

## THERMOREGULATION IN A PORCINE MODEL

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### INTRODUCTION

The use of swine in biomedical research to study human **diseases** has gained increased relevance due to the similarities between the two species. On the basis of anatomic and physiologic characteristics, swine have replaced dogs and primates in some research protocols. Swine have also been used as a model in numerous **studies** investigating thermoregulatory responses (especially during episodes of malignant hyperthermia). Advantages of this model include: availability, comparable cardiovascular systems and skin with **similar** properties. Yet, age-related differences in body composition exist within both species and thus, it is of interest to further characterize thermoregulatory properties of this model. The purpose of this study was to better characterize the correlation between skin and core temperature and skin perfusion, determine the effects of anesthetic agents on these correlations and investigate vasomotor changes during anesthesia.

### METHODS

**Three** to four month old mongrel swine weighing 30-40 kg were **used** for the study. All animals were housed in a controlled environment and followed similar regimens for diet and care. After two days to allow for acclimatization, an indwelling catheter was surgically inserted into the external jugular vein for subsequent administration of anesthesia. The animal was intubated and maintained on **1.5%** Isoflurane for a five hour period. The animal's core temperature was held normothermic ( $-38^{\circ}\text{C}$ ) or hypothermic ( $-35^{\circ}\text{C}$ ) by using Augustine Bair Hugger<sup>®</sup> forced-convection air therapy. During this time, core temperature, end-tidal PCO<sub>2</sub>, heart rate, and mean arterial pressure were recorded. Foreleg and hoof temperatures were measured **as** an indicator of the degree of vasodilation.

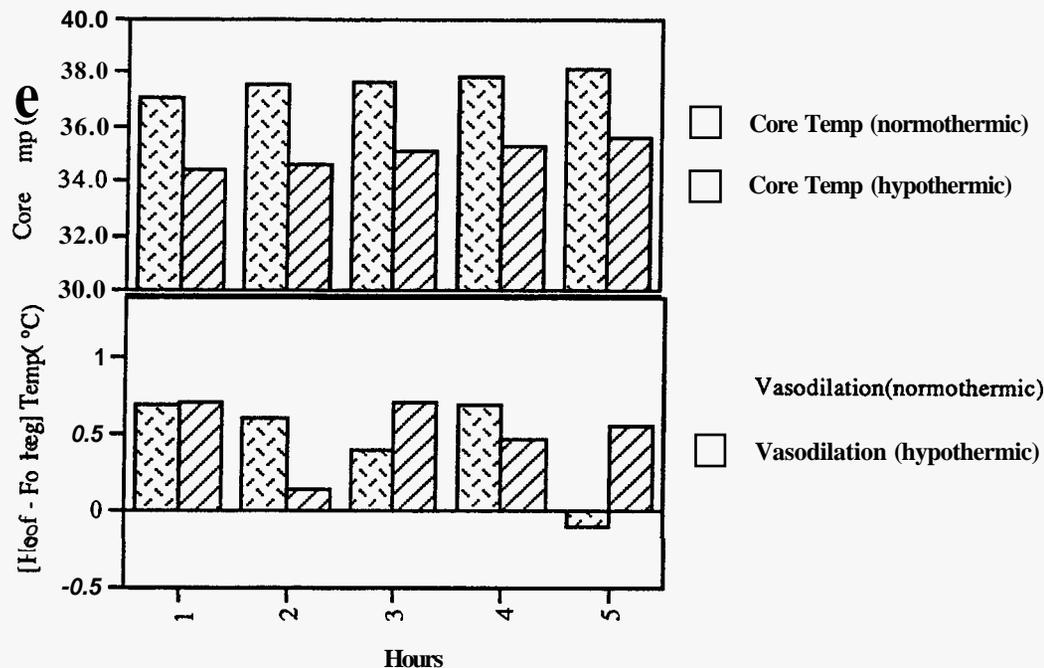
Subsequent physiological measurements were obtained every three days over a four week period while using Pentothal<sup>®</sup> (thiopental sodium for injection, USP) anesthesia. All experiments were performed at a room temperature of 24°C. **An** infrared scanner (Exergen D501 Microscan<sup>®</sup>) was used for **all** non-invasive surface temperature measurements. A comparison of the infrared scanner and commercially available skin thermocouples showed that the IR measurement had a greater degree of accuracy in the desired range. Core temperature was measured using a rectal probe (Mon-a-therm<sup>®</sup>). Skin blood flow was determined using a laser Doppler perfusion unit (Laserflo<sup>®</sup>). The Laserflo Blood Perfusion monitor uses a gallium aluminium arsenide semiconductor at a nominal wavelength of 780nm (as opposed to helium-neon laser), minimizing variations due to skin pigmentation. Heart rate and blood pressure were recorded via an automated cuff (Critikon Dinamap<sup>®</sup>).

