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Shivering and Shivering-like Tremor during Labor with and without Epidural Analgesia

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Background: **Effective treatment and prevention of hyperthermia and shivering-like tremor during labor is hindered by a poor understanding of their causes. The authors sought to identify the incidence of nonthermoregulatory shivering-like tremor and the factors associated with this activity.**

Methods: **The authors studied women in spontaneous full-term labor who chose epidural analgesia (n = 21) or opioid sedation (n = 31). Shivering-like tremor and sweating were evaluated by observation. Core temperature was recorded in the external auditory canal using a compensated infrared thermometer. Arteriovenous shunt tone was evaluated with forearm minus fingertip skin temperature gradients; gradients less than 0 were considered evidence of vasodilation. Tremor was considered nonthermoregulatory when core temperature exceeded 37°C and the arms were vasodilated. Pain was evaluated using a visual analog scale.**

Results: **Shivering-like tremor was observed in 18% of 290, 30-min data-acquisition epochs before delivery. The patients were both normothermic and vasodilated during 15% of these epochs. Shivering was observed in 16% of 116 postdelivery epochs and was nonthermoregulatory in 28%. Sweating was observed in 30% of predelivery epochs, and the patients were both hypothermic and vasoconstricted during 12%. The mean core temperature in patients given epidural analgesia was approximately 0.2°C greater than in those given sedation. Hyperthermia was observed during 10 epochs (38.4 ± 0.3°C) during epidural analgesia and during 10 epochs (38.4 ± 0.3°C) with sedation. The patients were vasoconstricted in more than 50% of these epochs in each group. Multivariate mixed-effects modeling identified high pain scores and vasoconstriction as significant predictors of shivering. There were no predictors for shivering epochs in patients who were simultaneously normothermic and vasodilated. Significant predictors of sweating were time before delivery, high pain scores, hypothermia with vasoconstriction, high thermal comfort, and low mean skin temperature. There were no predictors for sweating epochs in patients who were simultaneously hypothermic and vasoconstricted.**

Conclusions: **This study confirms the clinical impression that some peripartum shivering-like tremor is nonthermoregulatory. The authors also identified nonthermoregulatory sweating. These data indicate that shivering-like tremor and sweating in the peripartum period is multifactorial. (Key Words: Hyperthermia; hypothermia; temperature; thermoregulation; vasoconstriction.)**

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HORMONAL factors are likely to influence thermoregulatory responses during labor and delivery. Progesterone release during the normal menstrual cycle is associated with elevated circulating norepinephrine concentra-

tions, which in turn slightly augment core temperature.[1] The production of metabolic heat, which needs to be dissipated to the environment to maintain thermal steady state, is probably augmented further by the work of labor. On the other hand, heat loss may be exaggerated if laboring women are exposed too long to a relatively cool hospital environment. Clinical interventions, such as intravenous infusion of cold fluid,[2] can further exacerbate heat loss.

Hyperthermia is a generic term used to indicate an abnormally elevated core body temperature resulting from various causes. A reasonable clinical definition of hyperthermia is a temperature greater than 38°C, because core temperature normally never exceeds this value. Fever, in contrast, is a regulated elevation in body temperature.[3] It is likely that labor, and especially delivery, is associated with the release of fetal–placental products that trigger fever. However, the extent to which fever contributes to observed thermoregulatory patterns during and after delivery remains unknown.

Epidural analgesia peripherally inhibits vasoconstriction and sweating in the lower body.[4] Epidural analgesia thus augments heat loss from the lower body during most situations by inhibiting tonic thermoregulatory vasoconstriction, but it will decrease loss during sweating. The inhibition of tonic thermoregulatory vasoconstriction also may produce a redistribution hypothermia,[5] depending on the extent and intensity of the block and the patient's previous thermal status.[6] Neuraxial anesthesia also complicates the thermoregulatory situation by centrally impairing thermoregulatory control. Specifically, it impairs behavioral regulation[7] and decreases the vasoconstriction and shivering thresholds (triggering core temperature),[8,9] which increases the sweating-to-vasoconstriction interthreshold range (temperatures that do not trigger thermoregulatory responses).[10]

Prolonged labor analgesia is also associated with hyperthermia,[11–13] which can be sufficiently severe to require clinical intervention.[14] Similar hyperthermia has been reported in patients after surgery,[15] suggesting that the temperature elevation is not specifically related to pregnancy or labor. It seems unlikely that epidural analgesia would impair thermoregulatory control sufficiently to prevent adequate compensation for whatever imbalance between heat production and loss there might be in patients in labor or after operation. However, no established mechanism exists by which epidural analgesia should provoke fever. Therefore, it remains unknown even whether elevated core temperature during epidural analgesia is a simple passive hyperthermia or an actively regulated fever.

