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Comparison of hemodynamic and anesthetic effects of hyperbaric bupivacaine and tetracaine in spinal anesthesia

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Abstract
Purpose. To compare the anesthetic and hemodynamic effects and the predictive factor of anesthesia level of commonly used preparations of hyperbaric bupivacaine and tetracaine in spinal anesthesia.
Methods. Two hundred patients aged 40 to 75 years with ASA physical status I or II were anesthetized spinally via the L4–5 interspace using 0.5% hyperbaric bupivacaine in 7.27% glucose (Bupivacaine group, $n = 100$) or 0.5% hyperbaric tetracaine dissolved in a 10% glucose solution (Tetracaine group, $n = 100$) in a lateral position. The volume of anesthetic used was decided by the resident according to the surgical procedure. Patients were returned to the supine position immediately after drug injection. Blood pressure, heart rate, and anesthesia level tested by cold sensation were measured for 30 min.
Results. Blood pressure and heart rate decreased significantly but without any differences between the groups. The volume of drug used was significantly larger in the Bupivacaine group (2.6 ± 0.5 ml) than in the Tetracaine group (2.1 ± 0.4 ml) to obtain the same maximum anesthesia level. The time to reach the maximum anesthesia level was significantly longer in the Bupivacaine group (18 ± 7 min) than in the Tetracaine group (15 ± 6 min). The volume of the drug was the only predictive factor of the maximum anesthesia level in both groups: Level (as expressed by the number of anesthetized segments from S5 to cephalad) = $1.55 \times$ (volume in ml) + 13.06 in the Bupivacaine group, and $2.59 \times$ (volume) + 11.46 in the Tetracaine group.
Conclusion. In spinal anesthesia, hyperbaric tetracaine in 10% glucose induced a faster and higher spread of anesthesia than hyperbaric bupivacaine in 7.27% glucose without any differences in hemodynamics.

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Introduction

Tetracaine, dibucaine, and lidocaine are used in spinal anesthesia in Japan. However, owing to its neurotoxicity, dibucaine is not used in other countries. Lidocaine is also neurotoxic [1], and its use is quite limited because of the short duration of its anesthetic effects. Therefore, tetracaine has been the only safely and widely used anesthetic. Recently, 0.5% bupivacaine for spinal anesthesia was introduced into our country. There are many reports comparing the effects of bupivacaine and tetracaine in spinal anesthesia [2–8], but no comparative studies of these two agents with respect to the relation between anesthesia level and other factors considered to affect that level, such as dose, bodyweight, and so forth, are available. The purpose of this study was to compare the effects on hemodynamics and anesthesia levels, and the predictive factor of anesthesia level, of hyperbaric bupivacaine and tetracaine in spinal anesthesia.

Materials and methods

After receiving approval from our institutional research committee and obtaining informed consent from the patients, we enrolled in the study patients aged 40 to 75 with ASA physical status I or II scheduled for surgery in the lower extremities or for urological or gynecological surgery (except for intraabdominal procedures) under spinal anesthesia. Patients who had cardiovascular, respiratory, neurological, psychological, hepatic, renal, or spinal disease, and obese patients were excluded from the study. A total of 100 patients were enrolled in each of two groups, as descrised below.

Midazolam 2–3 mg with atropine 0.25–0.5 mg was intramuscularly administered as premedication 15–30 min before the patient entered the operating room. After an intravenous catheter was inserted, spinal anesthesia was performed at the L4–5 spinal interspace with a 25-gauge spinal needle with the patient in a lateral position. After drug administration, patients were returned to the supine position (horizontal) immediately. As the anesthetic, either 0.5% hyperbaric bupivacaine (0.5% Marcain, 1 ampule = 4 ml, Astra Zeneca, Osaka, Japan) (Bupivacaine group) or tetracaine (Tetocaine, 1 vial = 20 mg, Kyorin, Tokyo, Japan) dissolved in 10% glucose solution (20 mg per 4 ml, 0.5%) (Tetracaine group) was selected at random by a random number. These two preparations are commonly used in our country. The dose or volume administered was determined by the resident according to the surgical procedure, and the injection speed was controlled at 2 ml per 5 s as usual.

Noninvasive blood pressure, heart rate, and dermatome level of sensory anesthesia tested by cold sensation were monitored every 5 min for 30 min after spinal drug injection. The sensory level was checked on both right and left sides, and the level of the lower side at spinal injection was determined.

