>
<td>Old World Primates</td>
<td>0.15 mg/kg SC IM IV</td>
</tr>
<tr>
<td>New World Primates</td>
<td>0.075 mg/kg SC IM IV</td>
</tr>
<tr>
<td>Flunixin meglumine</td>
<td>0.3-1mg/kg q12-24h SC, IV</td>
</tr>
<tr>
<td>Meperidine, C-II (Demerol®)</td>
<td>2-4 mg/kg IM</td>
</tr>
<tr>
<td>Pentazocine, C-IV (Talwin®) not to exceed total dose of 60 mg</td>
<td>1.5-3.0 mg/kg q3-4h IM SC</td>
</tr>
<tr>
<td>Buprenorphine (Temgesic®)</td>
<td>0.01-0.03 mg/kg q8-12h IM, IV</td>
</tr>
<tr>
<td>Acetylsalicytic Acid (Aspirin)</td>
<td>10-20 mg/kg q6h PO</td>
</tr>
<tr>
<td>Acetaminophen</td>
<td>10 mg/kg q8h PO</td>
</tr>
<tr>
<td>Butorphanol tartrate (Torbugesic®)</td>
<td>5-10 mg/kg q6h PO</td>
</tr>
<tr>
<td></td>
<td>0.025 mg/kg q3-6h IM</td>
</tr>
</tbody>
</table>

Table 8: Analgesia suggestions for Non human primates.
**Chimpanzees**

Chimpanzees should be appropriately fasted for food and water prior to scheduled procedures requiring sedation or anaesthesia. Following sedation or anaesthesia, food and water should continue to be withheld until the animal has regained full consciousness. Selection of an anaesthetic is often based on the nature of recovery of individual animals; some exhibit severe motor movements and apparent hallucinations, and should be monitored carefully. Recovery cages, that restrict movement and permit access to the animal, should be used. Animals should not be returned to their home cage until they are fully recovered. Veterinary and care staff should learn the response of each animal to various procedures and sedatives and be aware that other chimpanzees, within the compound or in an adjacent cage, might attack a sedated animal. Recognition of pain in chimpanzees, and the need for analgesics, is best achieved by care-givers who know species-typical chimpanzee behaviours, and who are sufficiently familiar with the individual to recognize subtle changes in behaviour and mood (Fritz et al., 1999).

Diazepam has been used by some as a pre-requisite to immobilizing chimpanzees. One regime suggested has been 5mg per animal for juveniles and 10-15 mg per animal for adults, for 5 nights prior to immobilization with ketamine. However, this regime produces a ‘calmer’ animal, rather than drowsiness. An alternative to pre-induction sedation in chimpanzees is training them to accept hand injections.

**Induction recommendations: Ketamine: medetomidine combination or Zoletil or Zoletil: Medetomidine combination.**

For major surgical procedures in chimpanzees, properly administered inhalant anaesthetics, such as isoflurane or sevoflurane, are recommended, and offer many advantages over other anaesthetics, especially as they provide ready access to the respiratory system if the animal stops breathing. IV catheterisation should also be considered as standard procedure for all surgeries. Six adult female chimpanzees (*Pan troglodytes*) were anaesthetised for the placement of intrauterine contraceptive devices, microchips for identification, routine blood sampling, and physical measurements (Adams et al., 2003). Anaesthesia was induced with medetomidine, in combination with ketamine, administered by intramuscular injection with a projectile syringe. Induction was smooth and rapid but five of the animals were insufficiently relaxed for endotracheal intubation. The plane of anaesthesia was deepened by administering isoflurane delivered in oxygen and nitrous oxide, and general anaesthesia was maintained for up to 74 minutes. The action of medetomidine was reversed with atipamezole, at the end of each procedure, and the animals recovered smoothly and uneventfully.

Chimpanzees can develop tolerance to ketamine, especially if they must be frequently immobilised. In addition, there are times when the injection appears to have no effect and it must be considered that the dose had been injected into fat or muscle fascia: in these cases there might also be a prolonged recovery period.

Telazol/ Zolitel, a 1:1 mixture of cyclohexamine tiletamine (2-3 times more potent than ketamine), and the benzodiazepine zolazepam, are used for diagnostic procedures and short anaesthesia, when deeper anaesthesia and fewer muscular
contractions are needed than those achieved with ketamine alone. Note however that recovery time is extended beyond that of ketamine.

