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Comparison of equipotent doses of ropivacaine-fentanyl and bupivacaine-fentanyl in spinal anaesthesia for lower abdominal surgery

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SUMMARY

The aim of this randomised, double-blind study was to compare equipotent doses of plain ropivacaine and bupivacaine (19.5 mg and 13 mg respectively), both with fentanyl 20 μg, for spinal anaesthesia in lower abdominal surgery.

After written informed consent had been obtained, 52 ASA I to II male patients scheduled for lower abdominal surgery were randomly assigned to receive intrathecal plain ropivacaine 19.5 mg with fentanyl 20 μg (group R, n=26) or plain bupivacaine 13 mg with fentanyl 20 μg (group B, n=26) in 3 ml. The level and duration of sensory block, intensity and duration of motor block, time to mobilise and patient satisfaction were recorded.

All patients achieved sensory block to T10 or higher. The level of sensory block was significantly higher in group B (T4 [T3 to T7] vs T7 [T4 to T9], P <0.05). There was no difference in the onset time of motor block. The duration of motor block (Bromage score >0) was shorter in group R (139±39 minutes vs group B 182±46 minutes, P <0.05). The duration and intensity of complete motor block (Bromage score=3) were also shorter in group R (90±25 minutes vs 130±40 minutes, P <0.05).

We conclude that plain ropivacaine 19.5 mg plus fentanyl 20 μg is associated with a lower level of sensory block and a shorter duration of motor block when compared to bupivacaine 13 mg plus fentanyl 20 μg for spinal anaesthesia in lower abdominal surgery.

Key Words: spinal anaesthesia, local anaesthetic, ropivacaine

Reducing the duration of hospital stay is becoming more important, especially for in-patients. Therefore in operations performed under spinal anaesthesia, early ambulation as a consequence of a shorter duration of motor block is considered desirable[1]. In the past, hyperbaric lignocaine 50 mg.ml^{-1} was commonly used for spinal anaesthesia for short surgical procedures, but its use has declined because of concerns about cauda equina syndrome and transient neurological symptoms[2]. Local anaesthetics currently used have a longer duration of action. Ropivacaine has been advocated as a drug with similar characteristics of block but with a shorter duration of motor block than bupivacaine and was initially considered to have similar potency to bupivacaine[3]. However, equivalent doses of ropivacaine and bupivacaine have now been identified for different operations, with bupivacaine appearing 1.4 to 1.68 times more potent than ropivacaine.

The addition of fentanyl to local anaesthetic has several advantages including a synergistic analgesic effect. Intrathecal opioids enhance analgesia from subtherapeutic doses of local anaesthetic and make it possible to achieve successful spinal anaesthesia using what would otherwise be an inadequate dose of local anaesthetic[4].

Whether the addition of fentanyl to local anaesthetic changes the potency ratio or the characteristics of blockade has not been examined, and most studies have involved orthopaedic surgery, with few involving lower abdominal surgery.

The study hypothesis was that at equipotent doses, as defined for the drugs without the addition of adjuncts, ropivacaine with fentanyl would result in earlier mobilisation compared with bupivacaine plus

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fentanyl in patients undergoing lower abdominal surgery.

METHODS

Fifty-two male patients of ASA physical status I to II, between 18 and 75 years of age and undergoing lower abdominal or urological surgery under spinal anaesthesia were recruited. All gave written informed consent for the study, which was approved by the local research ethics committee. Types of surgery included inguinal and incisional herniorrhaphies, bilateral varicocoelectomies and open prostate resections. Patients were excluded if they had a known allergy to ropivacaine, bupivacaine or fentanyl or any contraindication to spinal anaesthesia.

