

Intraoperative Heat Conservation Using a Reflective Blanket

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Heat loss and hypothermia are common intraoperative complications.¹⁻⁵ The ill effects of hypothermia, especially in the immediate postoperative period, have been described by other authors.⁵⁻⁹ Attempts to reduce heat loss have included variations in anesthetic circuits; low flow, closed, to and fro, and heated humidifiers; radiant heaters; increased ambient temperature; active warming blankets; and reflecting blankets.^{4,6,10-16} Studies of the effectiveness of reflecting blankets in reducing radiant heat loss have shown conflicting results.^{4,16-19} Since radiant heat loss is usually the major source of heat loss in an anesthetized patient, we studied the effectiveness of another reflective blanket, aluminized Tyvek, type 1443,[¶] which is used as lining in survival apparel.

METHODS

With the approval of our hospital's Committee for the Protection of Human Subjects, we studied two groups of patients. Group 1 consisted of 60 consecutive ASA Class I or II patients scheduled for elective carotid endarterectomy. Patients were assigned randomly to either a control group for whom standard operating room draping was used or to a test group. Test patients were wrapped as completely as possible in the aluminized blanket; surgical draping was the same as for control patients. Group 2 consisted of 30 consecutive ASA Class I or II patients scheduled for neurosurgical procedures anticipated to be longer than 3 h. Patients were assigned randomly to a control or test group. All patients were placed on an active heating blanket whose temperature had equi-

brated with ambient temperature. Test patients were wrapped in the aluminized blanket as completely as positioning would allow; test and control patients were draped in standard manner.

For test patients in Groups 1 and 2, a copper cable connected the aluminized blanket to the operating table to prevent patient isolation. Patient temperature, monitored with an esophageal temperature probe,²⁰ operating room temperature, and relative humidity were recorded at half-hour intervals. Other aspects of anesthetic management were left to the discretion of the responsible anesthesiologist. Patients were observed for shivering in the recovery room by a nurse blinded to the treatment. Observations were subjected to chi-square analysis. Temperature and humidity data were examined by analysis of variance. All results are reported as significant if $P < 0.05$.

RESULTS

Carotid Endarterectomy Group. No problems were reported as a result of using the aluminized blanket in any patient. Control and test patients were similar with respect to age, weight, body surface area, ASA class, preoperative medications, anesthetic technique, and absence of other diseases. There were no differences in operating room temperature or humidity. The blanket covered $80 \pm 5\%$ (mean ± 1 SD) of the patient's body surface.²¹ Initial patient temperatures were the same in the test and control groups (fig. 1). Within 30 min, the test patients' temperatures had risen above initial temperature and remained so throughout the operative period. Control patients' temperatures dropped below the initial temperature at 30 and 60 min, but they were not below the initial temperature thereafter. Recovery room shivering occurred in 16 control patients and in five test patients ($P < 0.05$).

Neurosurgical Group. As in the patients undergoing carotid endarterectomy, there were no differences between control and test patients with respect to patient population, operating room environment, or anesthetic technique. Initial patient temperatures were similar for control and test patients (fig. 2). In the test patients, $62 \pm 8\%$ (mean ± 1 SD) of body surface area was covered, and temperatures did not fall below initial values throughout the 4-h study period. Control patients' temperatures were below initial at 1, 2, and 3 h. In the control group, active

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¶ King-Seeley Thermos Co., 37 East St., Winchester, Massachusetts 01890.

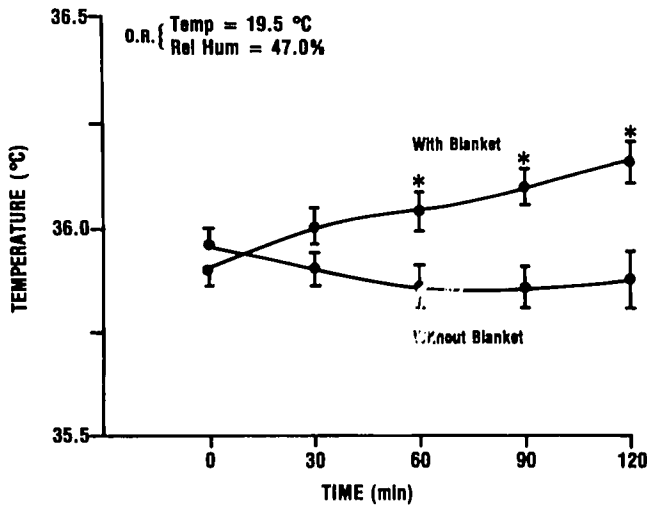


FIG. 1. Esophageal temperatures for carotid endarterectomy patients with and without reflective blanket. * indicates significant change from control, $P < 0.05$, $N = 30$ for each group.

warming blankets were turned on between the third and fourth hours to correct the lower temperatures. There were no differences between control and test patients' temperatures on admission to the recovery room. Since the tracheas of some neurosurgical patients remained intubated and they were paralyzed, we could not assess postoperative shivering.

