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Isobaric Versus Hypobaric Spinal Bupivacaine for Orthopedic Surgery in Lateral Position

M. Sadeghi, G. Shoeibi, A. Mehraein, H. Majedi and M.H. Ghafari
Department of Anesthesiology and Critical Care, Dr. Ali Shariati Hospital,
School of Medicine, Medical Sciences University of Tehran, Iran

Abstract: Comparing the effects of isobaric and hypobaric bupivacaine in lateral decubitus position. With operative side up, patients randomly received, 3 mL (15 mg) spinal injection of bupivacaine mixed with 2 mL of either normal saline (isobaric) or distilled water (hypobaric). Sensory level and degree of motor block were evaluated on nondependent and dependent sides. Hemodynamic changes were noted. In the hypobaric group, there was a prolonged time to sensory regression to L2 on the operative side; no difference in quality of motor block was noted. Hemodynamic changes were comparable. Spinal hypobaric bupivacaine is superior to isobaric.

Key words: Anesthetic techniques, regional, spinal, hypobaric bupivacaine, orthopedic surgery

INTRODUCTION

Unilateral spinal anesthesia is a special regional anesthesia technique generally applied in lower limb orthopedic surgery procedures, where it is perhaps useful and feasible to produce an anesthetic block only on the operated side (Atchison *et al*., 1989). The advantages of this technique include the reduction of hypotension during spinal anesthesia, faster recovery and increased patient satisfaction (Atchison *et al*., 1989).

Hypobaric bupivacaine can theoretically provide more selective subarachnoid distribution of local anesthetic on the nondependent (operative) side (Atchison *et al*., 1989; Horlocker *et al*., 1994). This can result in a more profound sensory and motor block of longer duration, which could be advantageous in the cases of unexpectedly prolonged surgery (Atchison *et al*., 1989; Horlocker *et al*., 1994). The use of hypobaric local anesthetic has been reported for single-shot injection (Atchison *et al*., 1989; Horlocker *et al*., 1994) and continuous spinal anesthesia (Kallos and Smith, 1972; Van Gessel *et al*., 1989).

The aim of the present study was to compare the anesthetic and hemodynamic effects of isobaric (plain bupivacaine mixed with normal saline) and hypobaric (Plain bupivacaine mixed with distilled water) solutions for orthopedic surgery performed with patients in lateral decubitus position.

MATERIALS AND METHODS

After getting approve from the ethics committee of our institution and informed consent preparation, 50 orthopedic patients, between 30-70 years old, ASA physical status I or II, scheduled undergoing elective orthopedic surgery under single-shot spinal anesthesia were enrolled in the study. This study was done between May 2005-Jan 2006 Shariati Hospital, Tehran University of Medical Science, Iran.

Exclusion criteria were coagulation disorders, local infection and obvious spinal postural abnormalities (kyphosis), diabetes or peripheral neuropathy, mental disturbance and obesity (body mass index >30).

Standard noninvasive monitoring consisted of continuous electrocardiogram, Etco2 peripheral pulse oxymetry and automatic noninvasive blood pressure measurement on nondependent hand. More invasive monitoring (i.e., central venous pressure, invasive arterial pressure, or an indwelling urinary catheter) was used only if required by the patient's clinical condition. After placement of a peripheral IV catheter in the dependent forearm, preanesthetic hydration consisted of 10 mL kg^{-1} of a crystalloid solution and during the 1st h after spinal injection, 5 mL kg^{-1} of the same solution was infused. Thereafter, fluids were given on the basis of changes in arterial blood pressure and estimated blood loss (replaced with a crystalloid solution on a 3:1 mL basis). When available, autologous blood was given if the

Corresponding Author: Gita Shoeibi, Department of Anesthesiology and Critical Care, Dr. Ali Shariati Hospital, North Karegar Street, Tehran 1411713135, Iran

hematocrit decreased to <30% and homologous blood was only administered if the hematocrit decreased to <26%.