### RESULTS

Core temperature changes in response to anesthesia in swine are similar to those reported in humans. The administration of isoflurane, a potent vasodilator, causes a drop in core temperature which correlates well with the degree of vasodilation **as** indicated by the absence of significant hoof-foreleg temperature gradient. This degree of vasodilation did not differ significantly with a change in core temperature induced by external temperature modulation (figure 1). A similar graph for the administration of non-volatile anesthetics (pentothal and surital) showed a significant hoof-foreleg gradient, indicating the animal's ability to vasoconstrict when exposed to a cool environment.

The blood flow and skin temperature measurements from all swine at all monitored locations and for all times were pooled and examined. There was no significant correlation between the two parameters. In particular, there was no evidence that an internally induced increase of skin temperature occurred simultaneously with an increase in dermal blood flow. This finding is in contrast to that of earlier work which involved applied changes of temperature in humans! and in animal?. In those studies, a qualitative correlation between temperature and blood flow changes was found. It is believed that the present lack of correlation could be due to the following factors: **1)** skin temperature changes were internally induced in contrast to the externally induced changes cited in prior work, **2)** anesthesia effects altered this relationship or **3)** temperature changes were not of sufficient magnitude to cause notable changes in blood flow. The skin temperatures at various locations along the back were averaged for all sites, and a Bonferroni multiple comparison test showed no significant differences between locations. However, this was not true of the perfusion alone, which was dependent on the location.

Figure 1



### CONCLUSION

The control of central body temperature is an overlooked variable in many biomedical studies utilizing animal models. In addition, studies in humans have indicated that commonly used anesthetic agents can alter thermoregulatory processes resulting in **hypothermia**.<sup>3</sup> On the other hand, there is an increased interest in utilizing changes in core temperature to clinical benefits: e.g., induced hyperthermia for the treatment of AIDS or mild hyperthermia (33-34 °C) for cerebral protection. More specifically, the use of blood perfusion and thermal mapping has become increasingly important in the detection of vascular diseases<sup>4</sup> and as a wound healing criterion. Therefore, it is important to note the physiological and environmental conditions under which biomedical studies are performed; e.g., one needs to account for heat losses or gains through alterations in metabolism, conduction, convection and/or radiation<sup>5</sup>. In this regard, it was observed here that convective-air cooling or warming was an effective means to induce and maintain a desired core temperature in the presence of various types of general anesthetics.

In the swine model, the **type** of anesthesia administered is an important factor to consider in investigations concerning thermoregulation: e.g., volatile anesthetics can be potent vasodilators which will influence the effector control of cutaneous blood flow. The observed modulations in thermoregulatory processes by various anesthetic agents may indicate a similarity of the swine thermoregulatory system with that of humans under anesthesia.

### REFERENCES

1. Richardson D. Effects of age on cutaneous circulatory response to direct heat on the forearm. *J Gerontol* 1989;44(6).
2. Song CW. Physiological factors in hyperthermia. *Natl Cancer Inst Monogr* 1982; (61)169-176.
3. Sessler DI, McGuire J, Hynson J, Moayeri A, Heier T. Thermoregulatory vasoconstriction during isoflurane anesthesia minimally decreases cutaneous heat loss. *Anesthesiology* 1992;76(5):670-5.(1:3)
4. Wagner WH, Keagy BA, Kotb MM, Burnham SJ, Johnson GJ. Noninvasive determination of healing of major lower extremity amputation: the continued role of clinical judgment. *J Vasc Surg* 1988;8(6):703-10.
5. Seifalian AM; Stansby G; Jackson A; Howell K; Hamilton G; Comparison of laser Doppler perfusion imaging, laser Doppler flowmetry, and thermographic imaging for assessment of blood flow in human skin. *Eur J Vasc Surg* 1994 Jan;8(1):65-9