Diazepam 5 to 10 mg was given orally one hour before spinal anaesthesia. The patients were continuously monitored with electrocardiography and pulse oximetry. Non-invasive blood pressure was recorded every five minutes in the operating room. Before spinal anaesthesia, an intravenous preload of 500 ml of lactated Ringer's solution was given over 10 minutes. The baseline mean arterial pressure and heart rate were determined from the average of three consecutive readings taken after the administration of fluids. The patients were placed in the right lateral position. A staff anaesthetist (EU), blinded to the choice of the study drug, performed all spinal blocks using a 25 gauge Whitacre needle via a midline approach at the second or third lumbar interspace. The patients were randomised and allocated with a sealed envelope technique to receive 2.6 ml ropivacaine (Naropine 0.75%, AstraZeneca, Turkey) 7.5 mg/ml (19.5 mg) with 0.4 ml of fentanyl 50 μg/ml (3 ml total) or 2.6 ml of bupivacaine (Marcaine 0.5%, AstraZeneca, Turkey) 5 mg/ml (13 mg) with 0.4 ml fentanyl 50 μg/ml (3 ml total). The anaesthetic solution was injected over 10 to 15 seconds without barbotage or aspiration. Immediately after the puncture, the patient was placed supine and the operating table was placed horizontal.

A staff anaesthetist (AY), blinded to the choice of the study drug, assessed sensory and motor block at timed intervals: 0, 5, 10, 15, 30, 45, 60, 90 and 120 minutes after injection. The assessments were continued at 30 minute intervals thereafter until the motor block had regressed completely (i.e. modified Bromage score=0).

Motor block of both legs was tested using a modified Bromage scale: 0=full movement; 1=inability to raise extended leg, can bend knee; 2=inability to bend knee, can flex ankle, 3=no movement.

The segmental level of sensory block to pin-prick was assessed on both sides. The operation was allowed to start once sensory block had reached at least T10 but general anaesthesia was induced if this had not occurred after 15 minutes.

Hypotension was defined as a decrease in mean arterial pressure of more than 30% from baseline and was treated with intravenous ephedrine 5 mg and lactated Ringer's solution as required. Bradycardia was defined as a heart rate <50 beats/minute. This was treated with intravenous atropine 0.5 mg as required. Intravenous fentanyl 50 μg was given if the patient complained of pain during the operation, but spinal anaesthesia was converted to general anaesthesia after three such boluses. All cases requiring general anaesthesia were excluded.

The end of the study period was defined as the longer of the time at which the sensory block had regressed below the T10 dermatome or at which the Bromage score was 0. The duration of motor block was defined as the time from intrathecal injection to the regression of motor block to Bromage score 0. Complete motor block was defined as a Bromage score of 3 and the duration of complete motor block was defined as the time from intrathecal injection to the regression of the block to a Bromage score of <3.

All patients had a follow-up visit on the day after the operation to assess sensory and motor function, post-dural puncture headache and transient neurological symptoms.

Statistical analysis

Sample size estimation (α=0.05 and β=0.1) indicated that 22 patients per group were needed to detect a 40 minute reduction in duration of motor block (modified Bromage score $\geq$1), this being equivalent to one standard deviation (SD) from pilot data.

In the case of continuous values, means (SD) are presented and the groups were compared using the t-test, but if the data were not normally distributed the Mann-Whitney U-test was used. Non-continuous numeric values are expressed as median [range] and were tested with the Mann-Whitney U-test. Binomial data were compared using chi-square or Fisher's exact test. Significant changes of sensory and motor block within the groups were tested with repeated measures of analysis of variance, with Dunn's test. Differences between the groups in sensory and motor block assessments were tested with the Mann-Whitney U-test. A P value <0.05 was considered statistically significant.

RESULTS

The groups were comparable with respect to age, height, weight and ASA physical status (Table 1). One patient in each group was withdrawn because they required general anaesthesia, leaving 25 patients in each group. There was no significant difference in the type and duration of surgery (Table 1).

The groups did not differ in haemodynamic parameters in the operating room (Table 2). Intraoperative hypotension requiring treatment with ephedrine occurred in eight of the patients in the bupivacaine group (32%) and five of the patients in the ropivacaine group (20%) (P=non-significant). The number needing treatment with atropine for bradycardia did not differ (Table 2).