Using a sealed envelope system, the patients were randomly assigned to receive either hypobaric or isobaric bupivacaine solutions, which were prepared as follows. Isobaric bupivacaine: 3 mL (15 mg) of plain bupivacaine 0.5% diluted with normal saline to a total of 5 mL; measured density at 25°C was 1008 g mL^{-1}. Hypobaric bupivacaine: 3 mL (15 mg) of plain bupivacaine 0.5% diluted with distilled water, to a total of 5 mL; measured density at 25°C was 1003 g mL^{-1}. The density measurements of study solutions were performed using an Anton Paar DMA 4500 densitometer (Anton Paar GmbH, Graz, Austria). For each solution, 3 measurements were performed and the mean value was considered (CSF density at 25° was 1006 g mL^{-1}).

With the operating table horizontal, the patients were placed in the lateral decubitus position with the operated hip up. Lumbar puncture was performed at the L3, L4 interspace with a 25-gauge quincke needle.

After observing Free Cerebrospinal Fluid (CSF) reflux, the needle aperture was oriented upward and 5 mL of the study solution injected at a rate of approximately 0.5 mL s^{-1}. The patients remained in the lateral position.

The following variables were measured throughout the study:

Evolution of upper sensory block level on nondependent (Operative) and dependent sides. A pinprick test (24-gauge needle) was performed on the mid thoracic line every 5 min during the first 45 min after spinal injection and then every 15 min until sensory regression to L2 (level of the surgical incision). Maximal upper sensory block level, its onset time and time to regression to L2 on both sides were recorded.

Evolution of degree of motor block using a modified Bromage scale (Martin-Salvaj *et al*., 1994) ranging from 0-4; able to move hip, knee, ankle and toes; unable to move hip, able to move knee, ankle and toes; unable to move hip and knee, able to move ankle and toes; unable to move hip, knee, ankle, able to move toes; unable to move hip, knee, ankle and toes) on both limbs, every 5 min during the first 45 min after spinal injection. In order not to interfere with the surgical procedure, motor block was not tested during the operation.

At the end of surgery, degree of motor block was determined for both limbs and tested every 15 min until total motor recovery. Maximal degree of motor block, its onset time and time to total motor recovery of both limbs were recorded.

Mean arterial blood pressure (MAP) and Heart Rate (HR) were recorded every 2.5 min during the first 45 min after spinal injection, every 5 min during surgery and every 15 min in the recovery room until the study termination (defined as sensory regression to L2 on both sides and/or total motor recovery of both limbs). Maximal decrease in MAP and HR from baseline value (determined with patients in the lateral decubitus position just before spinal injection) was recorded for the first 45 min after spinal Injection. Ephedrine 5-10 mg IV was given if MAP decreased >20% from baseline value or if systolic pressure decreased to <90 mm Hg. Atropine 0.5 mg IV was given if HR decreased to <45 bpm.

Duration of anesthesia was defined as time between spinal injection and the end of the surgery.

All of the above variables were determined during anesthesia by the anesthesiologist in charge of the patient and in the recovery room by nurses who were trained by the investigators. Discomfort related to the lateral position during surgery was treated with fentanyl 1 μg kg^{-1} IV (maximal 2 doses) and anxiety with midazolam 1 mg IV.

Prospective power tests defined the sample size using sensory block level regression time to L2 of 201±57 min using 3 mL of plain bupivacaine 0.5% (Racle *et al*., 1988). The sample size was computed to detect a 25% difference in favor of the hypobaric group, i.e., a longer duration of block with a power of 80% and a two-tailed significance level of 5% ($\alpha = 0.2$; $\beta = 0.05$). A minimal sample of 14 patients for each group met these criteria. Results are expressed as mean±SD or median (ranges) for discrete variables.

Comparisons between groups or between both sides in the same group were performed using the student's t-test for unpaired or paired data, the Mann-Whitney U-test and the χ^2 test as required. A $p<0.05$ was considered statistically significant.

RESULTS

Twenty five patients were allocated to each group. Patient's demographic and preanesthetic hemodynamic data were comparable between the 2 study groups (Table 1). There was no difference between corresponding sides in the 2 groups or between operative and nonoperative sides in the same group.