Shivering has a reported incidence of nearly 20% during labor without neuraxial analgesia,[16] and it is thought to be even more common with epidural analgesia.[17] It is curious that shivering is observed so often, because increased energy expenditure during labor presumably requires heat dissipation rather than heat production.[18] One possibility is that patients become febrile: this, of course, typically requires an increase in body heat content, which would often be supplied by shivering. Another possibility, however, is that some shivering-like tremor is not thermoregulatory. Consistent with this theory, tremor in approximately one half of normothermic patients after operation is accompanied by fingertip vasodilation, which precludes a diagnosis of normal thermoregulatory shivering.[19] Sweating also may be a response to stress rather than hyperthermia.

Effective treatment and prevention of hyperthermia and shivering-like tremor during labor is hindered by a poor understanding of their causes. Accordingly, we sought to (1) identify the incidence of nonthermoregulatory shivering-like tremor and factors associated with it; (2) evaluate the effects of epidural analgesia on core temperature and tremor incidence; and (3) compare thermoregulatory responses during labor with those in the immediate postdelivery period.

Methods

With approval from the Ethics Committee of the University of Vienna, we studied 52 women who had spontaneous onset of active labor at full term (37–41 weeks' gestation). The study was restricted to women who had (1) fetal membranes that were intact or ruptured for fewer than 6 h, (2) no clinical evidence or suspicion of infection, (3) core temperature less than 37.5°C, and (4) no concurrent complications or problems related to pregnancy. Active labor was defined by the presence of painful and regular uterine contractions and cervical dilation of at least 2 cm.

Protocol

Women without contraindications were offered epidural analgesia. In those who accepted (epidural group), a catheter was inserted into the L3-4 or L4-5 interspace using the loss-of-resistance technique. A test dose of 5 ml lidocaine, 2%, without epinephrine was given. Epidural analgesia was initiated with bolus administration of 8–12

ml bupivacaine, 0.125%. Bupivacaine, 0.125%, with 2 μg/ml fentanyl was then given as an infusion at a rate of 6–12 ml/h, adjusted as necessary to produce acceptable pain levels. Most patients who did not select epidural analgesia did not receive analgesics; a few patients were given intramuscular meperidine (100 mg). Nitrous oxide and anxiolytics were not given to patients in either group.

Measurements

Shivering-like tremor was evaluated by observation, as in previous studies, and was graded 0 when no tremor was detected, 1 when intermittent mild tremor was observed, and 2 when tremor was continuous and intense.[20] A sweating grade of 0 was assigned when no forehead moisture was detected; a grade of 1 was assigned when some moisture was detected; and a grade of 2 was assigned when distinct beads of sweat were visible. The forehead was swabbed dry with a gauze pad immediately after each sweating evaluation.[21]

Thermal comfort was evaluated using a 100-mm-long visual analog scale, with 0 being the worst imaginable cold and 100 indicating the worst imaginable warmth. Pain was evaluated using a similar 100-mm-long visual analog scale, with 0 indicating no pain and 100 identifying the worst imaginable pain. A new unmarked scale was used for each thermal comfort and pain measurement.

Core temperature was recorded in the external auditory canal using a scanning infrared thermometer that compensates for the effect of ambient temperature on aural temperature (Oto-Temp 3000; Gepa-Med, Vienna, Austria). Skin temperature was determined using an infrared thermometer (Gepa-Med); the mean skin temperature was calculated from four area-weighted sites.[22] Ambient temperature was measured from a thermocouple positioned at the level of the patient, well away from heat-generating equipment. Arteriovenous shunt vasoconstriction was evaluated from skin temperature gradients from the forearm to the fingertip.[23]

Values were recorded in the order just listed at each measurement epoch. Measurements were initiated in consenting patients soon after they were admitted to the delivery suite and continued until delivery. All data were recorded at 30-min intervals. In addition, we recorded the dose of meperidine given during labor, cervical dilation, and the type and time of delivery. In patients who consented, data acquisition continued for 2 h after delivery unless a cesarean delivery was required.

