

Postoperative shivering

BY JEAN-DENIS ROY, M.D.

Postanesthesia shivering was first described over fifty years ago. Although initially believed to be associated with hypothermia alone, postoperative shivering has since been observed on many occasions in normothermic patients.¹

While estimates of the incidence of postanesthesia shivering vary greatly, it is reported that from 5% to 65% of patients experience shivering following surgery and anesthesia. Although the precise origin of postoperative shivering remains uncertain, a number of hypotheses have been advanced. In addition to being a significant source of discomfort for patients coming out of surgery, it can cause other adverse effects. This issue of *Anesthesiology Rounds* endeavours to explain postoperative shivering and discuss preventive strategies and treatments.

Some authors suggest that two-thirds of all patients who have undergone anesthesia – general or regional – have been affected by postoperative shivering.² Not only is shivering uncomfortable for patients, but it is also associated with certain adverse effects,³ including increases in a patient's:

- oxygen consumption
- heart rate
- metabolic CO₂ production
- circulating catecholamines
- lactic acid levels.

Other effects that can have adverse outcomes for patients can also be ascribed in whole, or in part, to hypothermia, including:

- increased susceptibility to infection
- coagulation disorders
- reduced drug metabolism.

All of these phenomena can lead to a significant aggravation of postoperative pain and contribute to an increase in intracranial pressure and cardiopulmonary complications.

Several experiments have been conducted to diminish perioperative hypothermia as a means of preventing postanesthesia shivering, using a whole range of physical, mechanical (radiant heat, heated ambient air, heating blankets) and pharmacological methods. Given the variable efficacy of these techniques, it is not surprising that there does not seem to be general agreement on the effectiveness

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of any one method. The fact that interventions to prevent hypothermia have had only a partial impact on shivering has led several authors to consider a multifactorial explanation for this phenomenon. The important thing for clinicians is that they have effective means to, not only treat shivering when it occurs, but also to reduce its incidence.

THE PHYSIOPATHOLOGY OF SHIVERING

Postanesthesia shivering can cause a series of potential complications with varying seriousness in patients undergoing surgery. The factors that can contribute to episodes of shivering include the age and sex of the patient, the choice of anesthetic technique (such as the use of premedication or propofol), and the maintenance of spontaneous breathing.^{2,4,7}

In conscious unanesthetized patients, one of the first compensatory mechanisms in response to a marked drop in body temperature is vasoconstriction. In order for this reaction to occur during general anesthesia, a drop of 2.0° to 2.5°C is required. All anesthetic agents lessen the extent of shivering episodes caused by skeletal muscles. Muscle shivering, which is a mechanism that actively compensates for a decrease in body temperature, is of course, completely suppressed when muscle relaxants are used. However, the muscles retain some ability to generate heat independently of their ability to shiver. Under regional anesthesia (perimedullary and peripheral blocks), vasoconstriction and shivering are two responses that are inhibited in the region affected by the block.

General anesthesia induces changes that lead to a redistribution of heat in the body of the patient. A relative displacement of overall body temperature from core to periphery occurs when vasodilatation induced by anesthetic agents increases the perfusion of cutaneous tissues. During anesthesia, body heat is lost via several mechanisms such as radiation, convection, conduction, and evaporation. The largest perioperative heat loss is due to radiation (roughly 65%), with convection coming in second at about 25% of the total deficit. Anesthetics also cause a measurable lowering of the shivering threshold.⁸ This leads to an additional loss of heat because the patient's body is more tolerant and must reach a

more serious degree of hypothermia before responding. When the patient emerges from general anesthesia, the shivering threshold is restored, causing an abrupt stimulation that is sometimes associated with major postoperative shivering episodes.

However, postanesthesia shivering may not just be a thermoregulatory reaction.⁹ According to another possible etiology, associated more specifically with cardiac surgery and anesthesia, shivering is one manifestation of an inflammatory response associated with the release of cytokines triggered by extracorporeal circulation. Hence the suggestion that, because of its anti-inflammatory activity, dexamethasone may reduce the incidence of shivering in cardiac surgery patients.¹⁰

In an editorial on the contribution of body temperature to postoperative shivering, Crosley¹¹ suggested that a significant role may be played by the afferent thermal receptors. The fact that several types of drugs such as meperidine, clonidine, and physostigmine have been shown to be effective in treating postoperative shivering indicates that different systems with a variety of receptors (opioid, alpha-2 adrenergic and anticholinergic) are probably involved.

It is possible that some of the mechanisms responsible for the thermal perturbations and postoperative shivering associated with general anesthesia are also involved in the shivering episodes observed in locoregional anesthesia. In the latter case, the mechanisms only express themselves partially due to the segmentary nature of the disturbances induced by the various types of blocks (perimedullary, plexus, peripheral). The regions blocked by locoregional anesthetic evidently lose their autonomic thermoregulatory functions, thereby contributing to hypothermia and postoperative shivering, but the latter may be accentuated by a certain "behavioral" involvement inasmuch as the sensation of heat caused by locoregional anesthetics in the blocked regions tends to lessen the activation of the mechanisms that act to conserve body heat. In other words, there is an insidious side to locoregional anesthesia for patients, who do not have the sensations normally associated with a drop in temperature, being misled by an impression of heat in the regions affected by the block. However, unlike general anesthesia, the metabolic functions that

can contribute to rewarming and heat balance maintenance are largely preserved in the regions unaffected by the block. This is also true for the ability to shiver that remains present in the non-blocked regions.¹²

It is generally agreed that three main compensatory mechanisms operate to counter hypothermia subsequent to heat loss during anesthesia and surgery, namely:

- vasoconstriction
- thermogenesis without shivering
- skeletal muscle shivering.

