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Shivering Threshold during Spinal Anesthesia Is Reduced in Elderly Patients

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Background: **Both accidental and perioperative hypothermia are common in the elderly. The elderly are at risk because their responses to hypothermia may be delayed or less efficient than in those of younger subjects. For example, the vasoconstriction threshold during isoflurane anesthesia is ≈1°C less in elderly than younger patients. However, the extent to which other cold defenses are impaired in the elderly remains unclear, especially in those older than 80 yr. Operations suitable for spinal anesthesia provided an opportunity to quantify shivering thresholds in patients of varying ages. Accordingly, the hypothesis that the shivering threshold is reduced as a function of age during spinal anesthesia was tested.**

Methods: **Twenty-eight ASA Physical Status 1–3 patients undergoing lower extremity orthopedic procedures were studied. Spinal anesthesia was induced without preanesthetic medication, using bupivacaine sufficient to produce a dermatomal level near T9. Electrocardiogram signals were recorded at 10-min intervals. Subsequently, an observer masked to patient age and core temperature identified the onset of sustained electromyographic artifact consistent with shivering. The tympanic membrane temperature triggering shivering identified the threshold.**

Results: **Three patients did not shiver at minimum core temperatures exceeding 36.2°C. Fifteen patients aged <80 yr (58 ± 10 yr) shivered at 36.1 ± 0.6°C; in contrast, ten patients aged ≥80 yr (89 ± 7 yr) shivered at a significantly lower mean temperature, 35.2 ± 0.7°C ($P = 0.002$). The shivering thresholds in seven of the ten patients older than 80 yr was less than 35.5°C, whereas the threshold equaled or exceeded this value in all younger patients ($P = 0.0002$).**

Conclusions: **Age-dependent inhibition of autonomic thermoregulatory control in the elderly might be expected to result in hypothermia. That it usually does not suggests that behavioral regulation (*e.g.*, increasing ambient temperature, dressing warmly) compensates for impaired autonomic control. Elderly patients undergoing spinal anesthesia, however, may be especially at risk of hypothermia because low core temperatures may not trigger protective autonomic responses. Furthermore, hypothermia in the elderly given regional anesthesia may not be perceived by the patient (who typically feels less cold after induction of the block), or by the anesthesiologist (who does not observe shivering). Consequently, temperature monitoring and management usually is indicated in these patients. (Key words: Anesthesia: spinal. Thermoregulation: shivering; temperature.)**

ACCIDENTAL hypothermia (core temperature < 36°C) is relatively common in the elderly,[1,2] but rare in younger persons unless the condition is predisposed by intoxication[3,4] or extreme environmental exposure.[5] Similarly, intraoperative hypothermia is most common, and most severe, in elderly patients.[6–8] Hypothermia—whatever the cause—presumably increases the risk of temperature-related complications including myocardial ischemia,[9] wound infection,[10] and prolonged drug action.[11]

The elderly are at risk for hypothermia because their responses to hypothermia may be delayed[12] or less efficient than in younger subjects.[13] However, the extent to which thermoregulatory control is impaired in the elderly remains unclear. Most studies of perioperative thermoregulation in the elderly did not evaluate enough patients older than 80 yr,[14,15] or failed to specifically determine response thresholds (*i.e.*, triggering core temperature).[13]

Shivering thresholds usually were not determined in previous studies because investigators understandably were reluctant to cool elderly subjects to core temperatures <35°C. Such hypothermia is, however, com-

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mon during anesthesia and surgery.[16] We have previously demonstrated that the vasoconstriction threshold is ≈1°C less in elderly than younger patients during isoflurane anesthesia.[17] Interpretation of this result is, however, complicated by the large effect of general anesthesia *per se* on thermoregulatory control,[18] and the known age-dependent effects of volatile anesthetics.[19,20]

Operations suitable for spinal anesthesia provided an opportunity to quantify shivering thresholds in patients of varying ages with less confounding effect than might occur during general anesthesia. Accordingly, we tested the hypothesis that the shivering threshold is reduced more in the elderly than in younger persons during spinal anesthesia.

