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Comparison of Heating Devices for Maintaining Body Temperature in Anesthetized Laboratory Rabbits (*Oryctolagus cuniculus*)

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The purpose of this study was to compare the efficacy of various external heating devices in maintaining body temperature in anesthetized rabbits (*Oryctolagus cuniculus*). Rabbits were divided into 3 groups and placed on either no heating device, a circulating warm-water blanket, or a forced-air warming device. The animals underwent identical surgical procedures unrelated to the scope of the study, and body temperatures were monitored at 5-min intervals for a 45-min period. Results showed that rabbits had a statistically significant loss of body temperature during the procedure when no heating device was used, no significant loss in body temperature with the use of the forced air-warming device, and a minor increase in body temperature with the use of the circulating warm-water blanket. This study shows that external heating devices are necessary for maintenance of normal body temperature in rabbits under general anesthesia, and forced-air warming devices and circulating warm-water blankets are effective heating devices.

Monitoring and maintaining a patient's normal body temperature throughout a general anesthetic procedure is widely accepted as standard veterinary practice. It is also the nature of general anesthesia for the patient's body temperature to fall if there is no intervention. This procedurally induced hypothermia has many untoward effects, including prolonged recovery times, altered hemostatic functions,[5] and even death. There are many variables that contribute to the development of hypothermia, some of which can be controlled, and others that are inherent to the situation. For example, rabbits (*Oryctolagus cuniculus*) and other small mammals are particularly susceptible to hypothermia because of the relatively large ratio of surface area to volume.[1]

External warming devices are highly effective in the prevention of surgical hypothermia.[2,7] Some devices are not recommended for use, such as the electric blanket or heated fluid bags, because they have been implicated in skin burns.[1] More commonly, circulating warm-water blankets and forced-air warmers have been used with great success. Various types of external heating devices helped to maintain normal body temperature in dogs throughout a 3-h anesthetic period,[7] whereas forced air warmers have been noted to be effective in maintaining normal body temperature in cats.[2] Forced-air warming devices also have been shown to be the most effective device for rodent cage microenvironments.[4] These technologies are used widely although minimal objective data are available regarding the effectiveness of the different warming devices, especially in species such as the rabbit. To our knowledge, this report is the first to directly compare the effectiveness of the circulating warm-water blanket and a forced-air warmer in maintaining the body temperature of a rabbit during a surgical procedure.

Materials and Methods

Animals. This study used 15 male (weight, 3.2 to 3.6 kg) purpose-bred New Zealand White rabbits (*Oryctolagus cuniculus*) from Robinson Services Incorporated (Mocksville, NC). These animals were serologically negative for *Treponema cuniculi*, *Encephalitozoon cuniculi*, cilia-associated respiratory bacillus, and *Pasteurella multocida.* These animals were also negative for all fecal helminthes and external arthropod parasites.

The rabbits were housed indoors and maintained and handled in accordance with the *Guide for the Care and Use of Laboratory Animals*[3] and the animal care policies of Wake Forest University's Institutional Animal Care and Use Committee. The rabbits were singly housed in cages with perforated-bottom caging (Lenderking Caging Products, Millersville, MD) and fed a commercial diet (Prolab Hi-Fiber Rabbit Diet, Purina, Brentwood, MO). Wood shavings were placed in the pan beneath the cage. Multiple types of toys and food enrichments were used as a part of the husbandry care program. The use of the rabbits and the surgery performed were approved by the institutional animal care and use committee. Wake Forest University is accredited by the Association for the Assessment and Accreditation for Laboratory Animal Care, International.

Anesthetic protocol. Rabbits were anesthetized with a combination of ketamine (35 mg/kg intramuscularly; Ketaset, Fort Dodge Laboratories, Fort Dodge, IA) and xylazine (5 mg/kg intramuscularly; Phoenix Science, St Joseph, MO). The animals then were intubated and maintained on vaporized isoflurane (Isoflo, Abbott Animal Health, Abbott Park Illinois). The animals were recovered and provided analgesia with buprenorphine (Buprenex, Renckitt Benckiser Pharmaceuticals, Richmond, VA) at a dose of 0.01 mg/kg intramuscularly immediately postoperatively and then every 4 to 6 h for 3 d.

Heating devices. Two different heating devices were used in this experiment. The first device was a forced-air warmer (Bair Hugger model 505, Arizant Healthcare, Eden Prairie, MN) with a blanket (dimensions, 88 × 91 cm; Bair Hugger Blanket model 55577, Arizant Healthcare). The blanket was positioned between the rabbit and the composite tabletop, and the forced-air warmer was set at the highest warming setting (43 °C). The second heating device was a circulating warm-water blanket (dimensions, 30 × 45 cm; Engler Engineering Corporation, Hialeah, FL) and water pump (Gaymar T-Pump, Orchard Park, NY). The blanket

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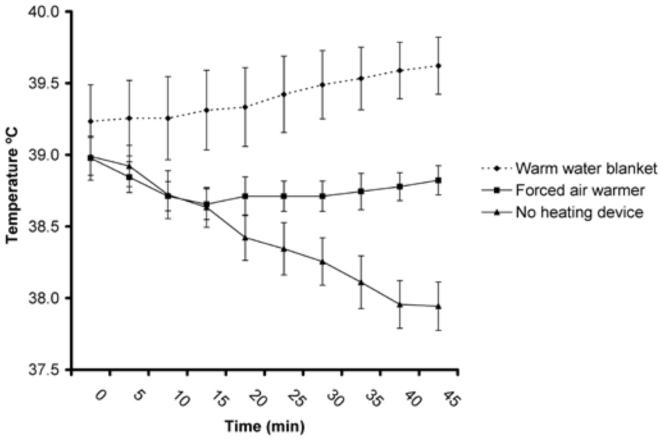

Figure 1. Mean body temperature. Bar, 1 standard deviation.

was positioned between the rabbit and the composite tabletop and set at the highest warming setting (42 °C).