When applicable, all numerical variables are shown as mean ± SD. Statistical analyses of demographic data were performed with a χ-squared test and Student *t* test. The time to the maximum dermatome level of sensory anesthesia, was analyzed with a two-way repeated measures analysis of variance (ANOVA) test. A contrasts analysis was used for a multiple comparison of blood pressure and heart rate. The Mann-Whitney U test and Friedman test were used to analyze dermatome levels of sensory anesthesia. All these tests were performed with SPSS V. 6.1J software (SPSS Japan, Tokyo, Japan). The possible predictive factors for the maximum dermatome level of sensory anesthesia, volume of the administered drug, age, body weight, height, and sex, were analyzed stepwise using StatView V. 5.0 software. In this analysis, the anesthesia level was expressed as follows: S5 = level 1, S4 = level 2, . . . , L5 = level 6, . . . , T12 = level 11, . . . , T9 = level 14. $P < 0.05$ was considered statistically significant.

Table 1. Demographic data of the patients

	Tetracaine group	Bupivacaine group
Age (years)[a]	57 ± 16	60 ± 17
Sex (male/female)	66/34	68/32
Height (cm)[a]	164 ± 7	162 ± 8
Body weight (kg)[a]	61 ± 10	61 ± 10
Surgical procedure		
Extremities	35	48
Urological	24	20
Gynecological	41	32
Duration of surgery (min)[a]	122 ± 24	108 ± 31

[a] Mean ± SD

Results

Demographic data were not different between the two groups (Table 1).

Blood pressure decreased significantly compared with the preanesthesia level 10 min after spinal anesthesia in both groups, but there were no differences between the two groups (Fig. 1). Heart rate decreased

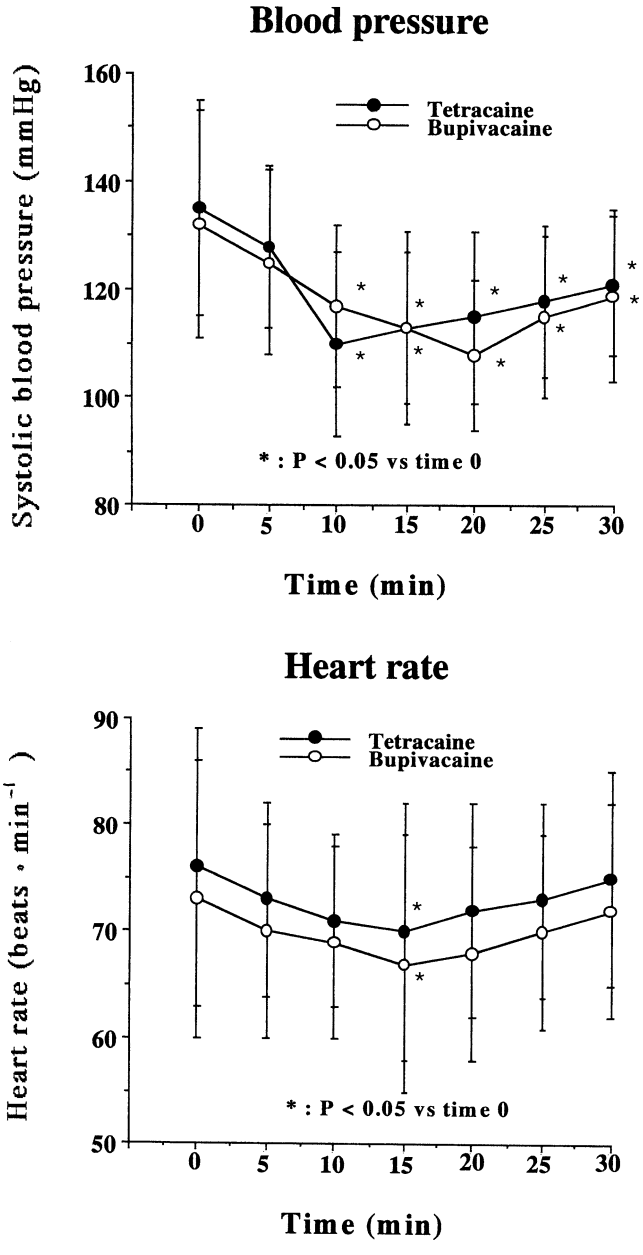

Fig. 1. Blood pressure (*upper*) and heart rate (*lower*): mean ± SD. Time 0 means time before spinal anesthesia, and time 5 is 5 min after spinal anesthesia