Skeletal muscle shivering is one mechanism that, it would seem, should be treated and, if possible, prevented.

THE PHARMACOLOGICAL APPROACH

Clinicians must realize that efforts to suppress body hypothermia and postoperative shivering should not be limited to arresting shivering when it occurs, given the availability of a variety of physico-chemical and pharmacological means to help prevent its onset. Active rewarming techniques have demonstrated particular effectiveness, although postanesthesia shivering is not always an attempt on the part of the patient's body to achieve thermoregulation or homeostasis. In fact, it is not uncommon to see shivering in recovery room patients whose core temperature has not dropped significantly. Let us now look at the various pharmacological options in the treatment of shivering.

The list of drugs used to treat postoperative shivering includes doxapram,¹³ tramadol, ketanserin (10 mg IV),¹⁴ clonidine, propofol, physostigmine (0.04 mg/kg),¹⁵ nefopam (0.15 mg/kg),¹⁶ and magnesium sulfate (30 mg/kg).¹⁷ The opioids stand out among the available treatments because they have been the most extensively evaluated. While a number of opioids are commonly used to suppress postoperative shivering, the possibility of side effects such as sedation, itching, nausea, and vomiting should be taken into consideration.

Many clinicians are familiar with the potential of meperidine in the treatment of shivering. Meperidine has a higher efficacy rate (70% to 80%) than other opioids.¹⁸ In most cases, a dose of 25 mg to 50 mg IV is effective in patients weighing 70 kg. Wrench *et al*¹⁹ suggest that the

minimum effective dose of meperidine to treat postoperative shivering is about 0.35 mg/kg. Higher doses may be necessary if the shivering patient has also been given opioid antagonists. Meperidine has proven effective in suppressing shivering regardless of the mode of administration – intravenous, intramuscular,²⁰ epidural,²¹ or intrathecal.²²

The mechanism whereby meperidine arrests shivering has not been completely elucidated, but there is a body of evidence suggesting that the main component driving its anti-shivering activity is mediated by kappa opioid receptors.

Meperidine is more effective in the treatment of shivering than are equianalgesic doses of mu receptor agonists such as morphine, fentanyl citrate, alfentanil, or sufentanil.²³⁻²⁵ Exactly how the action of meperidine differs from that of other opioids in preventing shivering and why it is more effective have not yet been determined. Meperidine can be administered intravenously or epidurally to effectively prevent shivering episodes that tend to occur in epidural anesthesia.²¹ Epidural administration of sufentanil or fentanyl citrate can also significantly reduce or prevent shivering in women who are giving birth.²⁶ In a study on caesarean sections, Roy *et al* observed that 0.2 mg/kg of intrathecal meperidine resulted in a significant decrease of the incidence and intensity of shivering associated with locoregional anesthesia.²²

According to a study by Buggy *et al*,²⁷ when administered at induction, a 150 µg dose of clonidine, an alpha-2 adrenergic agonist, reduces the incidence of shivering and the subjective sensation of cold experienced by patients recovering from general anesthesia. These findings suggest that alpha-2 adrenergic pathways play a role, and could be targeted as a means of controlling perioperative shivering. Although the mechanisms involved have not been precisely identified, these findings also point strongly to involvement of the central nervous system. Konrad *et al* have shown that 150 µg of clonidine administered intravenously can be just as effective as 25 mg of intravenous meperidine in treating recovery room shivering.²⁸

The administration of physostigmine increases the secretion of arginine-vasopressin, epinephrine, and norepinephrine via a mechanism

involving cholinergic stimulation of the hypothalamus-pituitary axis. Given that the hypothalamus is the dominant regulatory centre controlling body temperature in mammals, it is not surprising that a dose of 0.04 mg/kg of physostigmine¹⁵ can affect the incidence of shivering.

Powell and Buggy studied ondansetron, a 5-HT₃ antagonist used to treat postoperative nausea and vomiting, and found that an intravenous dose of 8 mg administered just prior to the induction of general anesthesia significantly reduced the incidence of postoperative shivering.²⁹ This effect is probably due to a central inhibitory mechanism, given that there was no measurable effect on heat redistribution. These observations suggest that the serotonergic pathways play a significant role in the regulation of postoperative shivering.

The kind of shivering observed postoperatively, as is the case with postoperative nausea and vomiting, practically never becomes chronic. It is also unlikely that these post-operative phenomena could be severe enough to cause death. However, shivering significantly increases the effort of the left ventricle as well as the oxygen consumption of the patient. Therefore, it makes sense to treat or prevent postoperative shivering, provided the interventions are sufficiently simple, inexpensive, and free of major side effects for the majority of patients.