Data Analysis

Shivering or sweating scores ≥1 were considered significant. Skin temperature gradients from the forearm to the fingertip that were less than 0 were considered evidence of vasodilation.[23] The average core temperature during labor without epidural analgesia is 36.5°C.[11,12] Furthermore, slight hypothermia does not trigger normal thermoregulatory shivering, because the threshold for this response is well below normal core temperature with[24] or without[25] epidural analgesia. Even fever, which can cause shivering in hyperthermic persons, first triggers vasoconstriction.[26] Therefore, we considered shivering-like tremor to be nonthermoregulatory when core temperature exceeded 37°C and the arms were vasodilated. Patient were considered hypothermic when their core temperatures were less than 36.5°C and hyperthermic when their core temperatures exceeded 38°C.

Morphometric and demographic characteristics in the patients given opioids or epidural analgesia were compared using two-tailed, unpaired *t* tests. Most data were evaluated on an epoch-by-epoch basis, because the thermoregulatory status of individual patients frequently changed considerably during the measurement period. Thus, we could not identify a single characterization of each patient's thermoregulatory situation.

In patients who chose epidural analgesia, only epochs during analgesia were considered in our epoch-by-epoch analysis. Thus any epochs between entry into the study and initiation of epidural analgesia were discarded in the patients who chose epidural analgesia. We took this precaution because otherwise some of the data presented as "epidural" could not actually be obtained during epidural analgesia. Epochs before and after delivery were considered separately. Results are presented as the mean ± SD.

A limitation of univariate epoch-by-epoch analysis is that it fails to compensate for repeated observations in specific patients. Accordingly, our primary statistical analysis was a generalized linear mixed-effects model. Patient name was considered a random factor, thus compensating for repeated observations in individual patients. Four dependent outcomes were considered: (1) shivering *versus* nonshivering epochs, (2) shivering epochs in patients who were simultaneously normothermic and vasodilated *versus* other shivering-like tremor, (3) sweating *versus* nonsweating, and (4) sweating epochs in patients who were simultaneously hypothermic and vasoconstricted *versus* other sweating. Epochs before drug administration in women who eventually re-

Table 1. Environmental, Hemodynamic, Obstetrical, and Thermoregulatory Characteristics

	Sedation	Epidural
Number of patients	31	21
Age (yr)	27 ± 4	27 ± 6
Weight (kg)	70 ± 14	67 ± 12
Height (cm)	164 ± 4	166 ± 6
Duration of labor (h)	3.3 ± 2.2	4 ± 2.6
Parity (null/1/≥2)	12/9/10	11/6/4
Meperidine, 100 mg (number of patients)	8	1

Data are presented as mean ± SD. There were no statistically significant differences between the two study days.

ceived epidural analgesia were included in this analysis as nonepidural epochs.

Factors entered into the multivariate model included type of analgesia (epidural *vs.* opioid), delivery (before *vs.* after), pain score (in centimeters), core-temperature status (normothermic *vs.* hypothermic *vs.* hyperthermic), vasoconstriction status (dilated *vs.* constricted), thermal comfort (in millimeters), and mean skin temperature (in degrees Celsius). Factors that had a predictive P value < 0.25 were entered into the regression; a $P < 0.10$ was necessary for factors to be retained in the analysis. Results are reported as odds ratios and 95% confidence intervals.

Results

Fewer patients chose epidural analgesia (40%, 21 patients) than intramuscular sedation (60%, 31 patients). However, morphometric, demographic, and obstetric characteristics were comparable in each group (table 1).

There were 290 data-acquisition epochs before delivery, and shivering was observed in 18%. Core temperature, thermal comfort, skin temperature, and blood pressures were comparable during shivering and nonshivering epochs. Pain scores, however, were greater during shivering. The patients were both normothermic and vasodilated during 15% of the shivering epochs, suggesting a nonthermoregulatory cause of the tremor (fig. 1).

There were 113 data-acquisition epochs after delivery, and shivering was observed in 16%. Pain scores were less than before delivery, but core temperature, pain, thermal comfort, skin temperature, and blood pressure were comparable in shivering and nonshivering patients. The patients were both normothermic and vasodilated during 28% of the shivering epochs, suggesting a nonthermoregulatory cause of the tremor (fig. 2).