The details of motor block are shown in Table 3. The primary outcome, the duration of motor block, was significantly shorter (P=0.010) in the ropivacaine group, as was the duration of complete motor block and the number of patients with complete motor block (Bromage=3). The patients mobilised sooner in the ropivacaine group. Cephalad spread of sensory block was higher with bupivacaine than ropivacaine (Table 3 and Figure 1). The duration of sensory blockade at the level of at least T10 did not significantly differ between groups.

No patient had pruritus, shivering, respiratory depression or nausea and vomiting. No patient had residual neurological deficit, post-dural puncture headache or transient neurological symptoms at the postoperative follow-up.

TABLE 1
Demographic characteristics of patients and duration of surgery

	Bupivacaine	Ropivacaine
Patients (n)	25	25
Age (y)	44 (16)	41 (15)
Weight (kg)	81 (11)	79 (10)
Height (cm)	174 (7)	175 (6.5)
ASA (I/II)	8/17	10/15
Duration of operation (min)	91 (25)	90 (30)
Surgical speciaity		
General surgery (n)	14	13
Urology (n)	11	12

Data are mean (SD). ASA=American Society of Anesthesiologists physical status.

TABLE 2
Haemodynamics in the operating room

	Bupivacaine	Ropivacaine
HR at start	81±10 (65-95)	76±13 (57-96)
Maximum HR	83±11 (62-97)	80±13 (60-98)
Minimum HR	71±10 (57-93)	69±11 (52-85)
Bradycardia, n (%)	2 (8%)	3 (12%)
MAP at start	87±8 (65-110)	85±7 (78-95)
Maximum MAP	83±9 (63-100)	82±9 (66-92)
Minimum MAP	77±9 (51-90)	78±8 (65-89)

HR=heart rate in beats/minute, MAP=mean arterial pressure (mmHg). Data are mean (SD) or number (%). No differences between the groups.

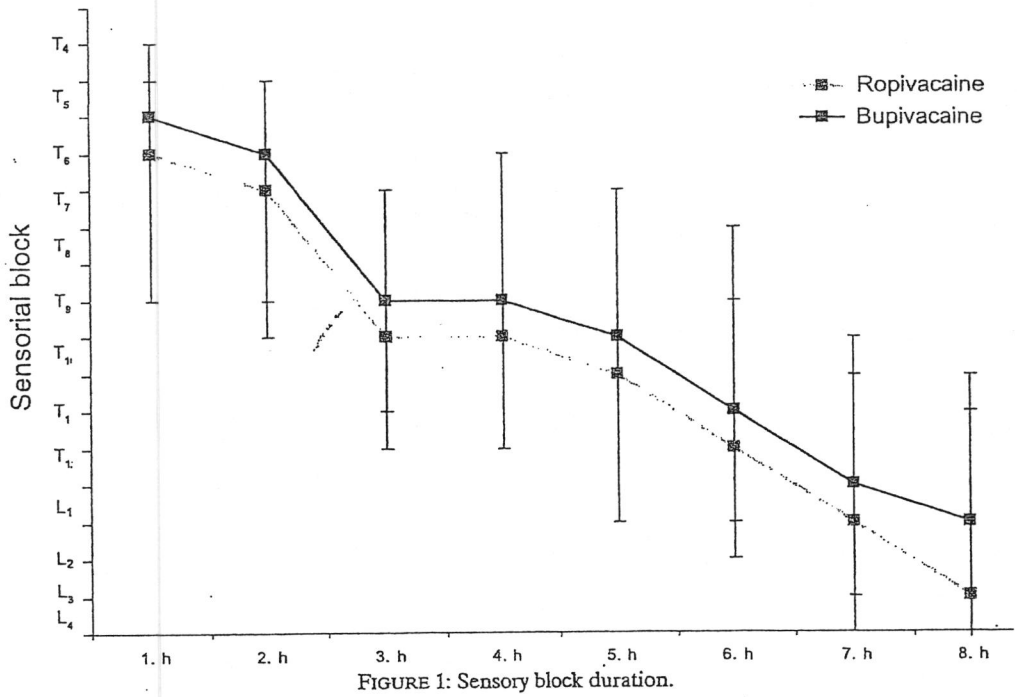


FIGURE 1: Sensory block duration.

