Regional Anesthesia and Pain

Hypobaric spinal anesthesia with 0.2% tetracaine for total joint hip arthroplasty

[La rachianesthésie hypobare avec de la tétracaïne à 0,2 % pour l'arthroplastie totale de hanche]

Jie Ae Kim MD PhD, Hyun Joo Ahn MD

Purpose: Hypobaric local anesthetics for total hip replacement (THR) have potential advantages related to body position and differential block. However, the dose requirements of hypobaric local anesthetics for THR have not been clearly established. Therefore, we undertook a dose-response study of hypobaric tetracaine for THR.

Methods: In a randomized, controlled, and double-blinded manner, three groups of 20 patients each undergoing THR received spinal anesthesia using either 10, 12, or 14 mg of 0.2% hypobaric tetracaine in a lateral decubitus position, with the operated side up. Adequate anesthesia was defined as: 1) upper sensory block between T10 and T4; 2) motor block of modified Bromage scale 2 or 3; and 3) time to sensory remission to the L2 level of more than three hours.

Results: The number of patients who achieved adequate sensory and motor block levels was similar amongst the three groups. However, all patients who received 14 mg had a sensory remission time to L2 of more than three hours while only 30% of the patients in the 12 mg group and no patient in the 10 mg group had the same remission time. A significant differential block was observed between the non-dependent and the dependent sides, but the degree of differential block was not different between the groups.

Conclusion: 10 to 14 mg of 0.2% hypobaric tetracaine achieved similar and adequate block levels, but different regression times. To ensure complete sensory block duration for THR, we recommend using 14 mg of 0.2% hypobaric tetracaine.

Objectif: Les anesthésiques locaux hypobares, utilisés pour l'arthroplastie totale de hanche (ATH), présentent des avantages potentiels quant à la position du corps et au bloc différentiel. Cependant, la dose nécessaire pour l'ATH n'a pas encore été établie. Nous avons donc entrepris une étude dose-réponse de la tétracaïne hypobare pour l'ATH.

Méthode : Des patients devant subir une ATH et répartis en trois groupes de 20, de façon aléatoire, contrôlée et à double insu ont reçu une rachianesthésie avec 10, 12 ou 14 mg de tétracaïne hypobare à 0,2 % en position de décubitus latéral, côté opéré vers le haut. L'anesthésie adéquate a été définie comme : 1) un bloc sensitif supérieur entre T10 et T4 ; 2) un bloc moteur de niveau 2 ou 3 à l'échelle de Bromage modifiée et 3) un temps de régression du bloc sensitif de plus de trois heures au niveau L2.

Résultats : Le nombre de blocs sensitifs et moteurs adéquats a été similaire dans les trois groupes. Toutefois, les patients qui ont reçu 14 mg ont connu un temps de régression du bloc sensitif à L2 de plus de trois heures comparativement à 30 % des patients du groupe 12 mg et à aucun du groupe 10 mg. Un bloc différentiel significatif a été observé entre les côtés déclives et non déclives, mais le degré de bloc différentiel n'a pas présenté de différence intergroupe.

Conclusion : Des doses de 10 à 14 mg de tétracaïne hypobare à 0,2 % permettent de réaliser des niveaux de bloc adéquats similaires, mais dont les temps de régression diffèrent. Des doses de 14 assurent une durée adéquate de bloc sensitif complet pour l'ATH.

From the Department of Anesthesiology and Pain Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea.

Address correspondence to: Dr. Hyun Joo Ahn, Department of Anesthesiology and Pain Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, 135-710, 50 Ilwon-dong, Kangnam-ku, Seoul, Korea. Phone: 82-2-3410-0784; Fax: 82-2-3410-0361; E-mail: hjahn@smc.samsung.co.kr

Accepted for publication March 15, 2005.

Revision accepted May 25, 2005.

