J Anesth (2011) 25:213–218
DOI 10.1007/s00540-010-1082-3

ORIGINAL ARTICLE

The effect of body mass index on the spread of spinal block in patients with rheumatoid arthritis

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Received: 1 July 2010 / Accepted: 5 December 2010 / Published online: 31 December 2010

Abstract
Purpose Body mass index (BMI) has a significant effect on the spread of sensory spinal block in rheumatoid patients. We tried to achieve the same spread of spinal block for patients in three different BMI groups and, on the basis of the results from a preliminary study, used a simple method feasible for clinical practice. We hypothesized that BMI-related inverse dosing of plain bupivacaine according to low, normal, and high BMI would result in no difference in block extent.
Methods Together 75 patients with seropositive rheumatoid arthritis were included in three equal-sized groups according to BMI: low (<23 kg/m^2), normal (23–28 kg/m^2), and high (>28 kg/m^2). Spinal anesthesia was induced with plain bupivacaine using doses 3.3, 3.0, and 2.7 ml, respectively. The spread of sensory block was recorded 30 min after injection of bupivacaine by use of a pin-prick test and a cold ice-filled container.
Results Spreads of sensory block were different in low, normal, and high BMI groups (mean (SD); 14.0 (2.6), 14.5 (2.5), and 16.3 (2.5) dermatomes, respectively, $P = 0.006$) because of greater block extent in the high-BMI group.
Conclusions Despite three-step dosing of plain bupivacaine inversely related to BMI (low, normal, or high), comparable block extent was not achieved because of greater spread in the high-BMI group. Adjustment of plain bupivacaine dose according to BMI could be used to achieve a more predictable spread of spinal block, but further reduction of dose is needed in patients with high BMI.

Keywords Body mass index · Bupivacaine · Rheumatoid arthritis · Spinal block

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Introduction

Despite the unpredictability of the spread of spinal anesthesia [1], patient-dependent factors, for example body mass index (BMI) [2–4], weight, height [2], age [5], and volume of cerebrospinal fluid [6, 7], have been pointed out as determinants of the sensory block level in surgical patients. Leino et al. [8] have recently observed a greater spread of spinal block, and a greater effect of BMI on the spread of spinal block in rheumatoid patients compared with non-rheumatoid control patients [8]. In obese rheumatoid patients both these effects may be superimposed causing significant adversities [9] and this might be deleterious in rheumatoid patients given the increased prevalence of cardiovascular disease in this cohort [10]. On the other hand, spinal block with standard dosing may give an unexpectedly low and inadequate spread in rheumatoid patients with a low BMI. This, in turn, could lead to conversion of an inadequate block to general anesthesia with potential problems. Consequently, predictability of peak sensory block height should increase patient convenience and perioperative patient safety.

With this objective in mind, we tried to achieve the same spread of spinal anesthesia despite different BMI and designed a simple tool for this purpose. Administering a standard dose (15 mg) of plain bupivacaine used in our clinical practice for patients with normal BMI (23–28 kg/m^2), reducing the dose by 10% for patients with increased BMI, and increasing the dose by 10% for those with low BMI seemed to work quite well in our preliminary study. Thus, our study hypothesis was that division of patients to three groups according to BMI and group-related inverse dosing of plain bupivacaine would result in even spread of sensory block in all rheumatoid patients.

Materials and methods

We included 75 American Society of Anesthesiologists I–IV patients with seropositive rheumatoid arthritis undergoing lower limb surgery under spinal anesthesia. Diagnosis of seropositive rheumatoid arthritis was made by a specialist in rheumatoid diseases according to the revised criteria of the American Rheumatism Association (1987) and the patients were operated on because of their rheumatoid disease. The patients were divided into groups according to BMI as follows: patients with BMI <23 kg/m^2 were named as group L (low BMI), patients with BMI 23–28 kg/m^2 as group N (normal BMI), and those with BMI >28 kg/m^2 as group H (high BMI). Neurological disease, mental disturbance, deformities of the spinal column caused by other than rheumatoid arthritis, sensitivity to local anesthetics, or any other contraindication for spinal anesthesia were defined as exclusion criteria. The study protocol was reviewed and approved by the Ethics Committee of Turku University Hospital and all patients gave their informed consent.

Diazepam 5–10 mg was used for premedication depending on the patient's age and weight. Monitoring in the operating room consisted of continuous electrocardiogram, blood pressure measurement at 5-min intervals, and continuous pulse oximetry. Ringer's solution was infused to all patients and etilefrine 2–3 mg was given intravenously when blood pressure decreased below 90 mm Hg, or earlier if clinically judged to be needed. When heart rate decreased below 50 beats/min glycopyrrolate 0.2 mg was given intravenously. Persistent bradycardia was treated with atropine 0.5 mg.