TABLE 3
Characteristics of neural block

	Bupivacaine	Ropivacaine	*P*
Cephalad spread of sensory block	T4 (T3-T7)	T7 (T4-T9)	<0.05
Onset time of sensory block T10 (min)	10 (4.5)	9 (4)	NS
No of patients with Bromage 3	24 (96%)	17 (68%)	<0.05
Duration of motor block (min)	182 (46)	139 (39)	<0.05
Duration of complete motor block (min)	130 (40)	90 (25)	<0.05
Time to mobilise (min)	300 (65)	255 (55)	<0.05
Duration of sensory block at T10 (min)	185 (40)	160 (40)	NS

Data are median (min-max) or mean (SD) or number (%). NS=not significant.

DISCUSSION

We have shown that despite administration of apparently equipotent doses (19.5 mg vs 13 mg [ratio 1.5:1], respectively), plain ropivacaine plus fentanyl 20 μg was associated with a shorter duration of motor block than plain bupivacaine plus fentanyl 20 μg. Another interesting finding of the study was that these 'equipotent' doses produced different sensory block levels.

The hypothesis of the study was that the two regimens would result in different times to mobilisation as a result of more rapid recovery of motor function with ropivacaine. This is important after surgery of short and intermediate duration but the best drugs and combinations to achieve this goal are controversial. In the past, the short-acting local anaesthetic hyperbaric lignocaine 50 mg.ml^{-1} was used for short surgical procedures and recovery from complete motor block occurred after approximately two hours[5]. However, its use has declined because of concerns about cauda equina syndrome and transient neurological symptoms[2]. This aroused interest in alternative regimens producing spinal anaesthesia of relatively short duration. The potential suitability of ropivacaine in this respect was suggested by in vitro and animal studies[6,7] and has since been confirmed by clinical studies showing that spinal ropivacaine is associated with motor block of shorter duration than bupivacaine[8,9]. Our clinical results are in agreement with these findings.

The shorter duration of motor block with spinal ropivacaine compared with bupivacaine can be explained by two possible mechanisms: a difference in potency or a difference in differential sensory and motor block. Some preliminary studies compared the same (i.e. not equipotent) doses of these drugs and noted that ropivacaine was associated with a shorter duration of action but also inadequate block in some patients[10,11], suggesting a difference in potency[12]. Subsequently, clinical trials of both epidural[13,14] and spinal[15,16] administration found that ropivacaine was less potent than bupivacaine. Two studies reported that intrathecal ropivacaine 12 mg produced similar sensory and motor block to 8 mg bupivacaine[10,17] and equipotent doses of ropivacaine and bupivacaine were also identified by others[18,19].

A second, but much less likely explanation is that in the study of Camorcia et al[18], 0.5% bupivacaine was compared with 0.5% ropivacaine using different volumes of the same concentration and also saline (which could cause a difference in baricity), whereas in our study we compared the same volume of different concentrations but without the addition of saline. The study was not designed to investigate this matter. With respect to possible differences in motor block, despite use of apparent equipotent doses (ratio of 1:1.5) including the same dose of fentanyl with each drug, we found that ropivacaine is associated with a shorter duration of block. This can be explained either by differences in differential sensory and motor block or a difference in actual potency using this dose ratio.

There are conflicting results as to appropriate doses of intrathecal ropivacaine for various settings. Successful blocks after ropivacaine 12 mg have been described in arthroscopy[10] and unilateral spinal anaesthesia[20]. On the other hand, for operations in which it is necessary to achieve a higher block, even much higher doses have proved insufficient. Wahedi et al[20] had a failure rate of 20% with intrathecal plain ropivacaine 15 mg (3 ml of 5 mg/ml solution) in abdominal surgery and Malinovsky et al[11] found 16% of spinal anaesthetics from plain ropivacaine 15 mg (5 ml of 3 mg/ml solution) inadequate for urological surgery. In our study, patients had lower abdominal surgery, which requires mid-thoracic block. Plain ropivacaine 19.5 mg plus fentanyl 20 μg was only inadequate in one patient. There are two major differences between our study and the studies reporting high rates of inadequate block; we used 30% more ropivacaine and fentanyl was added. McNamee et al found plain ropivacaine 18.75 mg (2.5 ml of 7.5 mg.ml^{-1} solution) or 17.5 mg (3.5 ml of 5 mg.ml^{-1} solution) provided adequate spinal anaesthesia for 98 and 100% of patients respectively[3,21]. Furthermore, it has also been reported that even after higher doses (20 mg), 30% of patients undergoing caesarean section have an

