

Introduction

A major concern when placing animals under general anesthesia is maintenance of core body temperature. Adverse effects of hypothermic states include reduced heart rate, respiratory rate, blood pressure, and cardiac output as well as prolonged recovery times. Animals undergoing invasive or non-invasive surgery, or having a low % of body fat or a high surface area: body weight ratio can experience up to an 8% loss of core body heat after just 90 minutes of general anesthesia or prolonged sedation in the absence of appropriate supportive care. The most common methods used today to avoid hypothermia under these circumstances (e.g., circulating warm water pads under the animal or heat lamps overhead) may be inadequate because heat loss also occurs through the extremities of common lab animal species. For example, rodents and cynomolgus monkeys use primarily their tails for thermo-regulation. In addition, there is risk of overheating and burns if the animal is not monitored closely, and some heating equipment is not compatible with MRI scanners. Therefore, a better means of maintaining body temperature during general anesthesia was explored for non-human primates, using strategies already proven for human patients.

Figure 1



Figure 2



Figure 3



Materials and Methods

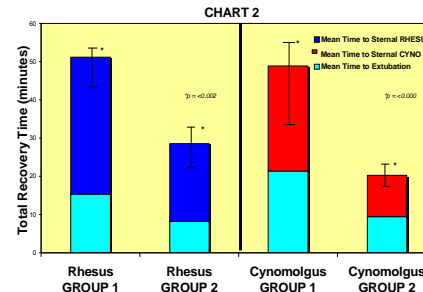
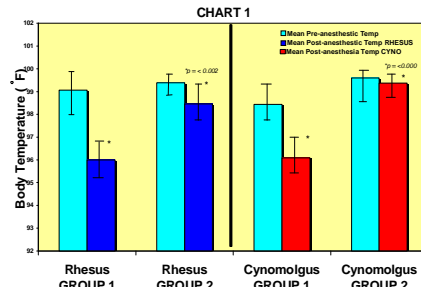
Six female and 6 male rhesus monkeys (*Macaca mulatta*) ranging from 3.5 to 4 years old were used while undergoing magnetic resonance imaging (MRI) scans of brain anatomy. Duration of anesthesia was 90-120 minutes. Twelve male cynomolgus monkeys (*Macaca fascicularis*) ranging from 6 to 8 years old were used while undergoing positron emission tomography (PET) scans of brain anatomy. Duration of anesthesia was 120-180 minutes.

Each animal's pre-anesthesia regimen consisted of ketamine 15mg/kg + atropine 0.04mg/kg IM + hand-carried for ≤10 minutes to the scanning room while in a filtered transport box. Animal preparation for each scan included placing one or more intravenous catheters, induction of anesthesia with propofol 4-6 mg/kg IV, and intubation to maintain a patent airway. Anesthesia was maintained with propofol at a constant rate of infusion of 0.250-0.500 mg/kg/min. Fresh oxygen was supplied and administered via flow-by method at 1-2L/min. All animals were covered with woolly blankets after sedation and during transport.

Animals were then randomly assigned to the following groups during anesthesia:

- Group 1: woolly blankets (**faux sheepskin fleece, OMDirect**) + heated water pad only (*Rhesus* and *Cynomolgus* negative controls) (Figure 1)
- Group 2 *Rhesus*: Group 1 + booties (**cotton fleece socks, pediatric size 8-10**) on hands and feet (Figure 2, before woolly blanket added)
- Group 2 *Cynomolgus*: Group 1 + tail wrap (**cotton fleece sock, adult size 7, with protective chuck, Kendall inc.**) (Figure 3, before woolly blanket added)

Body temperatures were measured in °F via digital rectal thermometers at three time points: after pre-anesthetic and during preparation for scanning (T1), at the end of the scan and anesthesia prior to extubation (T2), and from extubation to when the animal was sternal and responsive in its home cage (T3). Total recovery time was calculated as T3-T2. Changes in body temperature and recovery times between Groups 1 and 2 for both species were evaluated for statistical significance ($p < 0.05$) using a 2-tailed Student's t test.



Results

Insulating extremities against heat loss resulted in a significantly lower decrease in body temperature under anesthesia ($p < 0.05$) for both species (Chart 1). Similarly, full recovery from anesthesia was significantly shorter for both species when insulation was provided to their extremities in addition to covering their torsos with a blanket (Chart 2). Neither species showed adverse effects from the additional insulation.

Discussion

It is well documented that many anesthetics interfere with thermoregulation and contribute to peri- and post-operative hypothermia.² Hypothermia has been directly associated with pain, suppressed phagocytic activity, reduced anion production and metabolism, and systemic suppression of immune reactivity.¹ Thus-greatly lengthening the time to a conscious, awake state. By providing better insulation to key sites of body-heat loss during prolonged anesthesia, one can thereby improve vital parameters and animal well-being.

Only one conventional method of warming (i.e., a circulating warm water pump and pad) was included in the control group. It may be informative to compare these results when using other conventional methods used for animals, such as a heat lamp or a circulating warm air device, to further avoid body heat loss and shorten recovery times.

Other investigations to consider include measuring actual surface temperatures of the torso, hand, foot, and tail. Those sites may predict changes in core body temperature before it actually drops or raises, thereby providing a more sensitive and useful measure for monitoring anesthetized animals. Given the broad range of laboratory animal species used today, there remains much to be explored with respect to maintaining normothermia under anesthesia to improve animal welfare and to avoid artifactual changes in biomedical research data.

References

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2. Evans TA, Wilson D. 2007. *Anesthetic Emergencies and Procedures*, p. 1033-1044. In Tranquilli W, Thurmon J, Grimm K, editors. *Lumb and Jones' Veterinary Anesthesia and Analgesia*. Iowa: Blackwell Publishing.