Pediatric Anesthesia

EDITORIAL

Forced-air warming in infants and children

There is overwhelming evidence that even mild hypothermia causes numerous and severe complications in adults (1). Major complications include morbid myocardial complications (2), surgical wound infection (3), and increased blood loss and transfusion requirement (4). Hypothermia also reduces drug metabolism (5), prolongs recovery (6), and provokes thermal discomfort (7).

Pediatric patients are as susceptible to anesthetic-induced thermoregulatory impairment as adults (8,9). But complications of perioperative hypothermia have not specifically been evaluated in pediatric patients. However, it is likely that infants are at least as susceptible to many of these complications and may suffer others including respiratory embarrassment. It has thus long been the standard-of-care to maintain normothermia in pediatric surgical patients. To address this issue, Witt and colleagues report their evaluation of a new forced-air warming system (10).

Specifically, Witt and colleagues report a case series of 119 patients with a body weight approximately 4 kg having surgery lasting about 100 min; half had major abdominal procedures. Ambient temperature was maintained at 24°C, and body temperature was monitored in the esophagus, rectum, or bladder. Patients were warmed with a novel forced-air warmer from Moeck which is designed to provide higher air flow than conventional systems. All patients were normothermic within 2 h of anesthesia and surgery.

Cutaneous heat loss is roughly proportional to surface area, whereas metabolic heat production is roughly proportional to body mass. The consequence—as every pediatric anesthesiologist well appreciates—is that infants and children cool more quickly than adults. But for the same reason, infants and children rewarm more quickly than adults in a dry convective environment, such as under a forced-air warmer. It is thus usually easy to keep pediatric patients normothermic during surgery, especially when ambient temperature is kept at 24°C.

The clinical question therefore is not whether a novel forced-air system works, but whether it works as well (or better) than existing systems. This question cannot be answered by the study of Witt and colleagues because they did not include a control group. A placebo control was unnecessary—and might be considered unethical—because it is predictable that unwarmed infants having major abdominal surgery will become hypothermic. But it would have been helpful to have randomized patients to the novel warmer vs a conventional forced-air warming system. The same total number of patients would have easily been sufficient to evaluate either noninferiority or superiority.

Because all forced-air manufacturers agree that air temperature should not exceed 43°C, differing efficacy would only be expected on the basis of cover design or air flow. It is thus worth considering how forced-air warms patients and factors that influence heat transfer. There are two important mechanisms.

The first important heat transfer mechanism is that forced-air covers or mattresses provide a thermal barrier that prevents radiative heat loss from adjacent skin. Specifically, skin adjacent to the cover or mattress 'sees' the warm cover rather than cold walls. As the cover or mattress is typically warmer than skin, radiation moves heat from the cover to the skin and, from there, into the body.

Cover or mattress configuration is critical because poorly designed covers do not provide even heating over their entire surface area. The potential for poor heat distribution results from the trivial heat capacity of air. Air thus cools quickly when flow through a cover is not sufficiently rapid. Most air from clinical blowers is thus used to maintain a high flow through the cover or mattress which minimizes the temperature gradient between the central portion and peripheral areas. An enhanced blower might thus better distribute heat to its cover. But uneven cover or mattress heating is much more of an issue with adults than infants because the cover area for infants is so small that most any blower presumably distributes heat well.

Only a small fraction of the roughly 400 watts heat generated by typical forced-air systems is transferred into patients (11), and increasing air flow reduces this proportion. In other words, energy use is proportionate to delivered air volume, even if the incremental benefit small. Excess warm air is released into the operating room, eventually to be removed by the air conditioning system. From an environmental perspective, it is thus reasonable to ask whether a high-air-flow system really warms better than conventional ones.

The second important heat transfer mechanism is convection, which is the basis of the familiar wind-chill factor. Convection accelerates conduction by the square root of air speed. However, only air flow at the skin surface contributes to convective warming. The bulk of the air flowing through a cover or mattress, which primary provides even heat distribution, does not provide convective warming. What determines the degree of convective warming with a specific cover or mattress is thus the number and distribution of holes in the cover, or ability of air to flow through the cover material at velocity. In the case of a forced-air mattress, the amount of air flowing under the surgical drapes is an important determinant of heat transfer and depends critically on cover design.

Blower strength and cover design thus influence heating efficacy by distributing heat evenly, providing a thermal barrier, and by directing large amounts of air to the skin surface. Neither air flow nor the cover design is described in Witt and colleagues. However, the Moeck corporate web site* indicates that the system is based on a reusable mattress. Current forced-air systems transfer comparable amounts of heat into humans (12). Whether the system tested by Witt and colleagues transfers similar amounts, or perhaps more, remains to be determined.

In summary, Witt and colleagues present overwhelming evidence that the Moeck forced-air heating system keeps infants and children warm during even major surgery at an ambient temperature of 24°C. I look forward to future studies comparing this novel blower and cover to conventional forced-air warming systems under a variety of clinical circumstances, including in adults and at lower ambient temperatures.

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Conflict of interest

Dr. Sessler has no other financial interests related to this editorial.

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