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Patient Variables and the Subarachnoid Spread of Hyperbaric Bupivacaine in the Term Parturient

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To determine if age, height, weight, body mass index, or vertebral column length significantly influence the distribution of sensory analgesia or anesthesia after subarachnoid injection of hyperbaric bupivacaine, 52 women presenting for cesarean section were studied. All received 15 mg hyperbaric bupivacaine *via* subarachnoid injection at L-2 or L-3. Fifteen minutes after injection, while the women lay supine on a horizontal operating table, the maximum cephalad extent of sensory analgesia (loss of sensation of sharpness to pin prick) and anesthesia (loss of sensation of light touch) was determined. Age (20–42 yr), height (146.9–174.0 cm), weight (55.5–136.4 kg), body mass index (19.2–50.0 kg/m²), and vertebral column length (49.6–67.0 cm) did not correlate with the spread of sensory blockade. In conclusion, in parturients of age, height, weight, body mass index, and vertebral column length within the aforementioned ranges, it is not necessary to vary the dose of injected hyperbaric bupivacaine with changes in any of the patient variables studied. (Key words: Anesthesia, obstetric: cesarean section. Anesthetics, local: bupivacaine. Anesthetic techniques: spinal.)

MANY PATIENT VARIABLES have been suggested as influencing the ultimate spread of sensory blockade following subarachnoid injection of local anesthetics. These include age,[1–4] height,[5,6] weight,[3,7] and body mass index.[3,7] Of all of these variables, height is most commonly taken into account when determining the dose of drug to be used.[8] However, a recent study found no correlation between height and the spread of hyperbaric bupivacaine in term parturients undergoing cesarean section.[9] Any influence of height on the spread of subarachnoid hyperbaric local anesthetics would most likely occur through differences in the distance the local anesthetic diffuses from the site of injection to its site of action or in the dilution of drug by cerebrospinal fluid (CSF). Both of these effects should vary more directly with vertebral column length than with the overall height of the patient. Therefore, the purpose of this study was to evaluate the effect of vertebral column length on the spread of sensory blockade following subarachnoid hyperbaric bupivacaine in the term parturient. This study also reevaluates the effects of age, height, weight, and body mass index on the extent of sensory blockade.

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Methods

After receiving institutional review board approval, 52 term parturients consenting to spinal anesthesia for nonemergent (both elective and urgent) cesarean section were studied. Following ingestion of 30 ml 0.3 M sodium citrate and while receiving a rapid infusion of 2-l balanced electrolyte solution (Plasmalyte®), the women assumed the right lateral decubitus position on a horizontal operating table. An assistant, using a disposable measuring tape, measured the distance from the sacral hiatus to the C7 vertebral prominence. This value, along with patient's age, height, and weight, was recorded. Subsequently, the women received a subarachnoid injection of 2.3 ml solution containing 15 mg bupivacaine, 165 mg dextrose, and 0.15 mg morphine (2 ml 0.75% bupivacaine with 8.25% dextrose and 0.3 ml 0.5% morphine in sterile water, specific gravity 1.0199 g/ml) *via* a 25-G needle at the L2–3 or L3–4 interspace. The needle was inserted with its bevel oriented parallel to the dural fibers and then rotated 90° to direct the bevel cephalad. The solution was injected steadily over 10–15 s with terminal aspiration and reinjection of 0.2 ml. In laboring women the solution was injected between uterine contractions. The injections were performed by the investigator or by trainees under the direct supervision of the investigator. In all cases the angle between the spinal needle and the patient's back was estimated to be between 60° and 90°. The women were turned supine immediately after drug injection. Left uterine displacement was provided by a folded blanket placed under the right hip. No attempt was made to influence the level of sensory blockade by manipulating the operating table. Hypotension was treated with fluids and ephedrine, not by placing the patient in Trendelenburg's position. Fifteen minutes after induction of anesthesia (the time of maximum sensory blockade[9]), the investigator, blinded to the previously measured vertebral column length, determined the levels of sensory analgesia and anesthesia. Analgesia was determined by loss of sensation of sharpness to pin prick, and anesthesia was determined by loss of perception of light touch. Both were measured bilaterally in the midaxillary line, along the inner and outer aspect of the arm, on the side of the neck, and the back and top of the head. If the levels so obtained differed, the average value was used.