TOTAL hip replacement surgery (THR) is generally performed in the lateral decubitus position with the operated side up. Using hypobaric local anesthetics for THR, preparation time may be reduced by performing spinal anesthesia and surgery in the same position, without waiting for establishment of anesthesia in the supine position. Furthermore, hypobaric local anesthetics can produce a more selective block on the operated side and avoid unnecessary paralysis of the non-operated side, potentially resulting in more hemodynamic stability and better mobilization of patients during the recovery period.¹ In spite of these potential benefits, only three studies²⁻⁴ have examined single-dose spinal anesthesia using hypobaric solutions for THR in the lateral decubitus position, and none of these studies compared different doses of hypobaric solutions. Because the patient assumes a lateral decubitus position during a THR, in case of inadequate anesthesia or a high spinal that may necessitate conversion to general anesthesia, mask ventilation and intubation can be troublesome. Therefore, we undertook a study to determine the anesthetic profiles and dose-response of hypobaric tetracaine 10 mg, 12 mg, or 14 mg, commonly used dosages in our hospital, as a single-shot spinal anesthetic for THR.

Methods

With approval from the Institutional Research Board and written informed consent, 60 ASA class I or II patients undergoing THR were included in this prospective, double-blind study. Patients were randomly allocated using a sealed envelope technique into a 10 mg, 12 mg, or 14 mg group, each consisting of 20 patients. Excluded were patients with contraindications for regional anesthesia, including those with kyphoscoliosis, previous spinal surgery, back pain, neurologic abnormalities of the leg and re-operation of the same hip.

Preoperative medication was not given. Soon after the arrival of the patient in the operating theatre, 500 mL of lactated Ringer's (L/R) solution was rapidly infused over ten minutes before the induction of spinal anesthesia. Thereafter, L/R solution was administered according to blood pressure changes. Patients were monitored with an automatic blood pressure cuff at three-minute intervals, III-lead electrocardiography, and pulse oximetry. Patients were placed in the lateral decubitus position with the operated side up. Lumbar puncture was performed at the L2–3 or L3–4 interspace using a midline approach with a 25G Whitacre needle (Becton-Dickson, San Jose, CA, USA) with the orifice facing upward. After confirming free flow of

cerebrospinal fluid (CSF) and no abnormal sensation, local anesthetic was injected slowly. While maintaining the same lateral position, the patients' leg was sterilized and draped, surgery began once the block was established.

Ten millilitres of sterile water were added to 20 mg of tetracaine HCL (Pantocainsterile®, Daehan Med Co, Seoul, Korea, in niphanoic crystals) to make a 0.2% hypobaric solution. Five millilitres, 6 mL, or 7 mL of this solution was administered to give 10 mg, 12 mg, or 14 mg respectively, according to group allocation. The baricity of 0.2% hypobaric tetracaine is 0.9922 at 37°C.

More than a 20% reduction of mean arterial pressure from the patient's baseline value was regarded as hypotension, and treated by fluid infusion and ephedrine. Ephedrine 5 mg *iv* was administered at three-minute intervals until the target blood pressure was attained, and the total injected dosage was recorded.

Another anesthesiologist who was not involved with the procedure measured sensory and motor block levels at five-minute intervals for 30 min. Sensory block was determined by a pinprick in the anterior axillary line using a 25G needle. Motor block was evaluated using a modified Bromage scale (0 = no motor block; 1 = hip blocked, 2 = hip and knee blocked; 3 = hip, knee and ankle blocked). We observed block status for the first 30 min in the operating room in order not to disturb the operation. After 30 min of observation, fentanyl 50 µg *iv* and midazolam 1 mg *iv* were administered as required, to ameliorate any patient discomfort during prolonged lateral decubitus positioning and to ensure adequate sedation. The sensory remission time to L2, and the complete motor recovery time were measured in the postanesthetic care unit by a trained research nurse, at 15-min intervals.

We defined adequate anesthesia for a THR as: 1) upper sensory block between T10 and T4; 2) motor block of modified Bromage scale 2 or 3; and 3) the

TABLE I Patient characteristics and intraoperative course

	10 mg	12 mg	14 mg
Age (yr)	49.2 ± 16.1	51.3 ± 14.6	52.1 ± 13.1
Height (cm)	161.3 ± 11.4	160.7 ± 10.2	159.9 ± 9.2
Weight (kg)	63.0 ± 11.4	63.1 ± 12.6	59.4 ± 7.7
Male/female	11/9	10/10	13/7
Crystalloid (mL)	2600 ± 250	2450 ± 280	2500 ± 260
Blood loss (mL)	430 ± 193	450 ± 230	400 ± 234
Preparation time (min)	18.3 ± 3.2	19.1 ± 4.1	18.5 ± 2.7
Operation time (min)	76.3 ± 21.2	75.5 ± 19.7	72.2 ± 26.1

Values are mean ± SD. There were no differences among the three groups. Preparation time is the time from the end of spinal anesthesia to the beginning of the operation.