inadequate block[22]. It appears that for sensory blocks to T10 or higher, a dose of at least 15 mg of plain ropivacaine is required. In our study, 19.5 mg of ropivacaine plus fentanyl 20 μg was sufficient for low abdominal surgery, despite a lower maximum sensory spread than from bupivacaine 13 mg plus fentanyl 20 μg.

The baricity of the solution also influences intrathecal spread of local anaesthetics. We chose to study plain solutions of both drugs because hyperbaric ropivacaine is not commercially available.

Experience with intrathecal bupivacaine has shown that the addition of fentanyl increases the level and duration of sensory block, without altering motor block characteristics[4]. This allows the use of smaller doses of local anaesthetic and consequently a shorter duration of motor block, a lower incidence of excessively high block[23] and a lower incidence of hypotension[24]. The effects of adding fentanyl to ropivacaine have not been as well examined. In patients undergoing day surgery, Kallio et al[25] found that hyperbaric ropivacaine 10 mg plus fentanyl 20 μg resulted in similar onset and duration to hyperbaric ropivacaine 15 mg but that patients mobilised faster. However, our study was not designed to compare plain and hyperbaric ropivacaine, with or without fentanyl. Both our study regimens using plain solutions provided good cardiovascular stability and a low incidence of bradycardia, as previously reported[3,26].

This is one of the first studies to compare apparently equipotent doses of intrathecal ropivacaine and bupivacaine, based on recent research assessing the potency of these drugs, and to also examine the effects of the addition of an opioid. It did not confirm that the dose ratio used was equipotent, at least when combined with fentanyl. This re-opens the debate about in what ratio of these two drugs should be used to obtain similar sensory block.

In conclusion, we found that plain ropivacaine 19.5 mg with fentanyl 20 μg provided effective spinal anaesthesia for lower abdominal surgery. In spite of a significant difference in the upper level of sensory block, the quality of block was sufficient and similar to that from plain bupivacaine 13 mg with fentanyl 20 μg, but the mean duration of motor block and the time to patient mobilisation after ropivacaine spinal anaesthesia was shorter. Therefore, intrathecal ropivacaine and fentanyl combinations can be recommended when these are important clinical aims. Combinations using bupivacaine appear the method of choice for operations in which a complete motor block and a longer duration of block is necessary.