Using an aseptic technique, dural puncture was performed in the midline at the L3-4 interspace with the patients in the lateral decubitus position and the surgical side up. The operating table was in the horizontal position. Based on our preliminary study we administered plain bupivacaine (5 mg/mL) 3.3 mL (=16.5 mg) to patients in group L (BMI <23 kg/m^2), 3.0 mL (=15 mg) to patients in group N (BMI 23–28 kg/m^2), and 2.7 mL (=13.5 mg) to those in group H (BMI >28 kg/m^2). There were two reasons for this choice. We sought a simple method easy enough to be applied in practice to reach the same block level in all patients. In addition, difficulties in the preliminary study to determine feasible individual doses, especially for patients with high BMI, led to this choice. Bupivacaine injection was performed with a 29-gauge Quincke spinal needle with an introducer (Becton–Dickinson, Madrid, Spain) in 20 s after free flow of clear cerebrospinal fluid (CSF) was noticed. Barbotage or aspiration was not used. The patients were kept in the lateral position for 5 min, after which they were turned supine. The supine position was maintained for 25 min.

The maximum sensory block level was defined as the loss of sharp sensation to a pin-prick test and loss of cold sensation by using a cold ice-filled container. The peak sensory block level was recorded with these two methods 30 min from the dural puncture in the midclavicular line on the surgical side. To attenuate the effect of patient size on dermatome identification a stretchable rubber band with markings for every dermatome from jugulum (C4) to umbilicus (Th10) was positioned on the midline of the patient. The band stretches evenly according to patient size and maintains matching between markings of jugulum and umbilus and the anatomical landmarks, thus facilitating the identification of anesthetized dermatomes. The total number of dermatomes affected was recorded from sacral segments (S5) on.

ANOVA and the chi-squared test were used for analysis of demographic data and the level of sensory block. The effect of study group and patient-dependent factors were analyzed with a general linear model. The model had patient group, length, and BMI as fixed effects. We also performed a second analysis in which BMI was replaced with weight to evaluate the effect of weight in addition to BMI. Two separate analyses were needed because of the dependency of BMI on weight, i.e. BMI includes weight and simultaneous use of these factors in a single analysis of a general linear model is inappropriate and might blunt the results. A 95% confidence limit and a tolerance limit of two dermatomes (clinical significance) were used. A P value of less than 0.05 was defined as statistically significant. Data are expressed as mean (SD). 95% confident intervals (CI 95%) are provided for maximum extent of sensory spinal block.

Results

The study groups were comparable with regard to gender, age, and height, but different with regard to weight and BMI, as expected (Table 1). The operated joints of every patient were of Larsen score 3 or greater, indicating a developed seropositive rheumatoid disease.

Table 1 Patient characteristics

	Group L (BMI <23 kg/m^2)	Group N (BMI 23–28 kg/m^2)	Group H (BMI >28 kg/m^2)	*P*
Women/men	23/2	17/8	19/6	0.10
Age (years)	52.9 (11.5)	58.4 (12.2)	59.6 (14.1)	0.14
Height (cm)	163 (6.6)	167 (10.3)	167 (8.7)	0.14
Weight (kg)	54.8 (5.7)	71.2 (10.7)	88.9 (13.2)	<0.0001
BMI (kg/m^2)	20.6 (1.4)	25.3 (1.5)	31.8 (3.1)	<0.0001

Data are given as mean (SD). Weight and body mass index (BMI) were different between the groups, as determined by the protocol

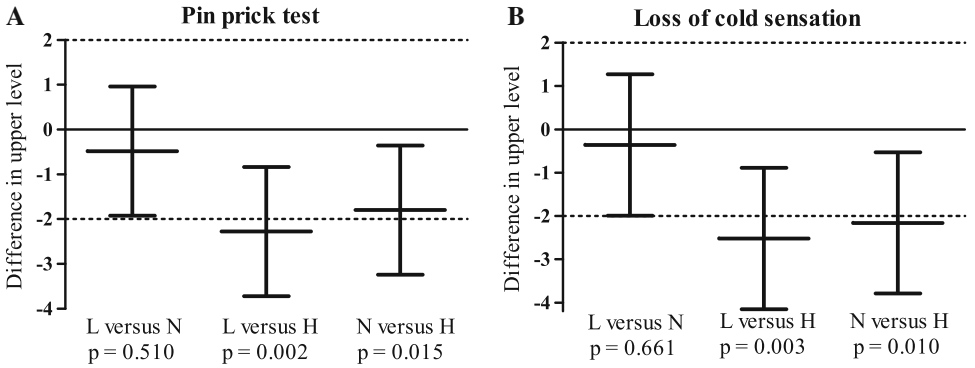

Fig. 1 Comparison between low (L), normal (N), and high (H) body mass index (BMI) groups assessed with a pin-prick test (**a**) and with loss of cold sensation (**b**). The difference in the spread of sensory block between the groups expressed as dermatomes is presented as means and 95% confidence limits (*error bars*). *Dashed lines* represent the level of clinical significance (±2 dermatomes) chosen for the analysis. The maximum sensory block height at 30 min was different between the groups because of greater spread of block in the H group ($P = 0.006$ for the pin-prick test and loss of cold sensation). The *P* values of the individual comparisons between the groups are expressed below the *error bars*. Equivalence was achieved between the L and N groups in terms of the predetermined clinical significance of two dermatomes