TABLE II Sensory and motor block

Group	10 mg		12 mg		14 mg	
	OP	Non-OP	OP	Non-OP	OP	Non-OP
Time to T10 (min)	6.8 ± 3.4	6.6 ± 4.7	6.8 ± 4.2			
Time to maximal level (min)	14.4 ± 2.0	13.7 ± 1.6	14.1 ± 1.1			
Maximum sensory level	T8 (T11-T4)	T9 (L5-T4)*	T7 (L1-T5)	T10 (L5-T6)*	T8 (T11-T4)	T9 (L2-T6)*
Time to BS 2 (min)	5.6 ± 2.5	6.4 ± 2.8	5.0 ± 2.4			
Time to BS 3 (min)	7.4 ± 3.4	8.0 ± 2.9	6.5 ± 3.2			
BS	3 (3-3)	2 (0-3)*	3 (3-3)	1(0-3)*	3 (3-3)	2 (0-3)*

Values are mean ± SD or median (range). OP = non-dependent leg; Non-OP = dependent leg; BS = modified Bromage scale. * $P < 0.05$ compared to OP leg.

sensory remission time to L2 of longer than three hours.

Power analysis

We regarded the proportion of patients who showed adequate anesthesia as a primary outcome variable, and set the significant difference of the proportion of patients between the groups at 40% with a standard deviation of 20%. A sample size of 20 in each group was required to achieve 80% power with an alpha error of 0.05.

Statistics

A Chi-square test or Fisher's exact test was used to compare the number of patients who showed adequate anesthesia or side effects. One-way analysis of variance (ANOVA) was used to compare the degree and duration of sensory and motor blocks between groups, and a Tukey test was applied for post hoc analysis. Comparison between the non-dependent and the dependent leg of the same patient was done by either a paired *t* test or the Wilcoxon signed ranks test according to the normality of data. $P < 0.05$ was considered significant.

Results

The groups were similar with respect to age, height, weight and sex ratio. Operating time, estimated blood loss and fluid administration were comparable amongst the three groups. No patient was transfused for bleeding. Mean preparation time (from the end of spinal anesthesia to the beginning of operation) was 18.6 ± 3.3 min (Table I).

There was no technical failure related to spinal anesthesia and surgery proceeded without difficulty in all cases. Sensory and motor block variables of the non-dependent side were similar amongst the

three groups. The maximum levels of sensory and motor block of the dependent side were also similar (Table II). There were significant differential blocks between the non-dependent and the dependent sides. However, the extent of differential blocks were not different between groups (Table II).

Sensory remission times to L2 for the non-dependent side were longer in the 12 mg and 14 mg groups compared to the 10 mg group (Figure).

The duration of motor block paralleled the dose of hypobaric tetracaine, with the longest motor block occurring in the 14 mg group (Figure). The complete motor recovery times of the dependent leg were not different, and were 93 ± 64 min, 113 ± 44 min, 100 ± 52 min in the 10 mg, 12 mg, and 14 mg groups, respectively.

A similar number of patients in the three groups reached adequate anesthesia (Table III). Only one patient from each group did not reach a T10 sensory level and the levels were T11, L1, and T11 in the 10 mg, 12 mg and 14 mg groups, respectively. All patients of the 10 mg group showed the sensory regression time to L2 shorter than three hours (Table III).

The frequency of hypotensive episodes and ephedrine requirements were similar in the three groups (Table IV). The highest sensory level attained amongst the groups was T4. Two, zero, and one patient reached a T4 sensory level in the 10 mg, 12 mg and 14 mg groups, respectively.

