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Estimation of spread of lumbar or lower thoracic epidural anesthesia by a simple equation

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Although the spread of epidural anesthesia has commonly been estimated by using an injected volume of local anesthetic per dermatome anesthetized [1–3], it has been found clinically that an increase in the injected volume does not result in a linear increase in the spread [4,5]. This finding suggests that there is a more complex relationship between these variables. Recently, we have suggested that the relationship can be defined by a cubic polynomial equation ($y = 3.021\,x - 0.274\,x^2 + 0.009673\,x^3$, where x is the injected volume of 2% mepivacaine (ml) and y is the number of sensory anesthetized dermatomes at 15 min) when the epidural catheter is inserted via the L1–2 interspace [6]. The adjustment R^2, coefficient P value, and analysis of variance P value in this regression were 0.937, 0.0435, and <0.0001, respectively. From the appearance of the scattergram reported in this article [6], another nonlinear regression, such as square or cubic root regression, also seemed to be suitable. By analyzing the same data, we could obtain statistical values of 0.941, <0.0001, and <0.0001 by using the square root of injected volume. This square root equation, $y = 4.005\,x^{1/2}$, which can be simplified as $y = 4x^{1/2}$, resulted in a higher adjustment R^2 than the cubic polynomial equation. If this simplified equation ($y = 4x^{1/2}$) is able to predict the spread as well as the cubic polynomial equation, it would be easier to use because of its simplicity and memorability. In this report, we evaluated whether this equation could be used to predict the actual spread of epidural anesthesia, using different clinical and consecutive data.

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After approval of the Institutional Review Committee, adult surgical patients less than 65 years old classified as ASA physical status I or II, who received combined epidural block and general anesthesia for lower abdominal gynecological or gastrointestinal surgery, were enrolled in this study. All patients gave informed consent. With the patient in the lateral position, an 18-gauge Tuohy needle was inserted in a paramedian approach via the L1–2 interspace for gynecological surgery or via the lower thoracic interspace (T8–12) for gastrointestinal surgery using the loss-of-resistance technique with less than 2 ml of air. A multiorificed epidural catheter (Perifix, B-Braun, Tokyo, Japan) was placed 7 cm cephalad into the epidural space, and the patient was placed in the supine position without injection of a test dose. Cephalad placement at 7 cm is our routine procedure to prevent catheter migration from the epidural space [7]. The injected volume of 2% mepivacaine was determined by the attending anesthesiologist, and the injection rate was fixed at 12 ml·min^{-1}. Fifteen minutes after the injection, another anesthesiologist, blinded to the treatment, tested the extent of hypesthesia above the S2 dermatome with an alcohol swab. Thereafter, general anesthesia was induced.

The Mann-Whitney U test was used to test whether the measured number of sensory anesthetized dermatomes differed from the estimated number calculated by the cubic polynomial or the square root equation. Linear regression analyses with zero intercept model ($x = 0$, $y = 0$) between the measured and estimated numbers were performed. $P < 0.05$ was considered significant. The numbers of dermatomes were expressed as medians (range), and other data as means ± SD (range).

One hundred sixty-nine female patients undergoing gynecological surgery were studied. Their mean age, height, and weight were 43 ± 9 (21–64) years, 156 ± 5 (140–166) cm, and 56 ± 9 (33–82) kg, respectively. The

Table 1. Statistical values of the data from patients undergoing gynecological surgery

Statistic	Cubic polynomial equation	Square root equation
Mann-Whitney U test *P*	0.2758	0.2497
Linear regression		
r (correlation coefficient)	0.978	0.977
Adjustment R^2	0.956	0.954
P (coefficient)	<0.0001	<0.0001
P (analysis of variance)	<0.0001	<0.0001

Table 2. Statistical values of the data from patients undergoing gastrointestinal surgery

Statistic	Cubic polynomial equation	Square root equation
Mann-Whitney U test *P*	0.0259	0.1578
Linear regression		
r (correlation coefficient)	0.986	0.985
Adjustment R^2	0.971	0.969
P (coefficient)	<0.0001	<0.0001
P (analysis of variance)	<0.0001	<0.0001

injected volume of 2% mepivacaine was 9.5 ± 1.1 (6–12) ml. The measured number of sensory anesthetized dermatomes and the estimated numbers calculated by the cubic polynomial and square root equations were 12 (4–17), 12 (10–14), and 12 (10–14), respectively. There were no statistically significant differences between the measured and estimated numbers by both equations. Linear regression showed almost the same correlation coefficient and high adjustment R^2 values in both equations, which were statistically significant (Table 1).

Thirty-three male and 16 female patients undergoing gastrointestinal surgery were studied. Their mean age, height, and weight were 46 ± 16 (18–64) years, 159 ± 8 (145–178) cm, and 57 ± 11 (37–87) kg, respectively. The injected volume of 2% mepivacaine was 8.3 ± 1.7 (5–12) ml. The measured number of sensory anesthetized dermatomes and the estimated numbers calculated by the cubic polynomial and square root equations were 11 (7–16), 11 (9–14), and 11 (9–14), respectively. There was a significant difference between the measured and estimated numbers in the cubic polynomial equation, but no difference in the square root equation. Linear regression showed almost the same correlation coefficient and high adjustment R^2 values in both equations, which were statistically significant (Table 2).

Our study showed that the estimated number of sensory anesthetized dermatomes calculated by either equation predicts the extent of lumbar epidural anesthesia. In lower thoracic epidural anesthesia, the extent of anesthesia could be predicted by the square root equation, but not by the cubic polynomial equation. These results suggest that the square root equation is useful for both lumbar and lower thoracic epidural anesthesia. Regarding the clinical application of the square root equation, we should be aware of some restrictions. Because the equation was derived from data from Japanese women [6], its application should be restricted to relatively small patients. Mepivacaine or lidocaine is poorly lipid soluble, whereas bupivacaine is lipid soluble, so that the equation would not apply to bupivacaine. Because the concentration of mepivacaine affects the spread [8], the equation should be applied when 2% is used. Because the patient's age also affects the spread [1,2,9], the equation may not be used in older patients.

From the present study, we conclude that $y = 4x^{1/2}$, where x is the injected volume of 2% mepivacaine (ml) and y is the estimated number of sensory anesthetized dermatomes at 15 min, is clinically useful in the prediction of the spread of lumbar or lower thoracic epidural anesthesia. We believe that this estimate would be more useful than the traditional estimate [1–3].

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