Methods

With approval from the Ethics Committee at the Cochin Port-Royal University Hospital and after obtaining patients' informed consent, we studied 28 ASA Physical Status 1–3 patients undergoing lower extremity orthopedic procedures. None was obese, febrile, receiving vasodilators or medications likely to alter thermoregulation, or had a history of thyroid disease or dysautonomia. Ambient operating room temperature was maintained near 19°C.

Spinal anesthesia was induced in each patient without preanesthetic medication, using ≈14 mg isobaric 0.5% bupivacaine. Typically, this produced a dermatomal level (as determined by lack of cutaneous cold sensation) near T9. One liter of lactated Ringer's solution warmed to 37°C was administered in the ≈15 min before induction of anesthesia. Subsequently, warmed crystalloid was given at a rate of 4 ml per estimated ml of surgical blood loss. No patients required blood transfusion. Postoperatively, patients were rapidly rewarmed using an electric blanket; this blanket could not be used during surgery because it is not approved for intraoperative use.

Core temperature was recorded from the tympanic membrane using Mon-a-Therm thermocouples (Mallinckrodt Anesthesiology Products, Inc., St. Louis, MO). The aural probe was inserted until patients detected the thermocouple touching the tympanic membrane; appropriate placement was confirmed when patients easily detected a gentle rubbing of the attached wire. The aural canal was occluded with cotton, the probe securely taped in place, and a gauze bandage positioned over the external ear. There is an excellent correlation between tympanic membrane and distal esophageal temperatures in the perianesthetic period.[18]

Sentient skin temperature was estimated from four sites using the following regional percentages: chest, 33%; upper arm, 31%; forearm, 21%; and finger, 15%.[21] Ambient temperature was measured using a thermocouple positioned at the level of the patient, well away from any heat-producing equipment. All thermocouple probes were connected to Mon-a-Therm Model 6510 thermometers (Mallinckrodt). Temperatures were recorded at 10-min intervals.

Blood pressure was determined oscillometrically at 5-min intervals. We used oscillometric rather than direct arterial blood pressure measurements to minimize the artifact induced by thermoregulatory vasoconstriction.[22] Heart rate was monitored continuously using lead-two electrocardiography. Silver-silver chloride electrodes were applied after skin degreasing and mild abrasion. Electrocardiographic signals were recorded on a strip chart at 10-min intervals; recordings were made during periods in which electrosurgery units were inactive. Subsequently, an observer masked to patient age and core temperature identified the onset of sustained electromyographic artifact consistent with shivering. The signals were considered to be shivering when they demonstrated the typical 4–6 cycle/min waxing-and-waning pattern. The core temperature triggering shivering identified the threshold.

From the patients' heights (Ht) in centimeters and weights (Wt) in kilograms, lean body mass in kg was calculated using formulas adapted to gender[23]: females: lean body mass = $(1.07 \cdot Wt) - [148 \cdot (Wt/Ht)^2]$; males: lean body mass = $(1.10 \cdot Wt) - [128 \cdot (Wt/Ht)^2]$. The percentage body fat was then calculated from the lean body mass and weight of each participant. The body surface area in m^2 of each patient was estimated using the equation: Area = $(Wt^{0.425}) \cdot (Ht^{0.725}) \cdot (0.0072)$.[24] As in previous studies,[25] we estimated the ratio of heat production to heat loss by dividing patients' weights by their calculated surface areas.

Shivering thresholds, sentient skin temperatures, ambient temperatures, morphometric data, and hemodynamic data in patients aged older and younger than 80 yr were compared using two-tailed unpaired *t* or Fisher Exact tests, as appropriate. An age of 80 yr was used to divide the patients because results differed substantially in patients younger and older than this age. Data are reported as means ± SD; $P < 0.01$ was considered statistically significant.