Linear regression analysis was used to search for any correlation between the spread of sensory blockade (analgesia and anesthesia) and the measured patient variables

TABLE 1. Demographic Characteristics

	Mean ± SD	Range
Age (yr)	31.1 ± 5.1	20–42
Height (cm)	162.4 ± 6.4	147.3–174.0 (4'10"–5'8.5")
Weight (kg)	77.0 ± 13.3	55.5–136.4
Body mass index (kg/m²)	29.2 ± 4.7	19.2–50.0
Vertebral column length (cm)	59.0 ± 4.3	49.6–67.0

[age, height, weight, body mass index (weight/height^2) and vertebral column length]. Power was estimated by determining the t value at $P < 0.05$ and the appropriate number of degrees of freedom and multiplying it by the standard error of the estimate as obtained from the regression equation. The resulting value is the minimum effect of a given variable that would have been detected in this study.

Results

Table 1 shows demographic data, and figure 1 shows the distribution of sensory analgesia and anesthesia. The regression equations are listed in table 2. Vertebral column length correlated weakly with patient height. Age, height, weight, body mass index, and vertebral column length (fig. 2) did not correlate significantly with the spread of sensory analgesia or anesthesia.

Discussion

The effect of patient variables on the extent of sensory blockade induced by subarachnoid injection of local anesthetics has received attention from many investigators. Cameron *et al.*[1] studied the effect of age on the spread of sensory blockade when using isobaric 0.5% bupivacaine. In 33 patients ranging from 37 to 97 yr of age, they found a statistically significant ($r = 0.5$, $P = 0.003$) correlation between increasing age and increasing level of sensory blockade.[1] Others, in patients ranging from 15 to 92 yr, have found weaker, but still statistically significant, correlations ($r = 0.227$–0.33) between age and sensory blockade with isobaric bupivacaine.[2,4] In each of these studies the extent of sensory blockade varied widely at all ages. In contrast, Touminen *et al.* found no influence of age on the distribution of sensory analgesia following subarachnoid injection of hyperbaric tetracaine in nonpregnant patients ranging from 15 to 80 yr of age.[10] In the data presented here, a weak, statistically insignificant trend toward increasing level of anesthesia but not analgesia with increasing age is discernible. The mechanism of any possible effect of age on the subarachnoid spread of isobaric local anesthetics is unclear,[1] but some suggest a pharmacokinetic or pharmacodynamic effect.[4] In the case of hyperbaric drugs, the effects of baricity may predominate over those of age.[10] Regardless of mechanism, any effect of age is small and probably of little significance in normal clinical circumstances,[5,7] especially within the narrow age range encountered in obstetrics.

Whereas some experts doubt that weight per se alters the spread of spinal anesthesia,[5] others have published data suggesting some effect. Two studies have found significant correlations between increasing weight and increasing spread of isobaric bupivacaine.[3,7] In both studies body mass index correlated more significantly with the cephalad extent of sensory blockade than did weight alone. Pitkanen administered 15 mg isobaric bupivacaine to 70 subjects and found the level of analgesia increased by one dermatome with each kg/m^2 increase in body mass

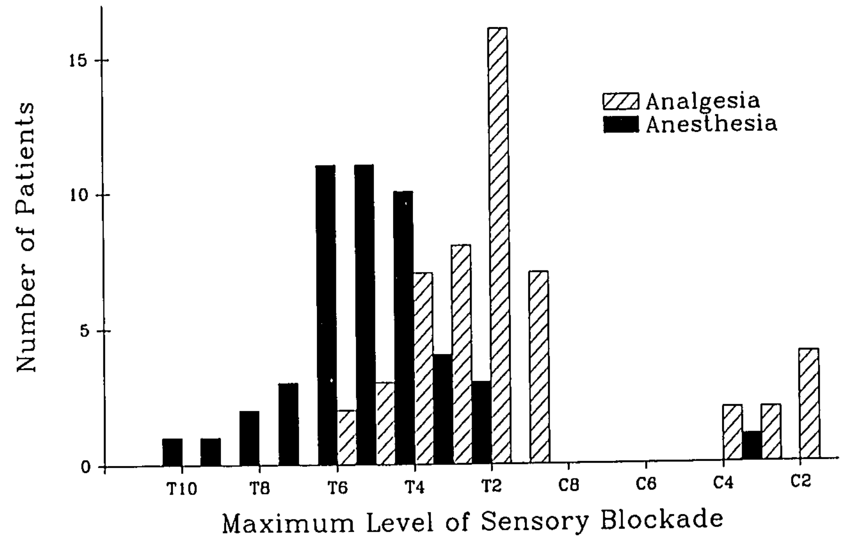

FIG. 1. Maximum cephalad extent of analgesia to pin prick and anesthesia to light touch in 52 term parturients following subarachnoid injection of 15 mg hyperbaric bupivacaine.