Only one patient in the 12 mg group required additional analgesia, and fentanyl $100 \mu\text{g}$ *iv* was administered. Except for this case, all surgeries were completed without further anesthetic supplementation. No other patient complained about pain or discomfort.

FIGURE Duration of sensory and motor blockade (mean $\pm$ SD). The duration increased with dosage. * $P < 0.05$ compared to the 10 mg group. † $P < 0.05$ compared to the 12 mg group.

Discussion

In this study, we evaluated the dose-response of 0.2% hypobaric tetracaine in the lateral position. 0.2% hypobaric tetracaine in the range of 10 to 14 mg reached the same anesthetic level. However, to ensure enough time for THR, 14 mg of 0.2% hypobaric tetracaine was desirable.

Hypobaric local anesthetics compared to other baricities have advantages in the positioning of the patient and differential block for THR. The baricity of 0.2% hypobaric tetracaine is 0.9922 at 37°C.⁵ The hypobaric solution can be obtained by mixing local anesthetics with water, and baricity lower than 0.9990 is considered to be hypobaric.⁶ Solutions of 0.1% to 0.33% tetracaine in water are reliably hypobaric in all patients,⁷ and because of its high anesthetic potency and lipid solubility, even 0.1% to 0.33% solutions of tetracaine can provide good sensory anesthesia and motor relaxation.⁷

For THR, a sensory block greater than T10 and modified Bromage scale 2 or 3 motor block^{6,8} are required.⁴ Side effects including hypotension and high spinal block should be minimal. We chose 10 mg, 12 mg, and 14 mg of tetracaine, because less than 10 mg or more than 14 mg produced inadequate or high anesthetic levels in other studies.^{3,4,8} Hypobaric tetracaine 7.5 mg did not reach T10 sensory block or modified Bromage scale 2 motor block in more than 33% of patients,⁸ and 15 mg of hypobaric bupivacaine³ and 17.5 mg of hypobaric tetracaine⁴ reached a maximal sensory level of T2 (range: T4–C8) and T4

TABLE III Onset and duration of anesthesia by patient response

Group	10 mg (n = 20)	12 mg (n = 20)	14 mg (n = 20)
T10 and BS 2,3 at 10 min	15	14	15
T10 and BS 2,3 at 30 min	19	19	19
2 hr	10	18*	20*
3 hr	0	6*	20*†

The number of patients in each group who achieved a T10 sensory level and modified Bromage Scale (BS) at ten minutes and 30 min is shown. Values at 2 hr and 3 hr are number of patients who showed longer than two hours and three hours of sensory regression time to L2. * $P = 0.01$ compared to 10 mg. † $P < 0.001$ compared to 12 mg.

TABLE IV Hypotensive episodes and ephedrine requirements

Group	10 mg (n = 20)	12 mg (n = 20)	14 mg (n = 20)
Hypotension (n)	9	10	12
Ephedrine (mg)	7.8 $\pm$ 7.9	6.0 $\pm$ 7.9	8.0 $\pm$ 9.5

Values are number of patients or mean $\pm$ SD. There were no differences amongst the three groups.

(range: T2–T10), respectively. With due concern for either inadequate anesthesia or a high spinal, we chose not to administer beyond this dosage range.

In our study, we expected a dose-dependent increase of the block level. However, the maximal sensory block level was T7–T8 (range: L1–T4) and the median motor block was similar (modified Bromage scale 3) in all dosage groups (Table II). As a possible explanation, we can consider a widely different lumbosacral CSF volume (20–60 mL) in each individual. A correlation exists between the CSF volume and block level, but CSF volume cannot be predicted by body weight, height, body mass index, and age. The reason for unpredictable spinal anesthetic levels observed in everyday practice is related primarily to variable CSF volumes.⁹ Considering this fact, it might be predicted that the dosage difference over a range of 10 mg to 14 mg may not produce significant differences in the level of block. Very small or large doses of local anesthetics may, however, result in apparent differences in anesthetic levels.^{3,4,8}