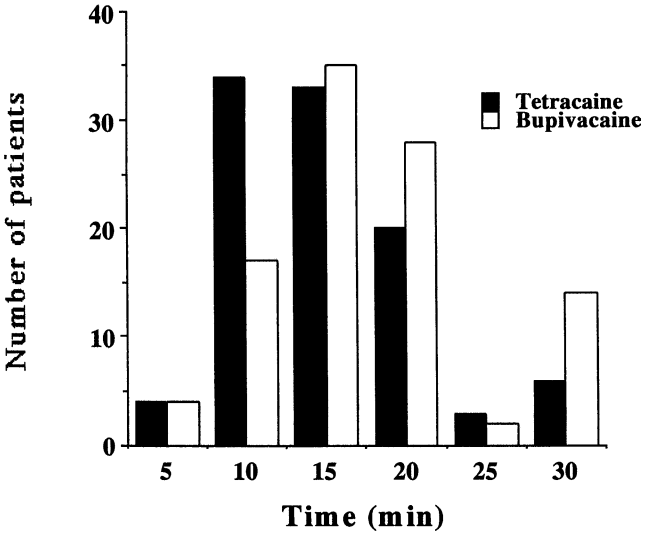

Fig. 2. Time to the maximum dermatome level of sensory anesthesia. Dermatome level of sensory anesthesia was checked every 5 min by cold sensation. The mean time was 15 ± 6 min in the Tetracaine group and 18 ± 7 min in the Bupivacaine group ($P < 0.05$)

15 min after spinal anesthesia with no difference between the two groups (Fig. 1).

The volume of the drug administered was 2.6 ± 0.5 (range, 2.0–3.2) ml in the Bupivacaine group, which was significantly larger than the volume of 2.1 ± 0.4 (range, 1.5–2.7) ml in the Tetracaine group, but the maximum dermatome level of sensory anesthesia was not different between the two groups (Th6 ± 2.5 in the Bupivacaine group and Th6 ± 3.0 in the Tetracaine group). The time to reach maximum dermatome level of sensory anesthesia was significantly longer in the Bupivacaine group (18 ± 7 min) than in the Tetracaine group (15 ± 6 min) (Fig. 2).

Age, body weight, height, and sex were not predictive factors for the maximum dermatome level of sensory anesthesia in either group. Only the volume of the administered drug was a predictive factor for the maximum anesthesia level in both groups as follows: Maximum anesthesia level = 1.55 × (volume in ml) + 13.06 in the Bupivacaine group ($P = 0.0057$, $r = 0.274$). Maximum anesthesia level = 2.59 × (volume in ml) + 11.46 in the Tetracaine group ($P = 0.0004$, $r = 0.348$).

Discussion

In spinal anesthesia with hyperbaric solution as commonly used in our country, more bupivacaine than tetracaine was necessary to obtain the same dermatome level of sensory anesthesia in the present study. Age, body weight, height, and sex were not predictive factors; only the volume (dose) of the administered drug was related to the maximum anesthesia level.

In the present study, we did not restrict the body position on injection of anesthetics to right sided or left sided. However, all patients were returned to the supine position just after spinal anesthesia, and the sensory anesthesia level at the end of the study was not different between right and left side. In addition, it has been reported that posture does not control the spread of a hyperbaric solution as much as was once thought [9]. Injection speed was controlled, but it is difficult to control it strictly in this kind of study. However, different speeds of administration of hyperbaric bupivacaine or tetracaine have been reported not to induce any changes in anesthesia level [10]. Therefore, these two factors probably had no effect on the results of this study.

We used only cold sensation to check dermatome level of sensory anesthesia. In spinal anesthesia with hyperbaric local anesthetics, blockade appears in the order sympathetic nervous system, sensory nerves, and finally motor nerves. The level of the sympathetic block is a few spinal segments higher than that of the sensory block [11]. When hyperbaric tetracaine was used, the sensory anesthesia level when tested by cold sensation averaged two spinal segments higher than that when tested by pinprick [12]. The differential sensory block between pinprick and temperature is essentially the same with both tetracaine and bupivacaine, and the widths of the zones of differential sensory blockade remain constant during onset, maintenance, and offset of spinal anesthesia [4]. Therefore, cold sensation alone is probably adequate for comparing the level of anesthesia, which was comparable in the two groups.