TABLE 2. Regression Analysis

Independent Variable	Dependent Variable	Slope + SE of Estimate	R^2	Minimum Detectable Effect*
Age	Analgesia	−0.019 ± 0.089 seg/yr	0.001	0.17 seg/yr
	Anesthesia	0.112 ± 0.061 seg/yr	0.07	0.12 seg/yr
Height	Analgesia	−0.062 ± 0.070 seg/m	0.016	0.14 seg/m
	Anesthesia	0.001 ± 0.052 seg/m	8×10^{-6}	0.11 seg/m
Weight	Analgesia	−0.012 ± 0.034 seg/kg	0.003	0.07 seg/kg
	Anesthesia	0.005 ± 0.026 seg/kg	8×10^{-4}	0.05 seg/kg
Body mass index	Analgesia	0.003 ± 0.096 seg/kg/m²	2×10^{-5}	0.19 seg/kg/m²
	Anesthesia	0.012 ± 0.073 seg/kg/m²	6×10^{-4}	0.15 seg/kg/m²
Vertebral column length	Analgesia	−0.056 ± 0.105 seg/cm	0.006	0.21 seg/cm
	Anesthesia	−0.088 ± 0.078 seg/cm	0.028	0.16 seg/cm
Height	Vertebral column length	0.218 ± 0.084 cm/m	0.106†	

* Power estimate (t at $P = 0.05 \times$ SE of estimate). † $P < 0.05$.

index ($y = -1.0142x + 34.601$, $r = 0.5253$).[7] McCulloch and Littlewood found a similar, highly significant ($P < 0.001$) correlation between spinal analgesia and body mass index.[3] These authors suggested that obesity causes vena caval obstruction with subsequent shunting of blood to the epidural veins, reducing the volume of CSF, and encouraging greater spread of local anesthetic solutions.[3] Studies using hyperbaric bupivacaine have found no correlation between weight or body mass index and the extent of local anesthetic blockade, suggesting that in this situation position and baricity are more important determinants of spread.[7,9,10] Similarly, the data presented here show no significant correlation between weight or body mass index and the cephalad spread of sensory blockade.

Unlike age, weight, and body mass index, height is claimed to have a significant effect on the spread of sensory blockade after subarachnoid injection of local anesthetics.[5] Greene argued that in taller patients, with their larger and longer spinal columns, local anesthetics would reach a lower dermatome level after traveling a similar distance than they would in shorter patients.[5] Similarly, the greater volume of CSF in the taller patient would dilute the injected local anesthetic, limiting the area of spinal cord exposed to adequate blocking concentrations of drug.[5] Clinical data on this subject conflict. One investigator claimed a significant correlation between height and the spread of sensory blockade when using hyperbaric bupivacaine or tetracaine.[6] However, no data are presented to support this conclusion. More recently, Pitkanen found a significant effect of height on the cephalad spread of sensory blockade in 70 patients undergoing orthopedic surgery who received isobaric 0.5% bupivacaine ($r = -0.35$) and in 20 patients receiving hyperbaric 0.5% bupivacaine ($r = -0.48$).[7] In contrast, Brown *et al.* noted that men and women receiving hyperbaric tetracaine developed similar levels of sensory blockade (T8–9) despite the greater height of the men (173 *vs.* 160 cm).[11] In this author's previous study,[9] as in the current study, no cor-