REFERENCES

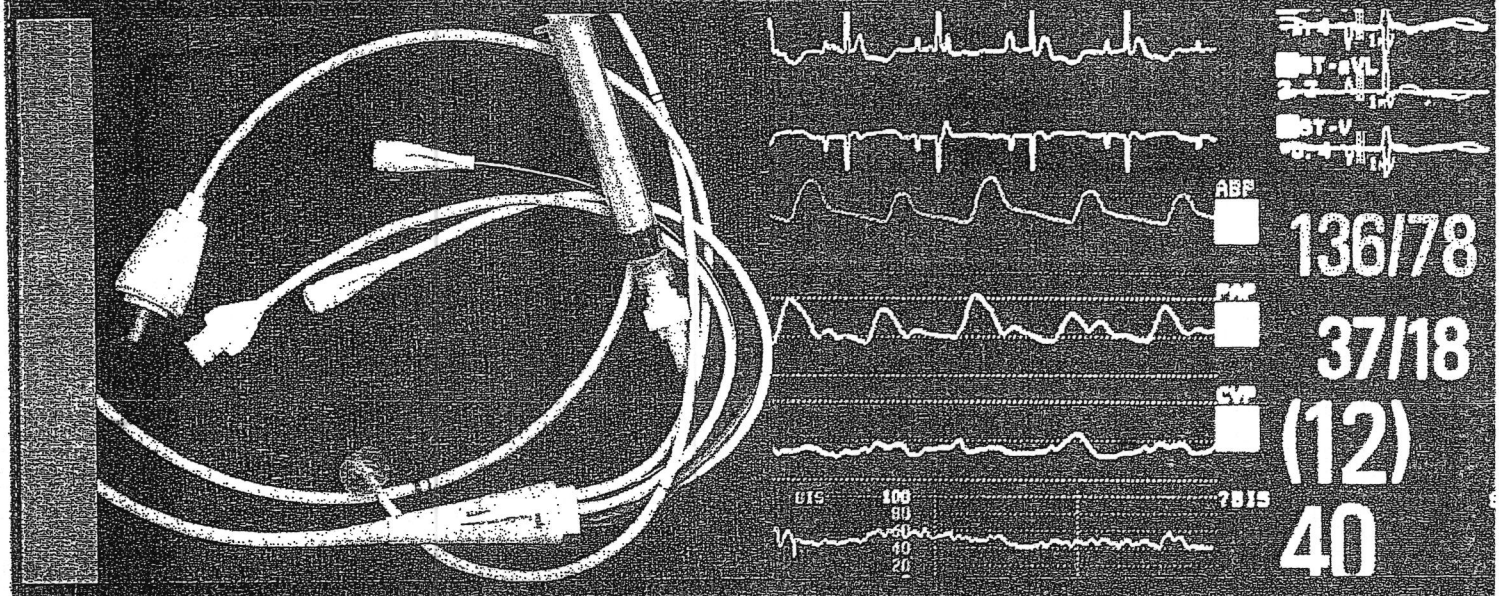
1. van Kleef JW, Veering BT, Burm AG. Spinal anesthesia with ropivacaine: a double-blind study on the efficacy and safety of 0.5% and 0.75% solutions in patients undergoing minor lower limb surgery. Anesth Analg 1994; 78:1125-1130.
2. Gaiser RR. Should intrathecal lidocaine be used in the 21st century? J Clin Anesth 2000; 12:476-481.
3. McNamee DA, McClelland AM, Scott S, Milligan KR, Westman L, Gustafsson U. Spinal anaesthesia: comparison of plain ropivacaine 5 mg.ml^{-1} with bupivacaine 5 mg.ml^{-1} for major orthopaedic surgery. Br J Anaesth 2002; 89:702-706.
4. Ben-David B, Solomon E, Levin H, Admoni H, Goldik Z. Intrathecal fentanyl with small-dose dilute bupivacaine: better anesthesia without prolonging recovery. Anesth Analg 1997; 85:560-565.
5. Markey JR, Montiague R, Winnie AP. A comparative efficacy study of hyperbaric 5% lidocaine and 1.5% lidocaine for spinal anesthesia. Anesth Analg 1997; 85:1105-1107.
6. Bader AM, Datta S, Flanagan H, Covino BG. Comparison of bupivacaine- and ropivacaine-induced conduction blockade in the isolated rabbit vagus nerve. Anesth Analg 1989; 68:724-727.
7. Feldman HS, Covino BG. Comparative motor-blocking effects of bupivacaine and ropivacaine, a new amino amide local anesthetic, in the rat and dog. Anesth Analg 1988; 67:1047-1052.
8. Ogun CO, Kirgiz EN, Duman A, Okesli S, Akyurek C. Comparison of intrathecal isobaric bupivacaine-morphine and ropivacaine-morphine for caesarean delivery. Br J Anaesth 2003; 90:659-664.
9. Lee YY, Ngan Kee WD, Muchhal K, Chan CK. Randomized double-blind comparison of ropivacaine-fentanyl and bupivacaine-fentanyl for spinal anesthesia for urological surgery. Acta Anaesthesiol Scand 2005; 49:1477-1482.
10. Gautier PE, De Kock M, Van Steenberge A, Poth N, Lahaye-Goffart B, Fanard L et al. Intrathecal ropivacaine for ambulatory surgery. Anesthesiology 1999; 91:1239-1245.
11. Malinovsky JM, Charles F, Kick O, Lepage JY, Malinge M, Cozian A et al. Intrathecal anesthesia: ropivacaine versus bupivacaine. Anesth Analg 2000; 91:1457-1460.
12. Wildsmith JA, Brown DT, Paul D, Johnson S. Structure-activity relationships in differential nerve block at high and low frequency stimulation. Br J Anaesth 1989; 63:444-452.
13. Polley LS, Columb MO, Naughton NN, Wagner DS, van de Ven CJ. Relative analgesic potencies of ropivacaine and bupivacaine for epidural analgesia in labor: implications for therapeutic indexes. Anesthesiology 1999; 90:944-950.
14. Capogna G, Celleno D, Fusco P, Lyons G, Columb M. Relative potencies of bupivacaine and ropivacaine for analgesia in labour. Br J Anaesth 1999; 82:371-373.
15. McDonald SB, Liu SS, Kopacz DJ, Stephenson CA. Hyperbaric spinal ropivacaine: a comparison to bupivacaine in volunteers. Anesthesiology 1999; 90:971-977.
16. Camorcia M, Capogna G, Columb MO. Minimum local analgesic doses of ropivacaine, levobupivacaine, and bupivacaine for intrathecal labor analgesia. Anesthesiology 2005; 102:646-650.
17. Casati A, Moizo E, Marchetti C, Vinciguerra F. A prospective, randomized, double-blind comparison of unilateral spinal anesthesia with hyperbaric bupivacaine, ropivacaine, or levobupivacaine for inguinal herniorrhaphy. Anesth Analg 2004; 99:1387-1392.