DISCUSSION

Body temperature is determined by the balance between heat production and heat loss. Euthermia is maintained by the body's ability to vary heat production and to conserve heat. An anesthetized patient, with a relatively

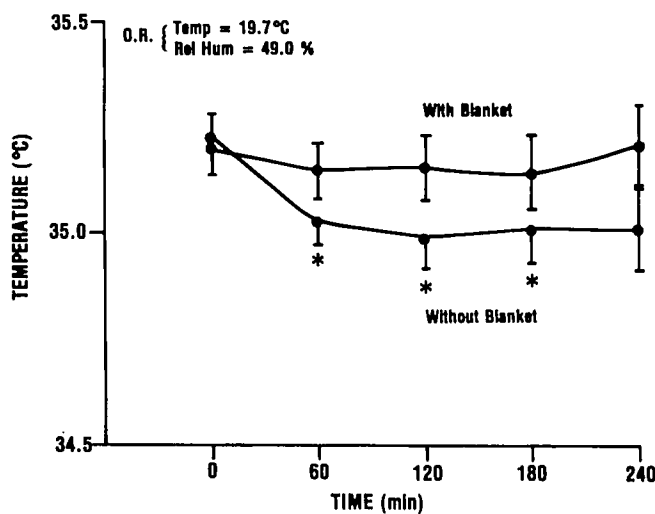


FIG. 2. Esophageal temperatures for neurosurgical patients with and without reflective blanket. * indicates significant difference between groups, $P < 0.05$, $N = 15$ for each group.

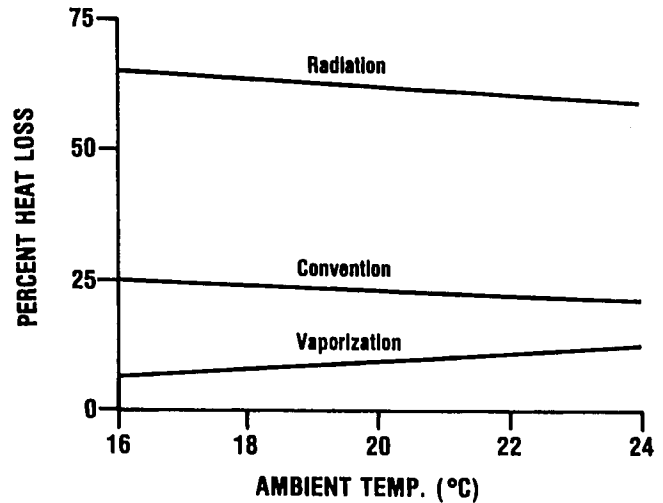


FIG. 3. Theoretic percentages of heat loss through various mechanisms at varying ambient temperatures for an undraped patient. See Appendix for equations.

low metabolic rate and minimal control over heat loss, is obviously at a disadvantage. Metabolic heat production in an anesthetized normal adult male is 60–70 kcal/h.^{22–24} Heat is lost through four parallel pathways: conduction, evaporation, convection, and radiation. Of these, conduction and evaporation cause the fewest intraoperative problems. Conductive loss is minimal (less than 10%) because of the low specific heat and conductivity of the drapes and mattresses. Although evaporative heat loss (*i.e.*, insensible perspiration plus evaporation from the respiratory tract) is approximately 25 kcal/h, the loss can be reduced to 10–15 kcal/h by using moist warm-inspired gases.

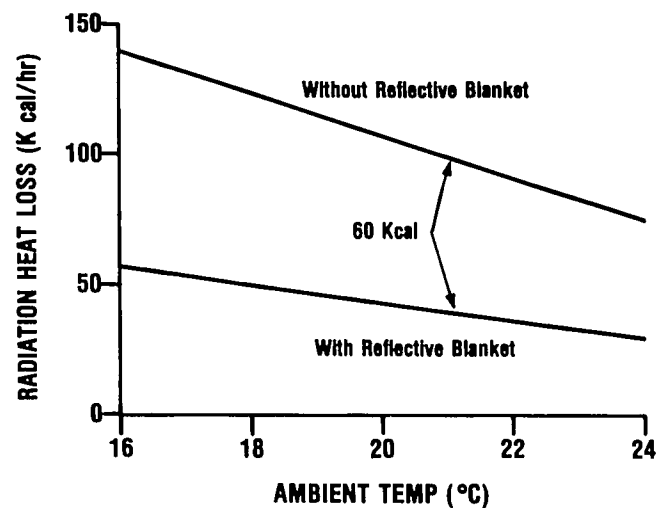


FIG. 4. Theoretic radiant heat loss from a surgical patient with and without a reflective blanket covering 80% of the body and reflecting 80% of incident photons. At an ambient temperature of 21° C the blanket conserves 60 kcal/h. See Appendix for equations.