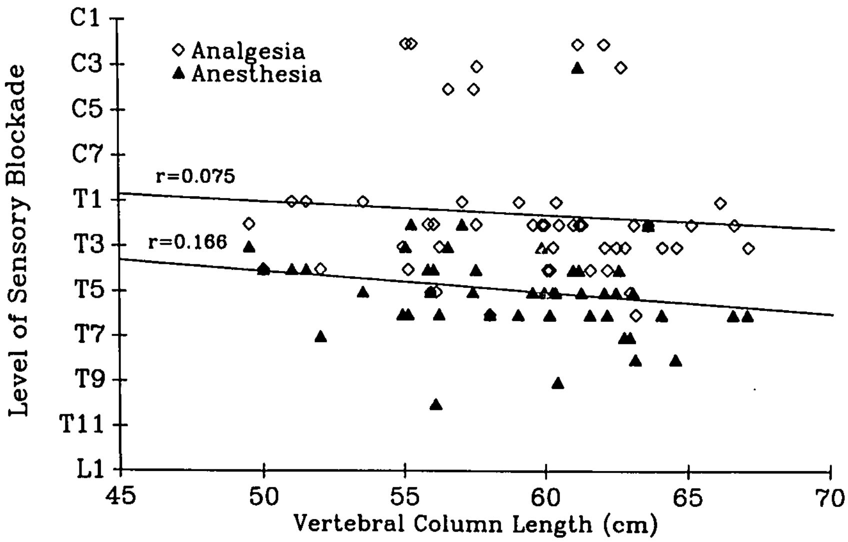

FIG. 2. Vertebral column length *versus* cephalad spread of analgesia to pin prick and anesthesia to light touch in 52 term parturients receiving a subarachnoid injection of 15 mg hyperbaric bupivacaine for cesarean section.

relation exists between height and the spread of sensory anesthesia or analgesia in term parturients between 147 and 174 cm tall receiving 12–15 mg hyperbaric bupivacaine.

Greene's argument suggests that vertebral column length—not height—may be the more appropriate variable to correlate with sensory blockade. Although a statistically significant correlation exists between height and vertebral column length, height accounts for only 10.6% of the variation in vertebral column length. Thus, one might predict that vertebral column length could be a better predictor of the spread of sensory blockade. However, in this study of women receiving spinal anesthesia for cesarean section, vertebral column length had no effect on the cephalad spread of sensory blockade. Recently, Hartwell *et al.* reported finding a weak ($r = 0.38$) but statistically significant ($P = 0.006$) correlation between vertebral column length and the spread of sensory blockade.[12] However, in that study the data gathering investigator was not blinded to the subject's vertebral length (unlike this study); in addition, those investigators manipulated the operating table in an attempt to maintain the vertebral column, not the operating table horizontal. Both of these methodologic differences may have contributed to the differences in our results. Interestingly, as in this study, Hartwell *et al.*[12] found no correlation between height, weight, or body mass index and the level of sensory blockade.

Other work, including laboratory studies, suggests that the interaction between gravity and baricity is the primarily determinant of the spread of hyperbaric solutions in the CSF. *In vitro* models using glass tubes and methyl violet dye,[13] and more recently consisting of tygon tubing, CSF equivalent, and hyperbaric lidocaine,[14] have demonstrated that gravity and baricity determine the spread of hyperbaric local anesthetic solutions in the CSF. *In vivo* studies in animals[15] and humans[11,16] have also demonstrated the role of baricity in determining the spread of subarachnoid local anesthetics. When the patient is in the supine position, the thoracolumbar vertebral column slopes 8–12° in the cephalad direction,[17] and hyperbaric solutions pool in the lowest part of the thoracic spine (T5–6).[18]

Power analysis of these results (table 2) suggests that this study should have detected even small effects of the variables measured on the spread of sensory blockade. It could have detected an effect as small as 4 segments (seg) over the 22-yr age span studied, 0.4 seg over the 27-cm height range studied, and 4 seg over the 17.4-cm range of vertebral column lengths studied. Any effect of these variables on the spread of sensory blockade is thus so small to be of minimal clinical significance. And, as can be seen from the r^2 values, these effects account for little of the variation seen in the spread of hyperbaric local anesthetic induced sensory blockade.

The results of this study can be applied directly only to the drugs used and to parturients in the age, height, weight, body mass index, and vertebral column length ranges studied. This study was performed using hyperbaric bupivacaine. Studies carried out in nonpregnant patients have documented that hyperbaric solutions of bupivacaine and tetracaine behave similarly.[19] In addition, in the study by Brown *et al.*,[11] height had no effect on the level of sensory blockade after tetracaine. Thus, we speculate that the results reported here can also be applied to hyperbaric tetracaine solutions and probably to all hyperbaric local anesthetic solutions. Although the morphine added to the local anesthetic solution slightly increased its volume (from 2.0 to 2.3 ml) and decreased its specific gravity (from 1.0245 to 1.0199), these small changes should not affect the ultimate extent of sensory blockade.[11,16,20,21] The range of demographic variables in these patients is narrow but encompasses the majority of obstetric patients. Possibly at some point below 147 cm (4′10″) and above 174 cm (5′8.5″) patients would develop too high or too low a level of sensory analgesia, but within the commonly encountered range of patient size, neither height nor vertebral column length significantly influences the extent of local anesthetic-induced sensory blockade.