**Anaesthetic Research Box . Transmucosal sedation in chimpanzees.**
A new sedation regime for juvenile chimpanzees has been developed by Carmen Vidal of HELP Congo, in her work with orphan chimpanzees. Medetomidine (Domitor 1mg/mL, Zalopine 10mg/mL) is an agonistic α-2 adrenergic drug with tranquilising, myorelaxant and analgesic properties. Carmen has been using it transmucosally since 1998, and has now had her work published (English version TBP). She has found that a dose of 75ug/kg PO (cf < 50ug/kg IM/V) works well. This was confirmed by the author in a series of anaesthetic workshops in 2003. A dose range, depending on the individual animal, is given as 50-100 ug/kg. N=60.

Clinical signs include bradycardia, hypovolaemia, temperature reduction to 35°C, while side effects include vomiting (on 2 occasions) and muscle tremors (in 10 of the animals). The dose MUST be aliquoted at 1 drop every 30 seconds onto the oral mucosa just inside the lower lip (thus some training is required). It must not be put in the food, as this is ineffective. The drug can be mixed with a small amount of chocolate or jam – something the animal will keep in the mouth.

Effect is seen after 30-45 minutes (15-20 minutes if the animal is very quiet). All reflexes are still present – useful if the animal climbs as it is less likely to fall, but laryngeal reflex also remains making intubation, if required, tricky. General procedures can be performed for up to 1 hour. The animal will stay quiet for up to 3 hours if no reversal is given.

The antagonist, atipamezole (Antisedan) is given at 150ug/kg IM/IV (about 2/3-3/4 the domitor volume). Reversal is rapid and complete. Reversal must be delayed at least 20 minutes after final domitor drop, to avoid secondary medetomidine effects due to delayed oral adsorption. Top-ups – anaesthesia can be prolonged with 1/3rd of the original medetomidine dose IM, with the addition of ketamine at 5mg/kg IM.
**Gorillas**

Gorillas can be anaesthetised with the same anaesthetic drugs, at similar dose rates to chimpanzees. In the authors experience, Zoletil (Telazol) at a dose rate of 1mg/kg (so half that published) has been enough for light anaesthesia and short procedures. All gorillas should be intubated.

If inhalation anaesthesia is to be used in large specimens (over 170kg), large animal circuits, such as those used for foals, or custom anaesthetic kits (see figure 10) may well be needed. However, animals up to 170kg can be maintained for procedures of up to 90 minutes on the gaseous anaesthetic field kit (figure 8).

*Figure 10. Custom anaesthetic kit used at Vienna Veterinary School for animals 150kg and above (Source Martina Mosing)*
Table 9. CHIMPANZEE AND GORILLA ANAESTHESIA AND SEDATION and ANAESTHETIC REVERSAL...