Table 1: Patient characteristics and preanesthetic hemodynamic variable

	Isobaric (n = 25)	Hypobaric (n = 25)
Age (year)	63±8	61±10
Weight (kg)	72±12	81±15
Height (cm)	166±8	166±10
ASA physical status (I/II)	6±19	2±23
Female/male ratio	11±14	11±14
*MAP (mm Hg)	103±15	104±13
Heart rate (bpm)	73±16	76±15

Values are expressed as mean±SD; *MAP = mean arterial blood pressure

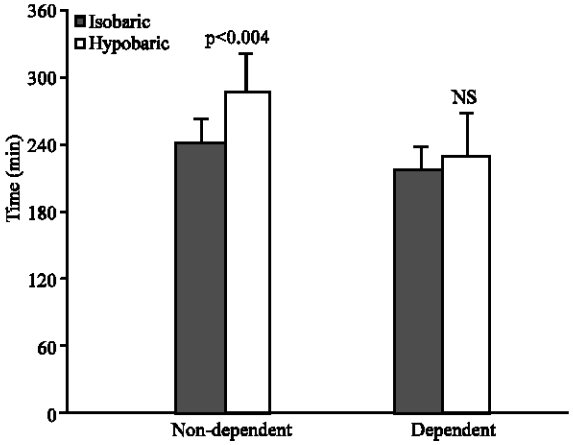

Fig. 1: Comparison of duration of sensory regression to L2 between nondependent sides, dependent side. Regression to L2 on the nondependent side is significantly prolonged in the hypobaric compared with the isobaric group

Prolonged maximal degree of motor block achieved and onset times were also comparable between the 2 groups and in the same group between both sides. In the isobaric group, these data were 4 (4) and 16±4 min for the nondependent and 4 (3-4) and 22±9 min for the dependent side. In the hypobaric group, these data were 4 (4) and 13±7 min for the nondependent and 4 (1-4) and 16±10 min for the dependent side.

Duration of anesthesia, defined as the time between the spinal injection and the end of the surgery, was comparable between the 2 groups; 175±25 min for isobaric and 169±23 min for hypobaric. When comparing the sensory regression times to L2 between the nondependent and the dependent sides, patients in both groups showed significantly prolonged sensory regression to L2 on the nondependent (operative) side (252±33 versus 228±29 min, $p<0.005$ and 296±42 versus 253±38 min, $p<0.0001$, for isobaric and hypobaric group, respectively). When comparing both groups (Fig. 1), regression to L2 on the nondependent side was significantly in the hypobaric group (296±42 versus 253±38 min, $p<0.004$).

Because the degree of motor block was not tested during surgery and because at the end of surgery complete motor recovery of one or both limbs was observed in some patients, only relevant data were available after surgery was completed in all patients i.e., 225 min after spinal injection. At this time in the hypobaric group, 5 patients had a complete motor block.

Recovery on the non-dependent side compared with 20 on the dependent side ($p<0.0001$). In the isobaric group, the number of patients were not statistically different between the 2 sides (8 versus 25). Also, there was no statistical difference when corresponding sides between the 2 study groups were compared. Hemodynamic changes, observed during the first 45 min after spinal injection, were comparable between the 2 groups. Maximal decrease in MAP was 29±14% versus 31±15% and for HR 12±10% versus 13±11% for the isobaric and hypobaric group, respectively. Nine patients in the isobaric and 5 in the hypobaric group received ephedrine; one patient in the isobaric group received atropine.

Finally, 2 patients in the isobaric group received fentanyl for discomfort and 4 received midazolam for anxiety. In the hypobaric group, 3 patients received fentanyl and 5 midazolam.

DISCUSSION

The results of the present study demonstrate an advantage of hypobaric over isobaric spinal anesthesia in patients undergoing orthopedic surgery in the lateral decubitus position.

Although, both solutions provide satisfactory analgesia, hypobaric bupivacaine showed a significantly delayed sensory regression to L2 on the nondependent side of 45 min.