A greater extent of sensory anesthesia to pinprick with bupivacaine was reported when equal doses (15 mg), concentrations (0.375%), volumes (4 ml), and glucose concentrations (5%) of solutions of tetracaine and bupivacaine were used [3]. On a milligram for milligram basis, the sensory effect of bupivacaine may be greater than that of tetracaine [2]. Gielen et al. [5], however, reported that hyperbaric bupivacaine and tetracaine had the same maximum cephalad spread of analgesia to pinprick. These results differ from ours, which show higher levels of sensory block with tetracaine anesthesia than with bupivacaine. The reason for this discrepancy among the studies was not clear. However, Bigler et al. [8] reported higher cephalad spread of sensory and temperature analgesia after tetracaine than after bupivacaine, but the difference was not significant. Janik et al. [13] also reported that the maximum cephalad spread of analgesia was significantly greater with tetracaine than with bupivacaine, which is similar to our results. Glucose concentration significantly influenced the spreading characteristics of tetracaine: an 8% solu-

tion achieved a higher level in a shorter time than a 5% solution [13]. The maximum cephalad spread of analgesia by spinal tetracaine was higher with 10% glucose than with 5% glucose [14]. The time from spinal injection to maximum spread of analgesia was significantly shorter with 10% glucose than with 5% glucose [14].

In our present study, tetracaine was administered with 10% glucose but bupivacaine was with 7.27% glucose. The higher glucose concentration of the tetracaine might have induced the higher sensory level of anesthesia and resulted in the shorter time to reach the maximum level compared with bupivacaine. However, both solutions are commonly used in Japan. Therefore, our results are clinically important even though they did not show differences between pure tetracaine and bupivacaine.

A higher dose of bupivacaine (22.5 mg compared to 15 mg) did not result in a higher cephalad spread, but was reported to prolong the duration of the blockade [15]. When 15 mg of bupivacaine was administered in solutions containing glucose, no difference in sensory blockade was seen, regardless of the volume (2 or 3 ml, in 0.75% and 0.5% glucose, respectively) injected [15]. In contrast, our results indicate that the volume (dose) is the most important factor determining the sensory anesthesia level with both hyperbaric bupivacaine and tetracaine anesthesia. Tetracaine 1 ml raised the sensory anesthesia level of 2.6 spinal segments, but bupivacaine raised the level of only 1.6 spinal segments, when the volume of anesthetic used was in the range of 1.5–2.7 ml for tetracaine and of 2.0–3.2 ml for bupivacaine. The volume administered was the immediate major factor affecting the extent of spread. When volume is held constant, increasing the dose concomitantly increases the concentration, resulting in a faster onset, longer block, and a higher peak level of anesthesia [16].

We did not measure the duration of the sensory block in this study because it is difficult to check the level during surgery. A longer total duration of sensory anesthesia with tetracaine was reported when equal doses (15 mg), concentrations (0.375%), volumes (4 ml), and glucose concentrations (5%) of solutions of tetracaine and bupivacaine were used [3]. Tetracaine also tends to induce a more complete and longer lasting motor blockade than bupivacaine [15]. Even a smaller dose of tetracaine (14 mg) had a longer duration of action than bupivacaine (15 mg) according to Bengtsson et al. [15]. In addition, times to ambulation and complete resolution of the block were significantly longer with tetracaine than with bupivacaine [17].

In a study by Janik et al. [13], tetracaine achieved a three-spinal-segment motor blockade significantly faster than bupivacaine. Tetracaine produced a significantly longer motor block in the lower extremities than did bupivacaine [2], and it has also been reported to produce a better quality of motor blockade than bupivacaine [7]. We did not measure motor function, but from these studies as well as the present results, in spinal anesthesia, tetracaine might have faster onset and stronger anesthetic effects that continue longer than bupivacaine.

Hyperbaric bupivacaine and tetracaine are associated with similar changes in blood pressure and heart rate [4,6]. However, better hemodynamic stability has been shown with bupivacaine compared with tetracaine. This difference was explained by an insignificant but consistently lower cephalad spread of sensory and temperature blocks and a less depressed response of plasma catecholamines to the fall in blood pressure with bupivacaine [8]. In bupivacaine spinal anesthesia, plasma norepinephrine increased significantly from before spinal puncture to the maximum fall in mean arterial pressure, whereas patients receiving tetracaine showed no change in plasma norepinephrine [8]. The suggestion that tetracaine leads to more profound hypotension than bupivacaine during spinal anesthesia [5] has not been supported by other studies [2,3]. Our results did not support this suggestion, either.

In conclusion, 0.5% hyperbaric tetracaine in 10% glucose induced a faster and higher spread of the dermatome level of sensory anesthesia in spinal anesthesia than 0.5% hyperbaric bupivacaine in 7.27% glucose, without any differences in hemodynamics. Age, body weight, height, and sex were not predictive factors. Only the volume (dose) of the administered drug was related to the maximum anesthesia level in the two anesthetics.

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