<table>
<thead>
<tr>
<th>Drugs</th>
<th>Dose Rate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diazepam</td>
<td>1.0-1.5mg/kg ORAL</td>
<td>Sedation only. Pre-med decadant approx 1 hour before anaesthesia with medetomidine and ketamine. Variable effect but can be used to reduce anxiety for hand injection, produces retrograde amnesia (ie cannot remember the events of anaesthesia) and it reduces the dose of medetomidine and ketamine (see below) by half. Post recovery vomiting seen in Chimpanzees.</td>
</tr>
<tr>
<td>Droperidol</td>
<td>2.5-5.0 mg per adult 1.3-2.5 mg per juv</td>
<td>Sedation only. Takes 45 mins to 60 mins to take effect. Gastric absorption only.</td>
</tr>
<tr>
<td>Ketamine</td>
<td>7-10mg/kg IM</td>
<td>Short acting. Can be given as a top up of other anaesthetics at 2-4 mg/kg Induction 3-10 minutes, recovery within 40 to 60 minutes Can have sedative effect when given orally.</td>
</tr>
<tr>
<td>Ketamine + Midazolam</td>
<td>0.075 – 0.1mg/kg ORAL</td>
<td>Excellent muscle relaxation. Prolonged recovery.</td>
</tr>
<tr>
<td>Ketamine + Xylazine</td>
<td>1mg/kg IM + 0.05mg/kg IM</td>
<td>Good relaxation. Can be reversed with atipamazole IM or at 0.3 to 0.4 total dose of xylasine.</td>
</tr>
<tr>
<td>Medetomidine</td>
<td>0.075 – 0.1mg/kg ORAL</td>
<td>Oral sedation (transmucosal absorption) – effectiveness is increased if not mixed with anything and if the animal is on an empty stomach.</td>
</tr>
<tr>
<td>Medetomidine + Zoletil</td>
<td>0.02mg/kg IM + 2mg/kg IM +</td>
<td>Excellent muscle relaxation. Medetomidine can be reversed with atipamazole at a dose rate of 3-5 times the total dose of medetomidine IM. Can be given 50% IV and 50% IM.</td>
</tr>
<tr>
<td>Medetomidine + Ketamine</td>
<td>0.03-0.05mg/kg IM + 3-4 mg/kg IM</td>
<td>Good muscle relaxation. Reversed with atipamazole at a dose rate of 3-5 times the total dose of medetomidine IM. Can be given 50% IV and 50% IM.</td>
</tr>
<tr>
<td>Zoletil</td>
<td>3-5mg/kg IM (1mg/kg in gorilla) 15mg/kg PO</td>
<td>Anaesthesia is dose dependent. Agent of choice for escaped or aggressive chimps. Can be made up to 500mg/ml Rapid induction 1-7 min, prolonged recovery 1-5 hours with drowsiness, dizziness and ataxia. Lower blood pressure. Oral sedation – variable effect</td>
</tr>
<tr>
<td>Atipamezole - Reversal for medetomidine and xylazine</td>
<td>0.1-0.5 mg/kg IM or IV</td>
<td>Decrease the doses regarding time elapsed after medetomidine administration</td>
</tr>
<tr>
<td>Flumazenil - Reversal for benzodiazepine</td>
<td>0.3mg/kg slow IV, then 0.1 to 0.2mg every minute</td>
<td>Increase alertness but don’t significantly enhance the speed or quality of recovery.</td>
</tr>
<tr>
<td>Naloxone - Reversal for opiates (can also use Naltrexone) yohimbine</td>
<td>1 to 2 μg/kg IV repeat after few minutes regarding effect</td>
<td>Can treat respiratory distress due to opiate use, but also has own set of adverse effects</td>
</tr>
<tr>
<td></td>
<td>0.125-0.25 mg/kg IM</td>
<td>Reversal for xylazine</td>
</tr>
</tbody>
</table>
Mandrills, Drills, Mangabeys, Guenons and Baboons

Induction recommendation: Ketamine:medetomidine combination or Zoletil or Zoletil: Medetomidine combination. Small species, soflurane or sevoflurane induction in a chamber.

Injectable anaesthetics should be used for induction and anaesthesia can be maintained at 1-1.5% isoflurane or sevoflurane in oxygen. Ketamine is the most commonly used agent, both for chemical restraint and for induction of anaesthesia in all but very young animals. It can be given intramuscularly, in small volumes, and has a wide safety margin. The ability to bite is lost at low doses and at an early stage of induction. Doses of 5-10mg/kg produce effective sedation for handling and close examination and for minor procedures, such as taking blood samples or passing a nasogastric tube. Doses of 10-25mg/kg give sufficient depth of anaesthesia for minor surgical procedures.

Due to the increased muscle tone when using ketamine alone, analgesia with good muscle relaxation can be produced by combining ketamine (5mg/kg) with medetomidine (50ug/kg), an alpha 2 agonist – see more specific dose rates below. This combination also has a wide therapeutic index, and is useful in any of the larger monkey species.

When using ketamine and medetomidine, it might be better to wait 30 minutes before the reversal administration: if done earlier, the individual will wake up under ketamine effect and might have a turbulent and disoriented behaviour.

What follows are some injectable anaesthetic doses for monkey species

ZOLETIL (Tiletamine + Zolazepam)

Mona guenons (Cercopithecus mona)
4-5mg/kg recommended for immobilisation. Anaesthesia can be prolonged with Ketamine or isoflurane gas. I have used doses in the range of 3.0 - 4.8mg/kg without serious complications. Doses of 3.0 - 3.9mg/kg may give less satisfactory results. Be careful and give attention to details when anaesthetising fat monas.

