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ORIGINAL ARTICLE

The effect of injection speed on the spinal block characteristics of hyperbaric bupivacaine 0.5% in the elderly

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Abstract
Purpose The purpose of this prospective, randomized, double-blind study was to compare anesthetic characteristics after two speeds of intrathecal injection of hyperbaric bupivacaine in elderly patients.
Methods Fifty-six patients, aged ≥65 years, undergoing transurethral surgery under spinal anesthesia were allocated randomly to two groups according to rate of intrathecal injection of 2 ml hyperbaric bupivacaine 0.5%: group Fast (maximum possible rate; mean 0.38 ml/s) $n = 26$; group Slow (over 40 s; 0.05 ml/s), $n = 25$. Spinal blocks were administered in the lateral position. Data collection at different times included sensory level, motor block, hemodynamic changes, and occurrence of neurological symptoms.
Results There was no significant difference between the groups regarding maximum sensory anesthetic level achieved (group Fast: T7 (T4–T10), median (range); group Slow T8 (T6–T10), $P = 0.184$); times (min) to reach (a) T10 sensory level (group Fast 5.3 ± 4.2 (mean ± SD), group Slow 8.0 ± 6.5, $P = 0.093$); (b) maximum sensory level (group Fast 11.6 ± 4.7; group Slow 13.6 ± 6.1, $P = 0.199$); and (c) 2-segment regression of anesthesia (group Fast 92.2 ± 29.6; group Slow 104.7 ± 36.1, $P = 0.182$). Degree and duration of motor block were similar ($P = 0.947$ and $P = 0.895$, respectively). Hemodynamic changes, ephedrine and atropine requirement, incidence of postoperative neurological symptoms after 24 h and 1 week were similar (all $P > 0.05$).
Conclusions An eightfold difference in speed of intrathecal injection of 0.5% hyperbaric bupivacaine did not affect the clinical characteristics of spinal anesthesia in elderly patients undergoing transurethral surgery.

Keywords Anesthetic techniques · Spinal · Speed of injection · Anesthetics · Local · Bupivacaine

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Introduction

The effect of speed of injection of local anesthetic solution on the anesthetic characteristics of spinal anesthesia remains controversial. The literature is replete with investigations using isobaric local anesthetic solutions [1–7]. However, data with regard to effect of injection speed using hyperbaric solutions for spinal block are limited [8–11]. Most studies using hyperbaric solutions of local anesthetics have not shown a difference in anesthetic profile [8–10], although a higher spread of sensory block with slow rate of injection has been reported [11].

Patient age and the volume of cerebrospinal fluid (CSF) affect the distribution of local anesthetic solution in the CSF [12]. Cameron et al. [13] suggested that a low CSF volume could explain the increase in spread of spinal anesthesia in the elderly. If CSF volume decreases with age, speed of injection of local anesthetic solution, would, perhaps have a greater effect on the spread of anesthesia in the elderly. Although baricity of the solution injected and

the subsequent posture of the patient are major factors determining intrathecal spread, manipulation of injection speed is within the clinicians' control and this may be used to produce different types of block. We tested the hypothesis that an eightfold difference in the rate of injection would result in significantly different maximum spread of anesthesia in an elderly population. The purpose of this prospective, randomized, double-blind study was to evaluate the effect of two speeds of intrathecal injection of hyperbaric bupivacaine 0.5% on the clinical characteristics of the block achieved, and on the occurrence of any adverse postoperative neurological outcome, in elderly patients undergoing transurethral surgery.

Methods

After hospital ethics committee approval and written informed consent, 56 ASA physical status 1–3 patients, aged 65 years and above, scheduled for transurethral (prostatic resection or bladder tumor) surgery under spinal anesthesia were included in this prospective, randomized, double-blind study. Patients receiving regular analgesic therapy, or those with marked scoliosis, neurological disease, diabetes mellitus, chronic headache or backache, or contraindication to spinal anesthesia were excluded from the study. Eligibility assessment, obtaining informed consent, and patient enrollment in the trial were conducted by one investigator. All patients were premedicated with alprazolam 0.25 mg orally the night before surgery. No premedication was administered on the day of surgery.