Sweating was observed in 30% of predelivery epochs. Sweating epochs were accompanied by greater core temperature, pain, and blood pressure; lower skin temperature; and a perception of excessive heat. The patients were both hypothermic and vasoconstricted during 12% of the sweating epochs, suggesting a nonthermoregulatory cause (Fig. 3). We observed virtually no sweating after delivery.

Before delivery, 46% of the 290 epochs were recorded during epidural analgesia. The mean core temperature in these patients was slightly (0.2°C) greater than in those given sedation, and they experienced less pain. Core temperatures did not increase as labor progressed, either as a function of time or cervical dilation. Maximum temperatures in the epidural group averaged 37.3 ± 0.8°C and 37.1 ± 0.7°C in those given sedation. The incidence of shivering was comparable with (16%) and without (20%) epidural analgesia (fig. 4). After delivery, 35% of the 113 epochs were recorded during epidural analgesia. Pain scores were comparable in the two groups and less than before delivery. Shivering was more common after delivery (23%) in the epidural analgesia epochs than with sedation (12%) (fig. 5).

Combining labor and the postdelivery period, core temperatures ≥38°C were observed during 10 epochs (38.4 ± 0.3°C) with epidural analgesia and 10 epochs (38.4 ± 0.3°C) with sedation. The patients were vaso-

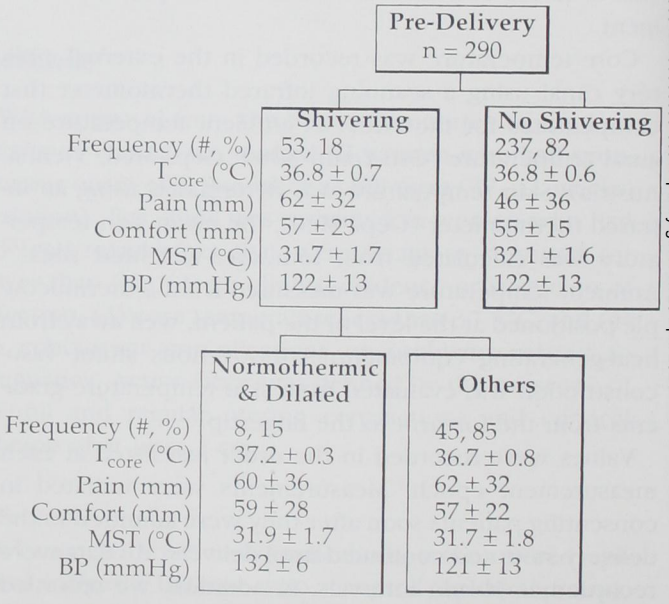

Fig. 1. The fraction of epochs before delivery in which shivering-like tremor was observed, and the fraction of those in which patients were normothermic and vasodilated (suggesting nonthermoregulatory tremor). Data are presented as the mean ± SD.

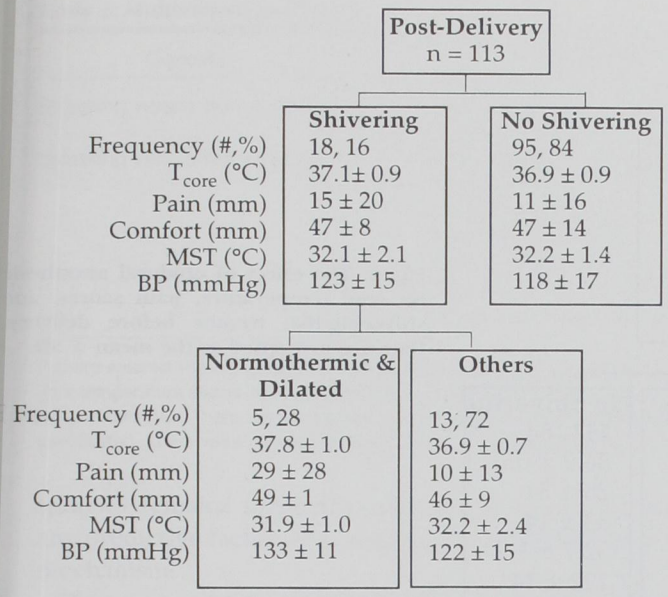

Fig. 2. The fraction of epochs after delivery in which shivering-like tremor was observed, and the fraction of those in which patients were normothermic and vasodilated (suggesting nonthermoregulatory tremor). Data are presented as the mean ± SD.

constricted in 70% of these epochs during epidural analgesia and during 50% of the epochs with sedation.