References

1. Cameron AE, Arnold RW, Ghoris MW, Jamieson V: Spinal analgesia using bupivacaine 0.5% plain, variation in the extent of the block with patient age. Anaesthesia 36:318–345, 1981
2. Pitkanen M, Haapaniemi L, Tuominen M, Rosenberg PH: Influence of age on spinal anaesthesia with isobaric 0.5% bupivacaine. Br J Anaesth 56:279–284, 1984
3. McCulloch WJD, Littlewood DG: Influence of obesity on spinal analgesia with isobaric 0.5% bupivaciane: Br J Anaesth 58:610–614, 1986
4. Veering BT, Burm AGL, van Kleef JW, Hennis PJ, Spierdijk J: Spinal anesthesia with glucose-free bupivacaine: Effects of age on neural blockade and pharmacokinetics. Anesth Analg 66: 965–970, 1987
5. Greene NM: Distribution of local anesthetic solutions within the subarachnoid space. Anesth Analg 64:715–730, 1985
6. Moore DC: Factors influencing spinal anesthesia. Reg Anesth 7: 20–25, 1982
7. Pitkanen MT: Body mass and spread of spinal anesthesia with bupivacaine. Anesth Analg 66:127–131, 1987
8. Shnider SM, Levinson G: Anesthesia for cesarean section, Anesthesia for Obstetrics. Edited by Shnider SM, Levinson G. Baltimore, Williams & Wilkins, 1987, p 163
9. Norris MC: Height, weight and the spread of hyperbaric bupivacaine in the term parturient. Anesth Analg 67:555–558, 1988
10. Touminen M, Pitkanen M, Doepel M, Rosenberg PH: Spinal anaesthesia with hyperbaric tetracaine: Effect of age and body mass. Acta Anaesthesiol Scand 31:474–478, 1987
11. Brown DT, Wildsmith JAW, Covino BG, Scott DB: Effect of bar-

icity on spinal anaesthesia with amethocaine. Br J Anaesth 52: 589–595, 1980
12. Hartwell BL, Hauch MA, Aglio LS, Datta S, Ostheimer GW: Vertebral column length and the spread of hyperbaric subarachnoid bupivacaine in the term parturient (abstract). Seattle, Society of Obstetrical Anesthesia and Perinatology, 1989
13. Barker AE: A report on clinical experiences with spinal analgesia in 100 cases, and some reflections on the procedure. Br Med J 1:655–674, 1907
14. Lui ACP, Munhall RJ, Winnie AP, Selander D: Baricity and the distribution of local anesthetics in a spinal canal model (abstract). Reg Anesth 14(Suppl):81, 1989
15. Denson DD, Bridenbaugh PO, Turner PA, Phero JC: Comparison of neural blockade and pharmacokinetics after subarachnoid lidocaine in the rhesus monkey: Effects of volume, osmolality, and baricity. Anesth Analg 62:995–1001, 1983
16. Chambers WA, Edstrom HH, Scott DB: Effect of baricity on spinal anaesthesia with bupivacaine. Br J Anaesth 53:279–282, 1981
17. Smith TC: The lumbar spine and subarachnoid block. ANESTHESIOLOGY 29:60–64, 1968
18. Kitahara T, Kuri S, Yoshida J: The spread of drugs used for spinal anesthesia. ANESTHESIOLOGY 17:205–208, 1956
19. Skretting P, Vaagenes P, Sundnes KO, Edstrom HH, Lind B: Subarachnoid anaesthesia: Comparison of hyperbaric solutions of bupivacaine and amethocaine. Br J Anaesth 56:155–159, 1984
20. Moller IW, Fernandes A, Edstrom HH: Subarachnoid anaesthesia with 0.5% bupivacaine: Effects of density. Br J Anaesth 56: 1191–1195, 1984
21. Sheskey MC, Rocco AG, Bizzarri-Schmid M, Francis DM, Edstrom H, Covino BG: A dose–response study of bupivacaine for spinal anesthesia. Anesth Analg 62:931–935, 1983