18. Camorcia M, Capogna G, Berritta C, Columb MO. The relative potencies for motor block after intrathecal ropivacaine, levobupivacaine, and bupivacaine. Anesth Analg 2007; 104:904-907.
19. Kallio H, Snäll EV, Kero MP, Rosenberg PH. A comparison of intrathecal plain solutions containing ropivacaine 20 or 15 mg versus bupivacaine 10 mg. Anesth Analg 2004; 99:713-717.
20. Wahedi W, Nolte H, Klein P. Ropivacain zur Spinalanästhesie: Eine Dosisfindungsstudie. Anaesthetist 1996; 45:737-744.
21. McNamee DA, Parks L, McClelland AM, Scott S, Milligan KR, Ahlen K et al. Intrathecal ropivacaine for total hip arthroplasty: double-blind comparative study with isobaric 7.5 mg ml^{-1} and 10 mg ml^{-1} solutions. Br J Anaesth 2002; 87:743-747.
22. Khaw KS, Ngan Kee WD, Wong EL, Liu JY, Chung R. Spinal ropivacaine for cesarean section: a dose-finding study. Anesthesiology 2001; 95:1346-1350.
23. Ben-David B, Frankel R, Arzumonov T, Marchevsky Y, Volpin G. Minidose bupivacaine-fentanyl spinal anesthesia for surgical repair of hip fracture in the aged. Anesthesiology 2000; 92:6-10.
24. Martyr JW, Stannard KJ, Gillespie G. Spinal-induced hypotension in elderly patients with hip fracture. A comparison of glucose-free bupivacaine with glucose-free bupivacaine and fentanyl. Anaesth Intensive Care 2005; 33:64-68.
25. Kallio H, Snall EV, Suvanto SHJ, Tuomas CA, Iivonen MK, Pokki JP et al. Spinal hyperbaric ropivacaine-fentanyl for day-surgery. Reg Anesth Pain Med 2005; 30:48-54.
26. Kallio H, Snäll EV, Tuomas CA, Rosenberg PH. Comparison of hyperbaric and plain ropivacaine 15 mg in spinal anaesthesia for lower limb surgery. Br J Anaesth 2004; 93:664-669.

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