Red-eared guenon (Cercopithecus erythrotis)
3.6mg/kg provided about 40minutes of anaesthesia/immobilisation.

Putty-nose guenon (Cercopithecus nictitans)
We have not used Zoletil in this species. Kreeger in 'Handbook of Wildlife Chemical Immobilisation' recommends 4.4mg/kg and supplementation with Ketamine at 4.4mg/kg.

Red-capped Mangabey (Cercocebus torquatus)
3mg/kg will give immobilisation of short duration but this is not suitable for any painful procedure. 5mg/kg will produce surgical anaesthesia. Anaesthesia can be prolonged with ketamine or isoflurane. Giving additional zoletil to prolong anaesthesia will result in very prolonged recovery periods.
**Medetomidine-Ketamine combination (NB for small guenons, induction using isoflurane in an induction chamber is recommended if it is available)**

This drug combination should not be used for escaped animals. Excitement just before anaesthesia (though difficult to eliminate in guenons - in my experience) significantly reduces the effect of medetomidine and ketamine combinations.

Animals intended to be anaesthetised with this drug combination should be isolated at least 24 hours before the anaesthetic event. However, depending on the animal, being isolated from the rest of the group can cause stress or excitement.

The major advantage this anaesthetic regime offers is that it can be reversed with atipamezole (Antisedan™). Atipamezole is generally administered at five times (5x) the dose of medetomidine given (thus an equal volume if using domitor™ or dexdomitor™).

Anaesthesia induced by medetomidine-ketamine combination can be prolonged by ketamine or isoflurane. Awakening from anaesthesia induced by this drug combination can be sudden and abrupt and animals are dangerous even at this point as they can inflict serious bite injuries.

**Mona guenon (Cercopithecus mona)**

Medetomidine: 72.5 - 103.3ug/kg

+ Ketamine: 3.6 - 5.2mg/kg

This combination in my experience often causes apnoea (temporary cessation of breathing), bradyarrhythmia and atrioventricular block in monas. Apnoea usually resolves spontaneously while bradyarrhythmia and atrioventricular block resolves after reversal with atipamezole. The higher doses are more likely to cause frequent apnoea.

**Red-eared guenon (Cercopithecus erythrotis)**

Medetomidine: 54.3 - 113.6ug/kg

+ Ketamine: 2.7 - 5.7mg/kg

Lowest doses produced light anaesthesia of short duration not suitable for painful procedures. Can cause apnoea of short duration, atrioventricular block and arrhythmia.

**Putty-nose guenon (Cercopithecus nictitans)**

Causes occasional apnoeas which resolves on its own. A combination of medetomidine 73.2ug/kg + Ketamine 3.7mg/kg did not produce safe immobilisation in an adult female with a fractured mandible. A combination of medetomidine 78.9ug/kg + ketamine 3.9mg/kg produced very light anaesthesia in another adult female. I will recommend a combination of medetomidine 80 - 100ug/kg and ketamine 4 - 5mg/kg for Putty nose guenons.
Preuss's guenons (*Cercopithecus preussi*)
Medetomidine: 64.5µg/kg
+ Ketamine: 3.2mg/kg

Red-capped mangabey (*Cercocebus torquatus*)
Medetomidine: 75 - 100µg/kg
+ Ketamine: 3.75 - 5mg/kg

Sclater's guenon (*Cercopithecus sclateri*)
Medetomidine: 63.6 - 100µg/kg
+ Ketamine: 3.2 - 5mg/kg

Combinations of 100µg/kg medetomidine and 5mg/kg ketamine can cause severe cardiorespiratory depression and I do not see the need to use this high dose in this species.
References


**MAJOR VETERINARY ANAESTHETIC MANUFACTURERS:**

**Pfizer** (Europe, USA, East Africa): Domitor, Dedomitor, Zalopine (As Orion – Finland). Pfizer have lost the patent rights to 1mg/mL medetomidine – check for cheaper alternatives from rivals. Antisedan

**Fort Dodge** (Europe, USA): Ketaset, Ketamine

**Abbott** (Europe): Isoflurane

**Kyron Labs** (Benrose, South Africa Ph 011 618 1544): 10mg/mL and 40mg/mL medetomidine, Naltrexone.