The multivariate mixed-effects model indicated that only pain and vasoconstriction predicted shivering. There were no predictors for shivering epochs in patients who were simultaneously normothermic and vasodilated. Sweating was predicted by many factors: time before delivery, great pain, normothermia and vasodilation, satisfactory levels of thermal comfort, and low mean skin temperature. There were no predictors for sweating epochs in patients who were simultaneously hypothermic and vasoconstricted (table 2).

Discussion

That components of postoperative shivering-like tremor might not be thermoregulatory has long been suspected because spontaneous muscular activity has been observed in normothermic patients,[27–29] rats,[30] and cats[31] after anesthesia. A recent study confirmed that some shivering-like activity during recovery from general anesthesia is indeed nonthermoregulatory.[19] The cause of this involuntary muscular activity remains unknown but may relate to an abnormal 5- to 7-Hz "bursting" tremor[32,33] that resembles pathologic clonus[34] but differs from the 4- to 8-cycle/minute waxing-and-waning pattern of normal shivering.[35]

Shivering-like tremor also has been observed in normothermic women during labor, and several studies have concluded that the incidence of spontaneous muscular activity is unrelated to core temperature.[17] None of these studies, however, eliminated fever as a trigger for normal shivering at normal or elevated core temperatures. Thus, a critical aspect of our protocol was to evaluate arteriovenous shunt vasoconstriction as an index of central thermoregulatory status. Requiring vasodilation as a criterion for nonthermoregulatory tremor eliminates fever as a cause, because the shivering threshold is a full degree Celsius less than the vasoconstriction threshold.[25] As a result, thermoregulatory shivering is always preceded by arteriovenous shunt vasoconstriction. Requiring vasodilation simultaneously guards against errors in core temperature measurements, because normal cold-induced shivering also provokes shunt constriction.

One of our major findings is that shivering-like tremor was observed in 15–18% of the epochs before and after delivery. Interestingly, core temperatures were high, and nearly identical, in the patients who shivered and those who did not. Mean skin temperatures and mean arterial pressures (an approximate index of autonomic nervous system activation) were also comparable. Similar and relatively high core and skin temperatures in patients who shivered and those who did not suggests that some

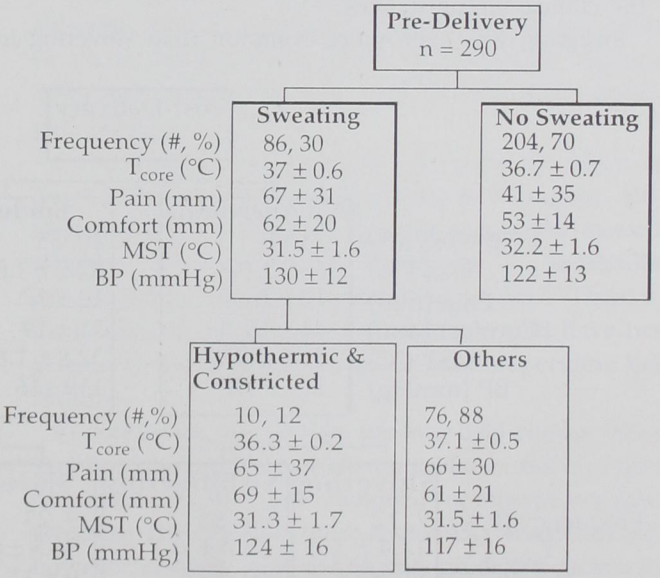

Fig. 3. The fraction of epochs before delivery in which sweating was observed, and the fraction of those in which patients were hypothermic and vasoconstricted (suggesting nonthermoregulatory sweating). Essentially no sweating was observed after delivery. Data are presented as the mean ± SD.