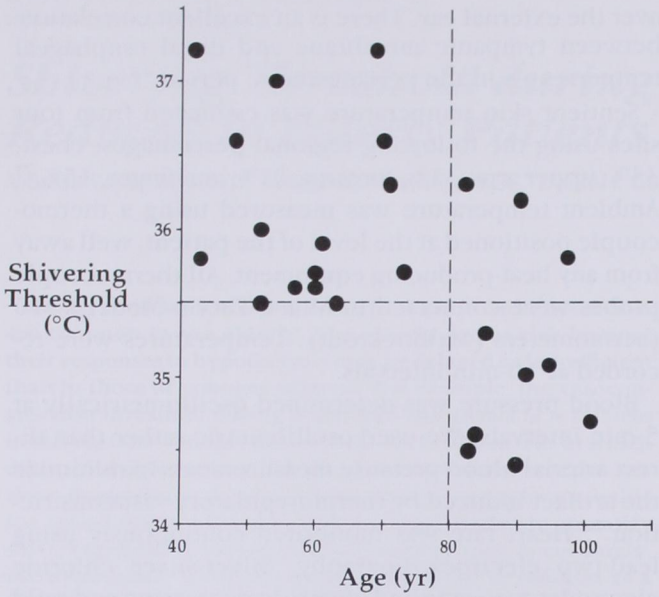

Fig. 1. Fifteen patients aged <80 yr (58 ± 10 yr) (mean ± SD) shivered at 36.1 ± 0.6°C; in contrast, eight patients aged ≥80 yr (89 ± 7 yr) shivered at a significantly lower mean temperature, 35.2 ± 0.8°C ($P < 0.001$). The shivering thresholds in five of the eight patients aged >80 yr was less than 35.5°C, whereas the threshold equaled or exceeded this value in all the younger patients.

Results

Three patients did not shiver at minimum core temperatures exceeding 36.2°C, two were aged >80 yr and one was younger. Fifteen patients aged <80 yr (58 ± 10 yr) shivered at 36.1 ± 0.6°C; in contrast, ten patients aged ≥80 yr (89 ± 7 yr) shivered at a significantly lower mean temperature, 35.2 ± 0.7°C ($P = 0.002$). The shivering threshold in seven of the ten patients aged >80 yr was less than 35.5°C, whereas the threshold equaled or exceeded this value in all younger patients ($P = 0.0002$, fig. 1). Two of the elderly patients with normal shivering thresholds were women.

Ambient temperatures and blood pressures at the time of shivering did not differ significantly in the two age groups. The weight and weight-to-surface area ratios were significantly less in patients aged 80 yr or older than in the younger patients (table 1). However, there was no relationship between the shivering threshold and body weight, lean body mass, or percentage body fat.

Table 2 shows the bupivacaine dose and resulting sensory block levels, shivering thresholds, and the corresponding sentient skin temperatures in patients younger than 80 yr and in those older than 80 yr. Elderly patients were given less bupivacaine, but had similar sensory block levels.

Table 1. Morphometric Characteristics

	≤80 yr	>80 yr	*P*
Age (yr)	58 ± 10	90 ± 6	<0.001
Weight (kg)	71 ± 12	52 ± 12	0.001
Height (cm)	167 ± 6	161 ± 6	0.05
Body fat (%)	28 ± 3	22 ± 9	0.03
Wt/SA ratio (kg/m^2)	39 ± 3	34 ± 4	0.003
Gender (M/F)	5/10	2/8	NS

Values are mean ± SD.

Discussion

Shivering thresholds in three of the elderly patients were similar to those in the younger patients. Shivering was delayed in seven others, however, until core temperatures were reduced to ≈34.8°C. This ≈1°C age-dependent decrease in the shivering threshold was similar to the reduction in the vasoconstriction threshold we reported previously in elderly patients during general anesthesia.[17] Combined with previous studies indicating that thermoregulation is impaired in aged subjects,[13,26,27] available data suggest that the elderly are especially at risk of hypothermia because low core temperatures often do not trigger protective responses.