In the operation room, automatic non-invasive arterial pressure, pulse oximetry, and electrocardiograph monitoring were established and baseline arterial pressure and heart rate were recorded. Ringer's lactate solution, 10 ml/kg, was administered i.v. over 15–20 min. The level of spinal injection, guided by the Tuffiers' line, was verified by counting the vertebral spines from both the cranial and caudad directions. Dural puncture was performed at the lumbar 3–4 interspace using the midline approach with a 25-gauge Quincke spinal needle (Spinocan®, B Braun, Melsungen) with the patient placed in the left lateral decubitus position with the bevel directed cephalad. Randomization (sealed envelopes for allocation concealment) was performed by means of a computer-generated random number list. After free flow of CSF was observed, 2 ml 0.5% bupivacaine in 8% dextrose (hyperbaric; specific gravity 1.0285) was administered with a hand-held 2.5-ml syringe (divided into 0.1 ml sections) as rapidly as possible (group Fast) or over 40 s (group Slow). Spinal fluid (0.2 ml) was aspirated at the beginning of the injection of bupivacaine. In group Fast the time period between start and end of injection was measured by an anesthesiologist using a stop watch. In group Slow, the anesthesiologist performing the block timed the injection over 40 s administering 0.5 ml every 10 s. Immediately after intrathecal injection, the patients were gently placed in the horizontal supine position. Ten minutes after intrathecal injection, patients were placed in the lithotomy position after ascertaining sensory block to T10 dermatomal level. All spinal blocks were performed by one anesthesiologist. The anesthesiologist responsible for data collection after spinal injection was unaware of patient group allocation.

During the performance of spinal block the following were noted: number of passes with needle, paresthesiae with needle, or presence of blood in CSF. Sensory block was assessed bilaterally in the anterior axillary line by loss of pin-prick sensation using a short-beveled 25-gauge needle. A modified Bromage [14] scale was used for evaluation of motor block: grade 0 = no motor block; 1 = inability to raise extended leg, able to move knees and feet; 2 = inability to raise extended leg, able to move feet; 3 = complete motor block. Systolic, diastolic, mean arterial pressure, heart rate, sensory levels, and motor block were recorded at 1-min intervals during the first 5 min of onset of block, at 5-min intervals thereafter until completion of surgery and at 15 min intervals during resolution of block. Times to onset of anesthesia to T10 dermatome, achieve maximum sensory anesthetic level, and two-segment regression of anesthesia were recorded. The patients were visited at 15-min intervals after surgery until their legs had returned to normal and this time recorded as the duration of motor block.

Oxygen was administered via a face mask at 5 l/min. Heart rate less than 50 beats per min was treated with atropine 0.3 mg i.v. A 20% or greater decrease in baseline systolic arterial pressure was treated with a rapid infusion of fluid and i.v. boluses of ephedrine 6 mg. The doses of ephedrine, atropine, and i.v. fluid administered were noted.

All patients were examined for any neurological symptoms 24 h after intrathecal injection by means of a postoperative questionnaire, described by Tucker et al. [15], which includes: presence of headache; back, or leg pain, leg numbness or weakness; urinary incontinence or difficulty voiding; fecal incontinence or difficulty emptying bowel; numbness or a burning sensation around the anal or genital area. Urinary incontinence and difficulty in voiding at 24 h were not assessed as all patients were catheterized. The patients were assessed again at 1 week to monitor the course of symptoms that were present at 24 h or any symptoms that developed after 24 h of intrathecal injection.

Sample size determination was based on the primary outcome, that is, maximum sensory anesthetic level achieved. It was calculated that a sample size of 25 patients per group would have 90% power at the 5% significance

level to detect a 2-segment difference in level of maximal sensory block between groups. To allow for potential dropouts, we decided to recruit 56 patients. Secondary outcome measures that we compared included the times required to reach T10 sensory level, maximum sensory level, or time for 2-segment regression of sensory level, degree and duration of motor block, and adverse neurological symptoms. Data are expressed as mean ± SD, median (range), or numbers (%). Student's unpaired *t* test (for continuous variables) and the chi-squared test (for categorical variables) were used to detect significant differences between groups. To assess the trend within the variables, 2-way analysis of variance was used. Sensory and motor block data were analyzed using Wilcoxon rank sum tests. $P < 0.05$ was regarded as statistically significant. SPSS 14.0 statistical software (SPSS, Chicago, IL, USA) was used for statistical analysis.

Results

Fifty six patients were enrolled in the study between October 2007 and April 2008. Five patients were excluded: 2 patients in group Fast (failed block) and 3 patients in group Slow (protocol violation). The two patients with failed block (no sensory block) received a repeat spinal anesthetic. Thus, data from 51 patients was analyzed; 26 patients in group Fast and 25 patients in group Slow. The mean time to intrathecal injection of 2 ml bupivacaine was 5.3 s in group Fast (speed of injection 0.38 ml/s) and 40 s in group Slow (speed of injection 0.05 ml/s).