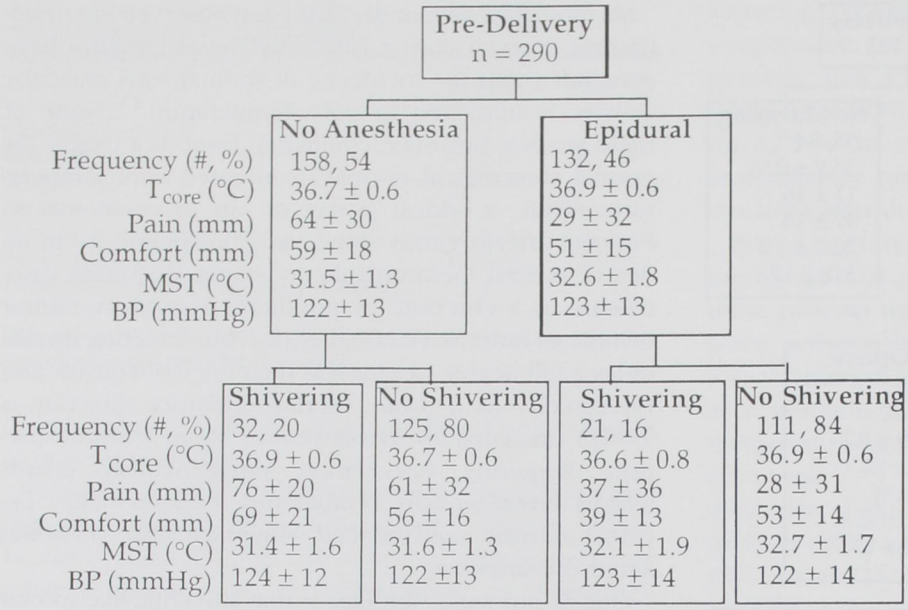

Fig. 4. The effect of epidural anesthesia on core temperature, pain scores, and shivering-like tremor before delivery. Data are presented as the mean ± SD.

shivering does not depend on body temperature. By considering only vasodilated epochs, however, we were documented that 15–28% of the shivering-like activity was inconsistent with normal thermoregulatory shivering. Thus, our data indicate that the incidence of nonthermoregulatory tremor in the peripartum period is similar to that after general anesthesia,[19] although the incidence in both cases likely depends considerably on the clinical circumstances.

Sweating was even more common than shivering in the predelivery period, although this response was virtually absent after delivery. Sweating was associated with slightly greater core temperatures but slightly reduced skin temperatures (perhaps because of evaporative cooling). Twelve percent of sweating in the predelivery epochs was accompanied by hypothermia and arteriovenous shunt vasoconstriction, which is not compatible with normal thermoregulatory sweating. Our study thus documents a fairly high incidence of nonthermoregulatory sweating and shivering. The causes of these re-

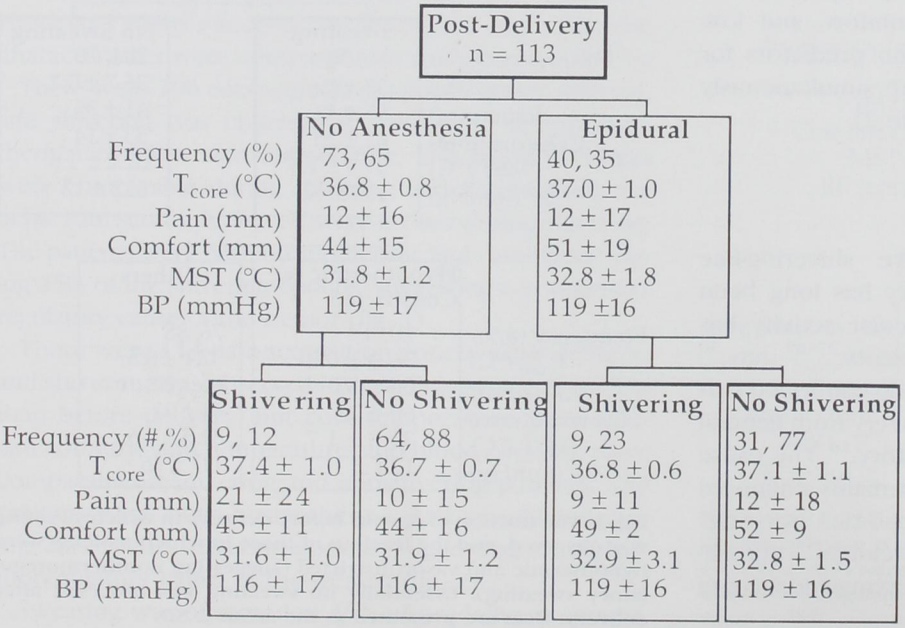

Fig. 5. The effect of epidural anesthesia on core temperature, pain scores, and shivering-like tremor after delivery. Data are presented as the mean ± SD.