That thermoregulatory responses were normal in some elderly patients, but markedly reduced in others is consistent with previous studies.[12,28] It is likely that thermoregulatory control does not simply gradually lose precision with increasing age. Instead, the elderly may consist of two populations—one with normal thermoregulation, and a second in which control is

Table 2. Bupivacaine Dose, Sensory Block Levels, and Sentient Skin Temperatures at the Shivering Threshold

	≤80 yr	>80 yr	*P*
No. of patients	15	10	—
Bupivacaine dose (mg)	14 ± 2	13 ± 2	0.06
Sensory block level (dermatome)	T8–10	T8–10	—
Shivering threshold (°C)	36.1 ± 0.6	35.2 ± 0.7	0.002
Sentient skin temperature (°C)	32.7 ± 1.6	31.6 ± 0.8	0.2

Values are mean ± SD.

diminished. Impaired thermoregulatory control is most likely in persons whose general health is poorer, but those in poor health would not usually be permitted to volunteer for physiologic investigations. In this scenario, subjects with abnormal thermoregulation might be systematically eliminated from volunteer studies, potentially producing a bias obscuring age-dependent changes.[15,29]

Despite current and previous[8,12,14,17,26] evidence that thermoregulatory response thresholds are impaired in the elderly, core temperatures are generally similar in old and young patients. At usual ambient temperatures, tonic thermoregulatory vasoconstriction typically is required to maintain core normothermia.[30] (It is inhibition of this tonic vasoconstriction that causes redistribution hypothermia on induction of anesthesia.[31]) Thus, inhibition of autonomic thermoregulatory control in the elderly might be expected to result in hypothermia. That it usually does not suggests that behavioral regulation (*e.g.,* increasing ambient temperature, dressing warmly) compensates for impaired autonomic control. Increased dependence on behavioral thermoregulation may partially explain the observation that the elderly frequently feel cold and tend to prefer warm environments.

Core hypothermia during regional anesthesia is usually associated with decreased cold sensation because it is associated with a slight actual increase in leg skin temperature[32] and a large apparent increase in skin temperature.[33] Sedative medications, which often supplement regional anesthesia, will further impair perception of core cooling and autonomic protective responses.[34] Hypothermia in the elderly given regional anesthesia thus may not be perceived by the patient (who typically feels less cold after induction of the block), or by the anesthesiologist (who does not observe shivering). Consequently, temperature monitoring and management usually are appropriate in these patients.

Regional anesthesia *per se* significantly impairs thermoregulatory control,[35] probably by increasing apparent leg temperature.[33] The shivering thresholds in most of our patients were thus probably less than might be observed in unanesthetized subjects. However, differences in the thresholds in elderly and younger patients most likely reflect age-related loss of thermoregulatory precision.

Exaggerated hypothermia in our elderly patients may also have resulted simply from morphometric differences, including decreased subcutaneous fat. Consistent with this possibility, the percentage body fat and weight-to-surface area ratios were slightly less in the younger patients. However, these relatively small morphometric differences would have little effect on the core cooling rate.[25] The efficacy of thermoregulatory responses, once initiated, is characterized by their gain, defined as the incremental increase in response intensity produced by a further deviation in core temperature. Previous work indicates that the gain of vasoconstriction is reduced in 80-yr-old subjects.[26] Although it is likely that efficacy of shivering also is reduced in the elderly,[27] gain was not evaluated in this study.

Sentient skin temperature at the shivering threshold was $\approx 1°C$ less in the elderly patients than in those younger than 80 yr. This decrease presumably resulted mostly because core temperature also was $\approx 1°C$ less in these patients. Skin temperature contributes $\approx 20\%$ to control of shivering.[36] Consequently, the reduced skin temperature in the elderly patients would have been expected to increase the shivering threshold $\approx 0.2°C$. Because the observed effect of age was an $\approx 1°C$ reduction in the core temperature triggering shivering, skin temperature is unlikely to have confounded our results.

In summary, the shivering thresholds in seven of the ten patients older than 80 yr was less than 35.5°C, whereas the threshold equaled or exceeded this value in all younger patients. This $\approx 1°C$ age-dependent decrease in the shivering threshold was similar to the reduction in the vasoconstriction threshold reported previously in elderly patients during general anesthesia. Elderly patients undergoing spinal anesthesia are especially at risk of hypothermia because low core temperatures may not initiate autonomic protective responses. Consequently, temperature monitoring and management usually are appropriate in these patients.

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