All anesthesia was uneventful except for the occurrence of hypotension and bradycardia. Etilefrine was administered to three patients in group L and to seven patients in group H and it was not needed in group N. Bradycardia was treated in two patients in group L and in one patient in groups N and H.

The extent of sensory spinal anesthesia was 14.0 (2.6) (CI 95% 13.0–15.1) dermatomes in group L, 14.5 (2.5) (13.5–15.5) dermatomes in group N, and 16.3 (2.5) (15.3–17.3) in group H from the fifth sacral segments on assessment with a pin-prick test ($P = 0.006$). The values for loss of cold sensation were 14.8 (2.6) (13.7–15.8), 15.1 (2.9) (14.0–16.3), and 17.3 (3.1) (16.1–18.5) dermatomes, respectively ($P = 0.006$). The *P* values for individual comparisons of different sensory block height between the groups are given in Fig. 1. As presented in Table 2 (the first data run including BMI) and Table 3 (the second data run, in which BMI was replaced by weight), study group had no effect on the spread of block in either of these analyses. Greater BMI and less height, when included in the same analysis together, favored cephalad spread of the block (Table 2). Greater weight and less height also promoted higher sensory peak level of the block in the second data run (Table 3). The individual BMIs of the patients according to the groups are plotted against the upper level of sensory spinal anesthesia in Fig. 2.

Table 2 Statistical significance of variables tested for affecting the spread of sensory block

	A *P* value	
	Pin-prick test	Loss of cold sensation
Group	0.874	0.801
Height	0.007*	0.001*
BMI	0.032*	0.027*

Results from the first data run with general linear model, where body mass index (BMI) was used. Less height and greater BMI favored more extensive spread of the block (*$P < 0.05$). Here the group means the combined effect of allocation of patients according to BMI to three groups and administering a different bupivacaine dose to each group

Discussion

This study was inspired by the earlier observation that BMI had a greater effect on the spread of spinal block in rheumatoid patients than in non-rheumatoid control patients [8].

Our hypothesis failed, because division of patients to three groups according to BMI and the group-related inverse dosing of plain bupivacaine still resulted in difference in the peak sensory block level between the groups at 30 min. This was because of the greater spread of block in the high BMI group than in the other groups. Clinically, however, we were able to counteract the effect of BMI and achieve an even spread of spinal block between the low and normal BMI groups by use of a simple method.

Studies on the effect of dose and volume on the spread of intrathecal plain bupivacaine have given conflicting results [11–13], although it is generally believed there is a difference primarily related to dose rather than volume [14]. None of these studies was performed with rheumatoid patients and the effect of BMI was ignored. Our preliminary studies indicated that BMI-guided change of dose (and simultaneous volume) by 10% from our standard dose of 15 mg would result in equal block height.

Even though the doses used in the study were based on preliminary findings, we underestimated the effect of BMI in the upper range of BMI. We probably could have achieved more even distribution of sensory block simply by reducing the bupivacaine dose in the high BMI group.

Table 3 Statistical significance of variables tested for affecting the spread of sensory block

	A *P* value	
	Pin-prick test	Loss of cold sensation
Group	0.902	0.850
Height	0.002*	0.001*
Weight	0.030*	0.028*

Results from the second data run with general linear model, where body mass index was replaced with weight. Less length and greater weight favored more extensive spread of the block (*$P < 0.05$). Here the group means the combined effect of allocation of patients according to BMI to three groups and administering a different bupivacaine dose to each group

We could also have used truly individual dosing and administered plain bupivacaine inversely related to BMI from the patient with the lowest BMI to the patient with the highest BMI. Our recent study with rheumatoid patients suggested positive linear correlation between BMI and block height in rheumatoid patients [8]. However, we sought a simple method easy enough to be used in practice and, despite the recent findings [8], had problems with negative BMI-related inverse dosing in a preliminary study. Estimation of individual bupivacaine dosing in the upper range of the BMI scale proved a challenging task. Consequently, to keep it simple we eventually chose three groups with a fixed dose for each group. It would be worth studying whether individual BMI-related inverse dosing based on a positive linear correlation between BMI and block height would work better than the method we used.