Before the present study, 2 other reports compared hypobaric and isobaric bupivacaine. Van Gessel *et al.* (1991) reported fewer failures with isobaric versus hypobaric bupivacaine during continuous spinal anesthesia for hip surgery. However, both injection of local anesthetic and surgery were performed with patients supine (Van Gessel *et al*., 1991). Kuusniemi *et al.* (1999) tested small doses (6 mg) of hypobaric and plain bupivacaine in the lateral position for knee arthroscopy; 20 min after spinal injection, the patients were turned supine for surgery. A differential spread for both sensory levels and motor block between nondependent and dependent sides was demonstrated for each solution (Kuusniemi *et al*., 1999). However, no difference was found between the 2 solutions, when comparing the same side during progression of spinal anesthesia, both solutions demonstrate qualities of isobaricity (no difference in upper sensory level and maximal degree of motor block between nondependent and dependent sides) (Kuusniemi *et al*., 1999). The results of other studies investigating subarachnoid distribution of hypobaric local anesthetic in the lateral position suggest a dose related effect in favor of the nondependent side. Kuusniemi *et al.* (1999) reported a differential sensory and motor block with hypobaric solution (6 mg of

bupivacaine in 3.4 mL). Van Gessel *et al.* (1989) observed a differential spread only for motor block when using hypobaric solutions of tetracaine or bupivacaine (7.5 mg in 3 mL). Atchison *et al.* (1989) studying the effects of speed of injection, documented a differential sensory spread between nondependent and dependent sides with 10 mg of hypobaric tetracaine in 5 mL when injected over 250 sec with an electrically driven syringe pump through a Whitacre needle with the aperture oriented upward (Atchison *et al.*, 1989). When the same solution was injected rapidly over 10 sec, approximating the usual clinical spinal injection speeds, no differential sensory block was found (Atchison *et al.*, 1989). Using an identical methodology, Horlocker *et al.* (1994) did not show any difference in sensory levels between the nondeendent and dependent sides in either slow or fast injection groups, using 15 mg of hypobaric bupivacaine in 5 mL. Consequently, the appearance of a differential block seems to be favored by using small dose hypobaric solution injected very slowly (Horlocker *et al.*, 1994).

In our study, the absence of early clinical signs of preferential distribution in favor of the nondependent side in the hypobaric group can be explained essentially by the following mechanism. Unlike in hyperbaric solutions (Lui *et al.*, 1998), there is a relatively small difference in density between the hypobaric bupivacaine solution used in the present study (1003 g mL^{-1}) and CSF using measurements previously made (Schiffer *et al.*, 2002) in our institution (1.006 g mL^{-1}). Given this slight difference in density and given the relatively large dose (15 mg) and volume (5 mL) of hypobaric bupivacaine, injected rapidly over 10 sec, it is not surprising that a dense initial bilateral subarachnoid block developed initially. Thus, despite injecting the anesthetic solution through a directional Quincke needle, there was no early evidence of a preferential spread. However, qualities of hypobaricity appeared during regression of spinal anesthesia in both groups, but were clinically more relevant in the hypobaric group: the regression time to L2 between nondependent and dependent sides was significantly different in the 2 groups; unlike in the isobaric group, fewer patients in the hypobaric group had complete motor block recovery on the nondependent compared with the dependent side. The appearance of this delayed asymmetrical block can be attributed to the differences in densities between anesthetic solutions and CSF, associated with prolonged lateral position of approximately 3 h in the present study.

We speculate that in the present study, 3 h of lateral decubitus positioning allows more neural fixation on the nondependent roots of hypobaric than isobaric bupivacaine. These arguments could explain the more pronounced differential spread of hypobaric over isobaric bupivacaine observed during regression of the spinal anesthesia. Block is documented for isobaric bupivacaine. Similar findings are reported by others for patients receiving plain bupivacaine and tested in the lateral position (Lui *et al.*, 1998; Blomqvist and Nilsson, 1989), questioning whether plain bupivacaine is isobaric or hypobaric (Blomqvist and Nilsson, 1989). Greene (1985) stated that the limit between hypobaric and isobaric local anesthetic solutions is a baricity of 0.99 dividing density of local anesthetic with that of CSF. Davis and King (1954) mentioned that this limit is a density of local anesthetic lower than 3 standard deviations below mean human CSF density. Using more precise techniques of measurement of CSF density, Richardson and Wissler (1996) determined the upper limits of hypobaricity as density of local anesthetic between 1.00016-1.00037 g mL^{-1} according to the variations of CSF density in a different subgroup of patients and considered the mixture plain bupivacaine morphine with a density of 0.99941 as hypobaric (Richardson *et al.*, 1998). Recently, Schiffer *et al.* (2002) reported the density of plain bupivacaine 0.5% of 1007 g mL^{-1} at 25°C. Compared with this value, the density of hypobaric bupivacaine investigated in the present study was (1003 g mL^{-1}) and that of the isobaric solution (1008 g mL^{-1}). Their baricities calculated with density of CSF of (1006 g mL^{-1}).