Table 2. Multivariate Predictors

Outcome	Predictor	*P* Value	Odds Ratio	95% CI
Shivering *versus* not shivering	Pain (cm)	0.0002	1.16	1.07–1.26
	Dilated (yes/no)	0.0410	0.54	0.30–0.98
Sweating *versus* not sweating	After delivery (yes/no)	0.0074	0.22	0.07–0.55
	Pain (cm)	0.0001	1.28	1.15–1.43
	Hypothermia (yes/no)	0.0110	0.16	0.04–0.65
	Constricted (yes/no)	0.0010	0.25	0.11–0.57
	Hypothermia * constricted interaction	0.0583	4.87	0.95–25.03
	Thermal comfort (mm)	0.0016	1.034	1.01–1.06
	Mean skin temperature (°C)	0.0056	0.60	0.42–0.86

Factors entered into the generalized, multivariate mixed-effects model included type of analgesia (epidural *vs.* opioid), delivery (before *vs.* after), pain score (cm), core temperature status (normothermic *vs.* hypothermic *vs.* hyperthermic), vasoconstriction status (dilated *vs.* constricted), thermal comfort (mm), and mean skin temperature (°C). There were no significant univariate or multivariate predictors for shivering epochs in patients who were simultaneously normothermic and vasodilated. There were no predictors for sweating epochs in patients who were simultaneously hypothermic and vasoconstricted.

sponses remains unknown, and we could not identify any predictive factors that might have suggested specific mechanisms.

Core temperatures were slightly greater in patients given epidural analgesia. Although the difference was only 0.2°C, this result confirms previous reports that epidural analgesia is associated with relative hyperthermia.[11,12] In contrast to previous observations, however, the difference in core temperatures in the two groups did not increase significantly as labor progressed, either as a function of time or cervical dilation.[36] We identified 20 hyperthermic epochs in which core temperatures exceeded 38°C. The epochs were comparably distributed among patients given epidural analgesia and sedation. The patients were vasoconstricted during at least half the epochs in each group, indicating that in those cases hyperthermia was actively maintained by the regulatory system. Thus these patients were febrile, whereas the others appeared to have passive hyperthermia. Hyperthermia during labor, with or without epidural analgesia, thus appears to have at least two mechanisms.

Pain scores were considerably less in patients given epidural analgesia, as might be expected. Nonetheless, the incidence of predelivery shivering was comparable in the two groups: 16% and 20%, respectively. Furthermore, the incidence of shivering remained similar after delivery, although pain scores decreased more than threefold in each group. These data suggest that pain, although highly associated with shivering, is just one of at least several factors that mediate spontaneous muscular activity.

A limitation of our protocol is that core temperatures were estimated from the aural canal using an infrared scanning thermometer. Infrared measurements introduce a degree of variability that could be avoided with carefully positioned thermocouples. However, most patients in this study were ambulatory, at least during the initial phase of labor, and refused tympanic membrane thermocouples. Fortunately, infrared thermometers are sufficiently accurate and precise to distinguish between hypothermia and normothermia.[37,38] A thermometer similar to ours has been used in previous studies of thermoregulation during labor.[12]

Naturally, patients had to be offered the option of epidural analgesia. Consequently, they could not be assigned randomly to epidural analgesia or sedation. Thus, it is likely that these populations differed somewhat, although their demographic, morphometric, and obstetric characteristics were similar. A potentially important difference that we have no way to evaluate is intrinsic pain tolerance.

One quarter of the patients who were not given epidural analgesia required meperidine to treat pain. Alfentanil and other μ-receptor agonists reduce the vasoconstriction and shivering thresholds.[39] Meperidine, however, has a special antishivering action.[40] Thus, it is likely that the incidence of shivering would have been greater in the nonepidural group had meperidine been avoided.

In conclusion, we confirm the long-held clinical impression that some peripartum shivering-like tremor is nonthermoregulatory. We also identified nonthermoregulatory sweating. The causes of these responses remain unknown, however, and we could not identify predictive factors that might have suggested specific mechanisms.

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