We used hypobaric tetracaine to induce differential block and faster mobilization of the dependent leg. In this study, we produced a differential block between the non-dependent and the dependent legs (Table II). In contrast, most other studies that used hypo-

baric local anesthetics in the lateral decubitus position reported no differential block.^{2-4,8} Only Van Gessel *et al.*⁸ reported differential in motor, but not sensory block, and Atchison *et al.*² showed that a slow injection rate of 0.02 mL·sec⁻¹ also resulted in a differential block. To explain these ostensibly contradictory results, we can consider a phenomenon that different baricities eventually become isobaric in the CSF. The lateral decubitus position induces a non-dependent side distribution of hypobaric solution. The upper nerve roots are blocked first. However, a relatively large amount of local anesthetic remains in the CSF before being removed by blood stream, and gradually mixes with CSF to block lower nerve roots also. Therefore, the anesthetic level tends to equilibrate bilaterally over time.⁶ The studies showing differential block, including ours, recorded the block levels for only the first 30 min. A prolonged observation resulted in the same sensory levels between legs even at the slow injection rate of 0.02 mL·sec⁻¹.³ However, the duration and density of the block could be much less in the dependent leg than in the non-dependent leg.⁴ In our study, complete motor recovery time of the dependent leg (93–113 min) was much faster than that of the non-dependent leg (284–346 min).

Forty five to 60% of patients developed hypotension without a difference between groups in the present study. Other studies also reported a 33 to 70% incidence of hypotension.^{2-4,8} Our study showed a relatively low sensory block level (T7–T8), and no cases of high spinal. Therefore, although the incidence of hypotension was relatively high because of the application of the strict criteria of hypotension, hypotension was not severe. Less than 8 mg of ephedrine were administered in all three groups, and the hemodynamic state was relatively stable for all patients.

In conclusion, 0.2% hypobaric tetracaine in the range of 10 to 14 mg achieved the same anesthetic level with similar sensory, motor, and differential block, and showed the same incidence of hypotension. But the sensory regression time to L2 was shorter in the 10 mg and 12 mg groups. To ensure sufficient time for THR, 14 mg of 0.2% hypobaric tetracaine is recommended.

References

- 1 Dietmar E. Unilateral spinal anaesthesia: gadget or tool? *Curr Opin Anaesthesiol* 1998; 11: 511–5.
- 2 Atchison SR, Wedel DJ, Wilson PR. Effect of injection rate on level and duration of hypobaric spinal anesthesia. *Anesth Analg* 1989; 69: 496–500.
- 3 Horlocker TT, Wedel DJ, Wilson PR. Effect of injection rate on sensory level and duration of hypobaric bupivacaine spinal anesthesia for total hip arthroplasty. *Anesth Analg* 1994; 79: 773–7.
- 4 Faust A, Fournier R, Van Gessel E, Weber A, Hoffmeyer P, Gamulin Z. Isobaric versus hypobaric spinal bupivacaine for total hip arthroplasty in the lateral position. *Anesth Analg* 2003; 97: 589–94.
- 5 Horlocker TT, Wedel DJ. Density, specific gravity, and baricity of spinal anesthetic solutions at body temperature. *Anesth Analg* 1993; 76: 1015–8.
- 6 Bernardis CM. Epidural and spinal anesthesia. In: Barash PG, Cullen BF, Stoelting RK (Eds). *Clinical Anesthesia*, 4th ed. Philadelphia: Lippincott Williams & Wilkins Inc.; 2001: 697–701.
- 7 Bridenbaugh PO, Greene NM, Brull SJ. Spinal (subarachnoid) neural blockade. In: Cousins MJ, Bridenbaugh PO (Eds). *Neural Blockade in Clinical Anesthesia and Management of Pain*, 3rd ed. New York: Lippincott-Raven Inc.; 1998: 213–21.
- 8 Van Gessel EF, Forster A, Gamulin Z. Surgical repair of hip fractures using continuous spinal anesthesia: comparison of hypobaric solutions of tetracaine and bupivacaine. *Anesth Analg* 1989; 68: 276–81.
- 9 Higuchi H, Hirata J, Adachi Y, Kazama T. Influence of lumbosacral cerebrospinal fluid density, velocity, and volume on extent and duration of plain bupivacaine spinal anesthesia. *Anesthesiology* 2004; 100: 106–14.