There were no differences in patient characteristics between the two groups (Table 1).

Maximum sensory anesthetic level achieved was similar in the two groups. There were no significant differences in times required to reach T10 sensory level, or maximum sensory level, or time for regression of sensory level by two segments between the groups (Table 2). Degree and duration of motor block was similar in the two groups (Table 2).

Table 1 Patient characteristics

	Group fast ($n = 26$)	Group slow ($n = 25$)	*P* value
Age (year)	70 ± 5	69 ± 3	0.521
Weight (kg)	58 ± 7	56 ± 9	0.512
Height (cm)	164 ± 5	165 ± 5	0.666
ASA PS 1/2/3	4/16/6	6/14/5	0.730

Data are mean ± SD or number

ASA PS Physical status classification of the American Society of Anesthesiologists

Table 2 Sensory and motor block data

	Group fast ($n = 26$)	Group slow ($n = 25$)	*P* value
Maximum sensory level	T7 (T4–T10)	T8 (T6–T10)	0.184
Times (min) to			
T10 dermatome	5.3 ± 4.2	8.0 ± 6.5	0.093
Maximum sensory level	11.6 ± 4.7	13.6 ± 6.1	0.199
Two-segment regression	92.2 ± 29.6	104.7 ± 36.1	0.182
Motor block (Bromage scale)	3 (2–3)	3 (2–3)	0.947
Duration of motor block (h)	3.5 ± 1.6	3.6 ± 1.4	0.895

Values are mean ± SD or median (range)

Bromage scale: grade 0 = no motor block; 1 = inability to raise extended leg, able to move knees and feet; 2 = inability to raise extended leg, able to move feet; 3 = complete motor block

There were no significant differences in hemodynamic changes or in ephedrine or atropine requirement between the two groups (Table 3). No patient experienced nausea or vomiting.

There were no significant differences between groups with regard to spinal block performance, incidence of headache, or in the occurrence of neurological symptoms at 24 h (Table 4). All patients were symptom-free at 1 week.

Discussion

We were unable to confirm our hypothesis that varying the speed of injection of hyperbaric bupivacaine solution would be reflected by the maximum spread of anesthesia in the elderly. An eightfold difference in speed of injection of 0.5% hyperbaric bupivacaine did not affect the maximum sensory anesthetic level, times to reach T10 sensory level, maximum sensory level, and two-segment regression; or the degree and duration of motor block. There were no significant differences in the incidence of hypotension, in ephedrine or atropine requirement, or in the occurrence of neurological symptoms between the two groups.

Table 3 Incidence of hypotension, bradycardia, and requirement for ephedrine, atropine, and intravenous Ringer's lactate

	Group fast ($n = 26$)	Group slow ($n = 25$)	*P* value
Hypotension	0 (0)	1 (4)	0.490
Bradycardia	2 (7.7)	0 (0)	0.490
Ephedrine requirement	0 (0)	1 (4)	0.490
Atropine requirement	1 (3.8)	0 (0)	1.000
IV Ringer's lactate (ml)	1,144 ± 284	1,210 ± 257	0.391

Values are numbers (%) or mean ± SD

Table 4 Spinal block performance and incidence of neurological symptoms at 24 h postoperatively

	Group fast ($n = 26$)	Group slow ($n = 25$)	P value
Number of passes (1/2/3)	16/9/1	17/5/3	0.341
Paresthesia with needle	0 (0)	0 (0)	–
Blood in CSF	3 (11.5)	0 (0)	0.235
Headache	1 (3.8)	0 (0)	1.000
Back pain	4 (15.4)	6 (24)	0.499
Leg pain	3 (11.5)	4 (16)	0.703
Leg numbness	1 (3.8)	0 (0)	1.000
Leg weakness	1 (3.8)	0 (0)	1.000
Fecal incontinence	0 (0)	0 (0)	–
Difficulty emptying bowel	0 (0)	0 (0)	–
Genital dysesthesia	2 (7.7)	0 (0)	0.490

Values are numbers (%)