The major causes of heat loss in the operating room are convection and radiation^{4,24,25} (fig. 3). Convective heat loss is a function of ambient temperature and the square root of air velocity (see Appendix). In a 21° C operating room, an exposed patient's convective heat loss can be 80 kcal/h. By reducing both the velocity and volume of interacting air, surgical draping usually decreases this loss to about 20 kcal/h.^{19,24,26}

Since the human body is nearly a perfect emitter/absorber at the wavelengths important for thermal exchange and since the probability of photon reflection is nearly zero in the typical operating room, radiant heat loss is a direct function of the difference between patient and ambient temperature.^{22,24} Therefore, using a blanket that reflects 80% of radiated heat in a 21° C operating room can reduce radiant heat loss from 100 to 40 kcal/h (fig. 4).

We are unable to explain the equivocal results of other investigators examining the use of the "space blanket." However, our study results are in concert with the above discussion. Although using the blanket results in small temperature differences, each degree centigrade represents the equivalent of approximately 1 hour's normal heat production. Replacing this deficit can put considerable stress on a patient's oxygen delivery system. Unless hypothermia is an essential element of the surgical procedure, it probably should be prevented from the outset. Prevention is best accomplished by maintaining high ambient temperatures when the body is exposed during prepping. Continued high ambient temperatures, however, are unnecessarily uncomfortable for surgeons and scrub nurses. Moreover, after the patient is draped, convective heat loss decreases. Thus euthermia can be maintained by various methods despite lower ambient temperatures.

We recommend using a reflective blanket when more than 60% of a patient's body surface can be covered and when the procedure is likely to last 2 h or longer. Reflective blankets cannot burn patients, are not subject to mechanical or electrical failures, and are lightweight, clean, and disposable. The following additional points should be noted: 1) the blanket does not interfere with radiologic procedures; our radiologists did not detect any loss of quality in x-rays exposed through as many as 16 layers of the Tyvek 1443 blanket; 2) because the blanket is perforated, it does not trap moisture that could condense and cause skin maceration during prolonged use; and 3) using a metalized blanket does not increase the risk associated with undetected electrocautery dispersion plate faults.**

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APPENDIX

Abbreviations

H_C	convective heat loss (kcal/h)
H_R	radiation heat loss (kcal/h)
K_C	constant
K_R	universal radiation constant
A	body surface area
e	emissivity
T	temperature absolute

Convection

Convective heat loss can be expressed as:

$$H_C = K_C A (T_1 - T_2).$$

K_C includes constants for the characteristics of the interacting gas and, in particular, a factor that varies directly as the square root of the interacting gas velocity. K_C for air and an exposed patient in a typical operating room is about 5, while the reduction in air velocity caused by drapes can lower K_C to about 2.

Radiation

A form of the Stefan-Boltzman equation that expresses the rate of radiant heat transfer between two interacting bodies is:

$$H_R = K_R A e (T_1^4 - T_2^4) \text{ (kcal/h)}.$$

Factoring $(T_1^4 - T_2^4)$ yields $(T_1 - T_2)(T_1^3 + T_1^2 T_2 + T_1 T_2^2 + T_2^3)$. Consider the second factor: let skin temperature, T_1 , be 33° C (306° A). Let ambient temperature, T_2 , be 20° C (293° A) and 27° C (300° A); if the second factor is evaluated for both values of T_2 , the results are within 4% of each other. The factor $(T_1 - T_2)$, however, changes considerably under the same conditions. If the second factor is replaced by a representative value and incorporated into the constant K_R , the equation simplifies to:

$$H_R = K_R A e (T_1 - T_2).$$

e is a function of the emissivities, absorptivities, shapes, and distance between the interacting bodies. Emissivity and absorptivity may be considered equal for a particular wave length and a constant temperature and expressed as C . There are a number of expressions for e , but the results are similar. In the following expression the patient is considered a cylinder within a cylindrical operating room.⁷

$$e = \frac{1}{\frac{1}{C_1} + \frac{r_1}{r_2} \left(\frac{1}{C_2} - 1 \right)}$$

Under the usual conditions, the patient's emissivity, C_1 , is nearly equal to 1; the operating room's emissivity, C_2 , is nearly 1; and the patient's radius, r_1 , is much smaller than the approximate operating room cylindrical radius, r_2 . Thus $e \rightarrow 1$. However, if the patient is wrapped in a blanket that reflects 80% of the emitted photons, then C_2 equals 0.2; r_1 and r_2 are nearly equal; and $e \rightarrow 0.20$. Therefore, as a theoretic approximation, and all other factors being equal, heat loss would be reduced by 80%.

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