However, the results of the present study suggest that local anesthetic solutions considered isobaric, with a density even more than that of plain bupivacaine but less than that of the CSF, can show some signs of hypobaricity in patients kept in prolonged lateral position.

In summary, for patients undergoing orthopedic surgery in the lateral position under spinal anesthesia, 15 mg of hypobaric bupivacaine, compared with the identical dose of isobaric bupivacaine, prolonged sensory regression to L2, without further compromising systemic hemodynamic. We believe that 45 min longer duration of spinal block is clinically relevant and increases the reliability of hypobaric spinal anesthesia in this type of surgical procedure.

REFERENCES

Atchison, S.R., D.J. Wedel and P.R. Wilson, 1989. Effect of injection rate on level and duration of hypobaric spinal anesthesia. Anesth. Anal., 69: 496-500.

Blomqvist, H. and A. Nilsson, 1989. Is glucose-free bupivacaine isobaric or hypobaric? Reg. Anesth., 14: 195-198.

Davis, H. and W.R. King, 1954. Density of cerebrospinal fluid of human beings. Anesthesiology, 15: 666-672.

Greene, N.M., 1985. Distribution of local anesthetic solutions within the subarachnoid space. Anesth. Analg., 64: 715-730.

Horlocker, T.T., D.J. Wedel and P.R. Wilson, 1994. Effect of injection rate on sensory level and duration of hypobaric bupivacaine spinal anesthesia for total hip arthroplasty. Anesth. Anal., 79: 773-777.

Kallos, T. and T.C. Smith, 1972. Continuous spinal anesthesia with hypobaric tetracaine for hip surgery in lateral decubitus. Anesth. Anal., 51: 766 -773.

Kuusniemi, K.S., K.K. Pihlajama¨ki, M.T. Pitka¨nen and J.E. Korkeila, 1999. Lowdose bupivacaine: A comparison of hypobaric and near isobaric solutions for arthroscopy surgery of the knee. Anaesthesia, 54: 540-545.

Lui, A.C.P., T.Z. Polis and N.J. Cicutti, 1998. Densities of cerebrospinal fluid and spinal anaesthetic solutions in surgical patients at body temperature. Can. J. Anaesth., 45: 297-303.

Martin-Salvaj, G., E. Van Gessel, A. Forster, A. Schweizer, I. Iselin-Chaves and Z. Gamulin, 1994. Influence of duration of lateral decubitus on the spread of hyperbaric tetracaine during spinal anesthesia: A prospective time-response study. Anesth. Anal., 79: 1107-1112.

Racle, J.P., L. Jourdren, A. Benkhadra, J.Y. Poy and F. Fockenier, 1988. Effect of adding sodium bicarbonate to bupivacaine for spinal anesthesia in elderly patients. Anesth. Anal., 67: 570-573.

Richardson, M.G. and R.N. Wissler, 1996. Density of lumbar cerebrospinal fluid in pregnant and nonpregnant humans. Anesthesiology, 85: 326-330.

Richardson, M.G., H.V. Collins and R.N. Wissler, 1998. Intrathecal hypobaric versus hyperbaric bupivacaine with morphine for cesarean section. Anesth. Anal., 87: 336-340.

Schiffer, E., E. Van Gessel, R. Fournier, A. Weber and Z. Gamulin, 2002. Cerebrospinal fluid density influences extent of plain bupivacaine spinal anesthesia. Anesthesiology, 96: 1325-1330.

Van Gessel, E.F., A. Forster and Z. Gamulin, 1989. Surgical repair of hip fracture using continuous spinal anesthesia: Comparison of hypobaric solutions of tetracaine and bupivacaine. Anesth. Anal., 68: 276-281.

Van Gessel, E.F., A. Forster, A. Schweizer and Z. Gamulin, 1991. Comparisonof hypobaric, hyperbaric and isobaric solutions of bupivacaine during continuous spinal anesthesia. Anesth. Anal., 72: 779-784.