Experimental design. The rabbits in this experiment underwent identical tibial nerve resection procedures unrelated to the scope of this study. The nerve resections required a 10-cm incision on the lateral aspect of the hindlimb, starting 3 cm above the knee. All procedures were performed in the same surgical suite with a room temperature range of 22.2 to 23.8 °C. The surgical tables were made from an X-ray-translucent composite surface (Pannomed Aeron Veterinary Surgical Table, Louisville, KY). Rabbits were divided into 3 groups: no heating device, forced-air warmer, and circulating warm-water blanket. The rabbits in the group with no heating device were placed on an absorbent disposable cloth to avoid direct contact with the surgical table. The rabbits in the other 2 groups were placed on their respective warming devices. Body temperatures were monitored and recorded every 5 min for a total of 45 min by use of an esophageal temperature probe (Advisor Vital Signs Monitor, SurgiVet, Waukesha, WI). Other vital parameters monitored were end-tidal CO_2 concentrations, pulse oximetry, and heartrate.

Data analysis. Analysis of variance was used to determine statistical significance of the baseline and final body temperature readings between the 3 different groups of rabbits. A paired Student *t* test was used to determine the statistical significance between the baseline and final body temperature reading within each group (Microsoft Excel, Redmond, WA).

Results

There was no statistical significance ($P = 0.502$) among the baseline body temperatures of the rabbits in all 3 groups, but there was a statistically significant difference ($P < 0.0001$) among groups at the final body temperature reading. There was no statistical difference between the baseline and final body temperature readings for either the forced-air heating device ($P = 0.618$) or the circulating warm-water device ($P = 0.158$). In contrast, there was a significant difference ($P < 0.01$) between the baseline and final body temperature readings in the group with no heating device. Average baseline and final body temperature readings and respective standard deviations for all groups are found in Table 1. Figure 1 shows the body temperature readings for all groups throughout the 45-min monitoring period.

Discussion

The aim of this study was to compare the effects of various heating devices and evaluate their efficacy in maintaining the normal body temperature of anesthetized rabbits. The normal body temperature of a rabbit was defined as 38.5 to 39.5 °C.[6] Our study shows a statistically significant difference between the presence and absence of heating devices during a surgical procedure. The circulating warm-water blanket was the most effective heating device, causing a slight elevation in mean body temperature by the end of the recording period. This elevation is not necessarily a desirable one, but it is minimal, and the temperature setting for the water-heating device was fixed as part of the experiment but easily could have been adjusted lower to prevent this rise.

Table 1. Average body temperature readings

Heating device	Baseline (°C)	Final (°C)
Forced-air warmer	39.0 ± 0.344	38.8 ± 0.227
No heating device	39.0 ± 0.295	37.9 ± 0.379

The forced-air heating device also was effective in maintaining a normothermic condition, with only a nonsignificant –0.2 °C drop from baseline body temperature. This finding is consistent with results for the use of forced-air heating devices in dogs, indicating that the forced-air warmer is effective but not the most effective heating modality for these species.[7] This finding is in contrast to the effectiveness of forced-air warmers with rodent cage microenvironments. This discrepancy can be explained by the amount of surface area covered by the heating device. The forced-air warmer was wrapped around the cage, rather than just being placed on top of the heating device, allowing it to more effectively heat the cage in a previous study.[4] This method of wrapping was impractical for the current study, so placing the animal on the heating device was the only practical option. Lack of a heating device resulted in a significant –1.1 °C decrease in body temperature across the 45-min recording period. This drop was sufficient to put the animal in mild hypothermia, with the presumption that a longer anesthetic period would exacerbate the fall in body temperature.

The overall decrease in body temperature seen in the forced-air warmer group was the result of an initial decline, followed by a moderate increase, in body temperature after 15 min of recording. The warm-water blanket group experienced increasing body temperatures starting at the 10-min point, with no transient drop in body temperature. The forced-air heating devices and warm-water blankets were turned on from a cold start for each procedure, so the initial decline in the forced-air warmer group could indicate that these devices require a longer time to achieve a clinically effective temperature than do the warm-water blankets.

The biologic significance of the body temperature changes seen in this experiment can be interpreted in different ways. The absolute change seen is not likely to cause any severe complications or have much biologic significance in any way. The trend in body temperature fluctuations that is seen, however, does carry biologic significance. For example, with a longer duration of anesthesia and more invasive abdominal surgeries, it would be expected that the downward trend in body temperature of animals without an external heating device would continue to decline to a biologically significant hypothermia. Although the current study is limited in its ability to extrapolate the performance of the forced-air warmer and the warm-water blanket in more strenuous conditions, the trends seen in the study indicate favorable performance and maintenance of a normothermic condition.

In conclusion, hypothermia during anesthetic procedures leads to multiple postoperative complications, and both the warm-water blanket and forced-air warmer effectively maintained normal body temperatures in rabbits. Warm-water blankets slightly outperformed forced-air warmers, but both devices kept body temperatures within normal ranges and statistically significantly higher than those of rabbits without heating devices.

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