Skin Circulation and the Thermoregulatory Threshold

To the Editor—Sessler et al. recently published their results of temperature measurements during general anesthesia with halothane, in support of a hypothermic threshold for thermoregulation. Their study was thought-provoking and served to highlight some of the problems associated with skin circulatory physiology.

Skin temperature is a useful indirect measure of serial changes in skin blood flow (SBF). However, it is a relatively insensitive modality being affected by various factors, such as equipment design, skin texture, contact of thermocouple with skin, and ambient temperature. In Sessler’s study, a gradient of 4°C between forearm and fingertip skin temperature during hypothermia was proposed as evidence of cutaneous vasoconstriction and “thermostatic” hypothalamic temperature regulation in 12 patients, corroborated by Laser Doppler and hand venous P02 measurements in two additional patients. The designation of the 4°C skin temperature gradient was determined by the authors in preliminary studies. The skin circulation is noted for its regional variations of anatomy and physiology. Total SBF consists of nutrient or capillary flow and arteriovenous (a-v) anastomoses flow. During body cooling, vasoconstriction of a-v anastomoses occurs, so that a-v shunt flow decreases significantly more than nutrient flow. Anastomoses are numerous in the digits, particularly the fingertips, and virtually absent in the forearm skin. Vasomotion of cutaneous precapillary vascular beds, accounting for changes in SBF velocity, occurs less frequently in the digits, compared to more proximal skin areas. One researcher concluded that “observations in one skin area cannot necessarily be applied to others at the periphery.”

This study raises a number of interesting issues related to the demonstration and interpretation of cutaneous vasoconstriction. Since the characteristics of SBF to the fingertip and forearm differ considerably, hypothermia would be expected to produce a larger temperature drop at the fingertip, compared to forearm skin, since a-v shunt flow would be predominately affected. Therefore, the observed skin temperature gradients in hypothermic patients could be explained on the basis of local blood flow phenomena instead of “thermostatic” hypothalamic mechanisms. It is not known whether halothane modifies this response, compared to other pharmacologic agents. The Laser Doppler used in this study can measure cutaneous blood flow velocity in any skin area of the body, even if conditions are changing. Photoplethysmography of the fingertip could provide information about the cutaneous pulsatile microcirculation. Thermography could be used to demonstrate skin temperature changes over a wider area compared to a single thermocouple. A combination of these monitors from various sites would provide more information about regional changes in skin circulation, and further characterize central thermoregulatory mechanisms.

I commend Sessler and colleagues for an interesting study. The review of thermoregulation was most informative.

PAUL G. LOUBSER, M.D.
The Institute for Rehabilitation and Research
Baylor College of Medicine
Houston, Texas 77030

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More on Thermoregulatory Thresholds with Halothane

To the Editor—We applaud the elucidation by Sessler et al. of mechanisms of human thermoregulation during anesthesia; also, we would like to comment on the interpretations of esophageal temperatures measured during the study.

First, when an esophageal stethoscope is positioned at the site of “maximum heart tones,” a subjectively determined location, its tip, with temperature sensor, may still be lying in a retrotracheal position. A previous study by Whitby and Dunkin elegantly demonstrated the nonuniform distribution of temperatures along the esophagus, both longitudinally and laterally. These investigators noted that the lower fourth of the esophagus was both the warmest and the most thermally stable segment. Of note was the observation that temperature varied almost 1°C with as little as a 2-cm change in depth of esophagus. In a more recently published study that confirms a temperature gradient along the esophagus, a shift of as little as 2 cm had “very little effect on the sounds,” the highest temperatures being recorded at a site 12–16 cm deeper than where best heart and breath sounds occurred (38–42 cm from the incisors). Second, esophageal temperature can be influenced by active warming of airway gases with a heated humidifier. In a study of how esophageal temperature is influenced by airway temperature, we demonstrated that even passive warming of inspired gases with a heat and moisture...
CORRESPONDENCE

Marc N. Siegel, M.D.
Resident in Anesthesiology

Nikolaus Gravenstein, M.D.
Assistant Professor of Anesthesiology and Neurosurgery

Departments of Anesthesiology and Neurosurgery
University of Florida College of Medicine
Gainesville, Florida 32610-0254

REFERENCES


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In Reply—Dr. Loubser’s comments provide a welcome opportunity to discuss thermoregulatory vasconstriction in detail. Metabolic heat is lost primarily via convection and radiation from the skin surface. Decreasing cutaneous blood flow reduces environmental heat loss and is the most consistently used thermoregulatory mechanism. In 1981, Grant and Bland observed that total digital skin blood flow is divided into capillary and arteriovenous shunt components, and subsequent studies have confirmed that peripheral skin has a dual blood supply. Thermoregulatory vasconstriction is believed to occur primarily in the cutaneous arteriovenous shunts. As Dr. Loubser notes, these shunts are concentrated in the fingers and toes so that blood flow to distal extremities during cold exposure is more affected than flow to more proximal skin (e.g., forearm). It is precisely this distribution that makes finger and toe temperatures useful indices of thermoregulatory vasconstriction. Forearm temperature is minimally affected by thermoregulatory vasconstriction (e.g., forearm and core temperatures are well correlated). In contrast, cold exposure decreases shunt flow, which decreases peripheral skin-surface temperature.

The decrease in peripheral flow that we observed is almost completely centrally mediated and does not result from changes in local ambient temperature. The pattern of vasconstriction indicates that peripheral cooling does not result from passive central cooling: if peripheral cutaneous flow decreased passively, the gradients would increase smoothly as central temperature decreased. Instead, the skin temperature gradients remained approximately constant until vasconstriction, and then increased rapidly to values ≥ 4°C (see figure 3 in reference 6). In studies using other anesthetics (which inhibit thermoregulation more than halothane), we have observed patients with central temperatures ≈ 32°C who maintained negative skin-surface temperature gradients.

Central-finger tip gradients are frequently used to evaluate peripheral vasconstriction because they correlate well with plethysmography, and thermal and helium dilution. Since forearm temperature is ≈ 30°C below core temperature, a central-finger tip gradient of 7°C is comparable to a forearm-finger tip gradient of 4°C. When the thermoregulatory threshold during halothane anesthesia is determined using central-finger tip gradients, the results are similar (34.43 ± 0.24°C) to those we reported previously using skin-surface gradients (34.44 ± 0.23°C). Furthermore, the duration of anesthesia preceding a finding of significant vasconstriction with each method differed by less than 10 min.

Since thermoregulatory vasconstriction produces a rapid, 5–10-fold decrease in peripheral flow, it is easily detected by both central-finger tip and forearm-finger tip gradients. Comparing two skin-surface temperatures (rather than central and skin temperatures) has the advantage of eliminating confounding factors caused by differences in equipment design, skin texture, core temperature, and ambient temperature. Adequate and consistent contact between skin and the thermocouples is easily maintained using self-sticking Mon-a-Therm® probes.

Although thermoregulatory vasconstriction is believed to occur primarily in the cutaneous arteriovenous shunts, capillary flow also decreases. Capillary flow can be determined using the laser Doppler perfusion monitor which correlates well with 133Xe washout, and dynamic capillaroscopy. We have recently demonstrated a good correlation between the laser Doppler perfusion index and skin-surface temperature gradients (Doppler index = 7.9 · Gradient + 67, r² = 0.65). We also have used multiple peripheral skin-surface monitors to demonstrate that the pattern of vasconstriction during anesthesia...