A number of side effects frequently associated with opioids can occur when they are used to suppress or prevent postoperative shivering. However, the doses required to treat shivering are relatively low and repeated doses are not usually necessary, meaning that the adverse effects (nausea, vomiting, and respiratory depression) are rare. Clonidine, on the other hand, is frequently associated with episodes of bradycardia or hypotension, even if only a single dose (150 µg) is administered.

It is currently considered that the treatment to arrest postoperative shivering providing the best cost/benefit ratio is a single intravenous dose of meperidine in the order of 25 mg. This approach is generally effective

and safe, and very inexpensive. However, it is important not to neglect preventive approaches, and particularly active perioperative rewarming that, although not completely suppressing postoperative shivering, can significantly reduce its incidence.

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Abstracts of Interest

A comparative study of three warming interventions to determine the most effective in maintaining perioperative normothermia.

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Perioperative hypothermia poses a challenge because of its deleterious effects on patient recovery. The current practice of applying two cotton blankets on patients during surgery is thought to be less ideal than using reflective insulation or forced-air warming. We studied 300 patients who underwent unilateral total knee replacement and were randomized equally to three groups: (a) the two-cotton-blanket group, (b) the one-reflective-blanket with one-

cotton-blanket group, and (c) the forced-air-warming with one-cotton-blanket group. Tympanic temperature readings were taken before surgery in the induction room, on arrival at the recovery room, and at 10-min intervals until discharge from the recovery room. On arrival at the recovery room, the forced-air-warming group had significantly higher temperatures (adjusted for sex, age, and patient's induction room temperature) of 0.577 degrees C +/- 0.079 degrees C (95% confidence interval [CI], 0.427-0.726; P < 0.001) and 0.510 degrees C +/- 0.08 degrees C (95% CI, 0.349-0.672; P < 0.001) more than the reflective-blanket and two-cotton-blanket groups, respectively. The forced-air-warming group took a significantly (P < 0.001) shorter time of 18.75 min (95% CI, 13.88-23.62) to achieve a temperature of 36.5 degrees C in the recovery room as compared with 41.78 min (95% CI, 36.86-46.58) and 36.43 min (95% CI, 31.23-41.62) for the reflective-blanket and two-cotton-blanket groups, respectively. The reflective technology was less effective than using two cotton blankets, and the forced-air warming was most efficient in maintaining perioperative normothermia.

IMPLICATIONS: Perioperative hypothermia has deleterious effects on patient recovery. We found in patients having knee surgery that reflective technology was less effective than using two cotton blankets, whereas active surface warming with the forced-air method was most effective in maintaining normothermia.

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Perioperative heat balance

SESSLER DI. SAN FRANCISCO, CA

Hypothermia during general anesthesia develops with a characteristic three-phase pattern. The initial rapid reduction in core temperature after induction of anesthesia results from an internal redistribution of body heat. Redistribution results because anesthetics inhibit the tonic vasoconstriction that normally maintains a large core-to-peripheral temperature gradient. Core temperature then decreases linearly at a rate determined by the difference between heat loss and production. However, when surgical patients become sufficiently hypothermic, they again trigger thermoregulatory vasoconstriction, which restricts core-to-peripheral flow of heat. Constraint of metabolic heat, in turn, maintains

a core temperature plateau (despite continued systemic heat loss) and eventually reestablishes the normal core-to-peripheral temperature gradient. Together, these mechanisms indicate that alterations in the distribution of body heat contribute more to changes in core temperature than to systemic heat imbalance in most patients. Just as with general anesthesia, redistribution of body heat is the major initial cause of hypothermia in patients administered spinal or epidural anesthesia. However, redistribution during neuraxial anesthesia is typically restricted to the legs. Consequently, redistribution decreases core temperature about half as much during major conduction anesthesia. As during general anesthesia, core temperature subsequently decreases linearly at a rate determined by the inequality between heat loss and production. The major difference, however, is that the linear hypothermia phase is not discontinued by reemergence of thermoregulatory vasoconstriction because constriction in the legs is blocked peripherally. As a result, in patients undergoing large operations with neuraxial anesthesia, there is the potential of development of serious hypothermia. Hypothermic cardiopulmonary bypass is associated with enormous changes in body heat content. Furthermore, rapid cooling and rewarming produces large core-to-peripheral, longitudinal, and radial tissue temperature gradients. Inadequate rewarming of peripheral tissues typically produces a considerable core-to-peripheral gradient at the end of bypass. Subsequently, redistribution of heat from the core to the cooler arms and legs produces an afterdrop. Afterdrop magnitude can be reduced by prolonging rewarming, pharmacologic vaso-dilation, or peripheral warming. Postoperative return to normothermia occurs when brain anesthetic concentration decreases sufficiently to again trigger normal thermoregulatory defenses. However, residual anesthesia and opioids given for treatment of postoperative pain decreases the effectiveness of these responses. Consequently, return to normothermia often needs 2-5 h, depending on the degree of hypothermia and the age of the patient.

Anesthesiology 2000;92(2):578-96.

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