With different study arrangements and performing a true dose-defining study it could also be possible to construct a correction coefficient or correction equation to achieve the same sensory block height despite differences in BMI. Such a study might result in equations too complex to be easily adopted in every day practice.

Our patients included only one close to the definition of morbidly obese (BMI 39.6 kg/m^2), who had the highest sensory block level. On the assumption that the dose reduction needed to achieve a standard block height with any method is significant in patients with high BMI, the following consequences related to the duration of the anesthesia must be taken into account. We did not assess block duration in this study.

The interpretation of our statistical data concerning BMI is that even though there was a difference between the groups in block height, the group itself was a very poor determinant of the spread of block. Of note, the group in this circumstance means the combined effect of allocation of patients according to BMI to three groups and administering a different bupivacaine dose to each group. BMI and weight were both significantly contributing to the extent of the block despite the BMI-guided administration of bupivacaine. Their effect was almost equal. Individual

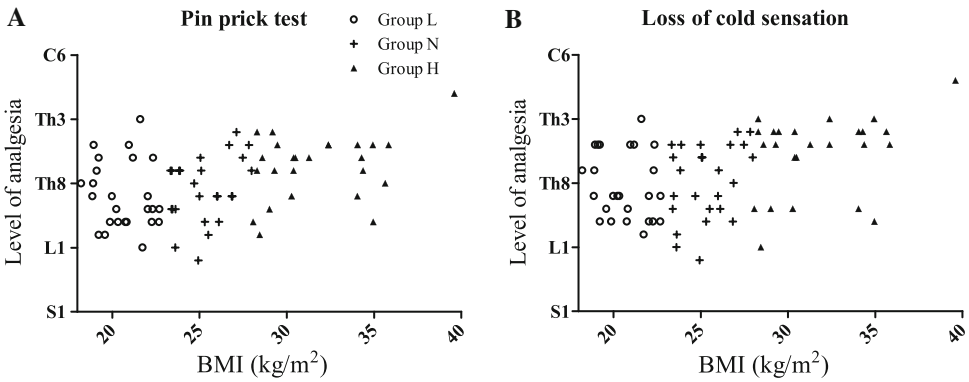

Fig. 2 Body mass indexes (BMIs) of individual patients according to groups (low, normal, and high BMI) plotted against the upper level of sensory spinal anesthesia at 30 min. Sensory block was assessed by use of two methods: pin-prick test (**a**) and loss of cold sensation (**b**)

comparisons between two groups (Fig. 1) revealed that we managed to achieve quite an even distribution of sensory block between the groups of low and normal BMI. We achieved equivalence in this comparison, which is a sign of a true similarity between these two groups in terms of the predetermined clinical significance of two dermatomes. Absence of a significant *P* value may wrongly imply there is no difference between the groups [15, 16].

The height is a patient-dependent factor that has been shown to contribute to block height in only one earlier study using plain bupivacaine [2]. Using length of spinal canal instead of height strengthens the correlation [17]. The height preserved statistical significance despite division of patients according to BMI in this study. This is an expected finding, because length and BMI or length and weight do not correlate as strongly as BMI and weight.

We assessed sensory block height only at 30 min after injection of bupivacaine. Intrathecal local anesthetics usually stop spreading before the measurement time point used, but there is some variability and mean times above 30 min to achieve the maximum block have been observed [2, 4]. In addition, a possible start of regression of the block before 30 min could not be recorded. There is, as far as we are aware, nothing that would suggest differences in the mean time to achieve a maximum block height or regression of the block in rheumatoid patients compared with normal patients. However, interpretation of our data is limited by the use of the single time point of 30 min.

The determinant that makes the spread of spinal block vary at the extremes of BMI is not thoroughly proven. The available data suggest that the volume of CSF [6, 7], which acts as the diluent for the local anesthetic agent injected during spinal anesthesia, plays a major role. Spinal block is quite reproducible in an individual patient [18], but patient-related characteristics, for example age, weight, BMI, and height, create interindividual variation acting through CSF volume so that lower volume promotes greater spread of block [1]. It is probable that inflammatory and degenerative changes observed in the thoracic [19, 20] and lumbar [21–24] rheumatoid spine may narrow the lumbosacral and thoracic subarachnoid space reducing CSF volume, thus contributing to the peak sensory block level.

We conclude that despite three-step dosing of plain bupivacaine inversely related to BMI (low, normal, or high), similar block extent was not achieved 30 min after injection of bupivacaine, because of greater spread in the high BMI group. Adjustment of plain bupivacaine dose according to BMI might be used to achieve even spread of spinal block, but further studies are warranted.

Acknowledgments There are no research grants or other financial support related to this study.

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