No previous studies have specifically investigated the effect of speed of intrathecal injection of local anesthetic solution in the elderly population. Thus, our results cannot be directly compared with those of others. Speed of injection using hyperbaric solutions has not been found to be an important determinant in the spread of spinal anesthesia in young adults [8–10]. Neigh et al. [8] found no difference in level of sensory anesthesia when a hyperbaric solution of tetracaine was injected at a rate of 1 or 0.2 ml/s. Similarly, hyperbaric bupivacaine injected at a rate of 0.02 or 0.25 ml/s failed to show any differences between highest level of sensory block or in times to achieve this [9]. A tenfold difference in the injection speed of hyperbaric bupivacaine did not affect the sensory level of spinal anesthesia in parturients undergoing Cesarean delivery [10]. In contrast, Janik et al. [11] reported a higher spread of analgesia with a slow rate (0.25 ml/s) of injection of hyperbaric bupivacaine compared with a faster rate (0.5 ml/s). However, the volume of bupivacaine used in their study was twice that used in ours (4 vs. 2 ml), and spinal injection was performed with patients in the sitting position which could, perhaps, explain the different results. The results of our study of an elderly population failed to show any difference in spinal block characteristics achieved by varying the speed of injection eightfold, consistent with the findings of previous workers in young adults [8–10]. This is probably because the baricity of hyperbaric solutions is so excessive that gravity effects overshadow the effects due to variation in speed [16].

Our results indicate that the varying turbulence created within the subarachnoid space when the rate of injection was altered had no clinically significant effect on the spread of spinal anesthesia in elderly patients. Perhaps, differences in the amount of turbulence created by varying the rate of injection eightfold through 25 gauge spinal needles was not large enough to produce clinically meaningful changes in the spread of the anesthetic solution used. Slow injection rates in clinical studies have varied from 0.02 to 0.05 ml/s [9, 10]. Previous studies that did demonstrate a higher spread with isobaric solutions when using the slow rate of injection [13, 17] used a much slower injection rate (1 ml/min) than studies that did not (3 ml/min) [1, 2, 6]. Such a slow rate of injection (0.016 ml/s) would be so tedious and impractical to perform that its clinical use would be unlikely. Therefore, we considered our slow injection rate of 0.05 ml/s to be feasible and in a clinically relevant range.

In our study the intrathecal injection was performed with the patients in the lateral position. We chose to study hyperbaric bupivacaine because, compared with isobaric solutions, hyperbaric solutions are more predictable and result in less inter-patient variability [18, 19]. It has been suggested that the unpredictability and greater variability in effect shown by isobaric solutions could be related to the effect of CSF density [12]. CSF density is unlikely to affect intrathecal distribution of hyperbaric bupivacaine because of the excess baricity above 1.0015 [12].

A potential limitation of our study is that because the injections were administered manually, the injection speeds may not have been uniform between groups. To facilitate the slow steady injection we used a 2.5-ml syringe (divided into 0.1 ml sections), administering 0.5 ml per 10 s. Electronic pumps have been used to maintain accurate injection speeds [3, 5]. We felt that the use of such devices would be cumbersome and not representative of clinical practice.

Previous studies assessing the effect of speed of injection of local anesthetic solutions have used Whitacre needles in which bevel direction is important [3, 8, 9]. The direction in which the bevel of a standard Quincke needle faces has no effect on the distribution of local anesthetic solutions in the CSF [8].When a solution is injected into air through a standard beveled spinal needle, the exit stream goes in the same straight line irrespective of the direction in which the bevel faces. In contrast, the exit stream from a Whitacre needle is essentially at a 90° angle to the shaft of the needle [12] and thus affects the distribution of spinal anesthetic solutions.

Accurate identification of vertebral level is difficult clinically [20]. The possibility of choosing the desired intervertebral space incorrectly may affect the spread of the sensory block. In our study, identification was made by palpating the iliac crest to confirm the position of the fourth lumbar vertebra and further verified by counting the spines of the vertebrae from both the cranial and caudad directions. Despite these measures, it is possible that misidentification occurred in some patients. Definite

identification of the correct interspace requires radiological location techniques, the use of which would invalidate the results for prospective use in routine clinical practice. For this reason, and also because of ethical concerns, we used clinical identification of the L3–4 interspace.

Our study is the first randomized double-blind clinical trial to compare the effect of an eightfold difference at clinically relevant rates of intrathecal injection of hyperbaric bupivacaine in elderly patients. In conclusion, regardless of the speed of injection, there are no differences between anesthetic characteristics of spinal anesthesia using hyperbaric bupivacaine 0.5% in elderly patients undergoing transurethral surgery.

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