Combined spinal epidural block versus spinal and epidural block for orthopaedic surgery

Björn Holmström MD,* Kjellfrid Laugaland MD,†
Narinder Rawal MD PhD,‡ Sune Hallberg MD§

In a controlled study a single segment combined spinal epidural (CSE) block was compared with spinal or epidural block for major orthopaedic surgery. Seventy-five patients, age 52–86 yr, were randomly assigned to receive one of the three blocks. Bupivacaine 0.5% was used for surgical analgesia. The postoperative pain relief after 4.0 mg epidural morphine was compared with the analgesic effect of 0.2 or 0.4 mg morphine administered intrathecally. With the spinal technique good or excellent surgical analgesia and muscle relaxation were achieved rapidly (11.8 ± 1.1 min). The time taken to provide an equally effective and reliable block with the CSE technique was no longer (14.9 ± 2.2 min). For epidural block with the catheter technique more time was required (35.9 ± 3.9 min) to provide acceptable surgical conditions ($P < 0.05$). Perioperative sedatives and concomitant analgesics were required more frequently and in larger doses by the patients undergoing surgery with epidural block ($P < 0.05$) than with CSE or spinal block. Our study demonstrated that the analgesia after surgery provided by 0.2 and 0.4 mg morphine administered intrathecally was comparable to that provided by 4.0 mg of epidural morphine. It is concluded that the analgesia and surgical conditions provided by the spinal and CSE blocks were similar and were superior to those provided by an epidural block.

Key words
ANAESTHESIA: orthopaedic;
ANAESTHETIC TECHNIQUES: regional, epidural, spinal, combined spinal epidural (CSE);
ANALGESICS: morphine,
PAIN: postoperative.

From the *Department of Anaesthesiology and Intensive Care, Lindesbergs Hospital; †Department of Anaesthesiology, Haugesunds Hospital; ‡Department of Anaesthesiology and Intensive Care, Örebro Medical Centre Hospital; and §Department of Surgery, Lindesbergs Hospital.

Address correspondence to: Dr. Björn Holmström, Department of Anaesthesiology and Intensive Care, Lindesbergs Hospital, S-711 82 Lindesberg, Sweden.

Accepted for publication 29th March, 1993.

Lors d'une étude contrôlée, on compare le bloc que produit l'association rachi-épidurale (CSE) à celui que produit chacune des deux techniques utilisées séparément en chirurgie orthopédique lourde. Soixante-quinze patients âgés de 52 à 86 ans sont assignés au hasard à recevoir un des trois blocs. La bupivacaïne 0,5% est employée pour l'analgésie chirurgicale. Le soulagement postopératoire avec morphine épidurale 4,0 mg est comparé avec celui que procure la morphine 0,2 ou 0,4 intrathécale. Avec la technique rachidienne, une analgésie de bonne à excellente et la relaxation musculaire surviennent rapidement (11,8 ± 1,1 min). Le temps requis pour obtenir les mêmes résultats avec la technique CSE n'est pas plus long (14,9 ± 2,2 min). Pour le bloc épidural avec cathéter, plus de temps est requis (35,9 ± 3,9 min) pour l'atteinte de conditions chirurgicales acceptables ($P < 0,05$) qu'avec le CSE ou la rachi. Notre étude montre que l'analgésie postopératoire obtenue par la morphine 0,2 et 0,4 mg intrathécale est comparable à celle produite par la morphine 0,4 épidurale. On conclut que les condition produites par la rachi et la CSE sont indentiques entre elles et supérieures à celles du bloc épidural.

For major orthopaedic surgery such as total hip and knee arthroplasty regional anaesthesia is believed to have certain advantages over general anaesthesia.[1-3] The two most common regional techniques are spinal and epidural anaesthesia. Spinal block is a simple method which requires a small dose of local anaesthetic to establish an intense and reliable block quickly. Epidural block with a catheter technique (EDA) is technically somewhat more difficult, but offers the possibilities of extending the block during surgery, and of pain relief with a local anaesthetic and/or opioids in the postoperative period. However, both techniques have drawbacks. To avoid some of the problems of epidural and spinal blocks a combined spinal epidural (CSE) technique has been described.[4,5]

A controlled study comparing CSE and EDA for Caesarean section has shown that CSE is a safe method which combines the reliability of a spinal block and the versatility of an epidural block.[6] Several reports suggest in-

creasing international interest in the technique.[7-9] Although CSE is probably most commonly used for major orthopaedic surgery, no controlled studies have been published in this group of patients.

The present controlled study was undertaken with the following aims:

- To compare the surgical analgesia and motor block among (a) spinal, (b) epidural and (c) combined spinal epidural (CSE) block for total hip and knee arthroplasty.
- To compare the analgesia after 0.2 or 0.4 mg intrathecal morphine with analgesia after 4 mg epidural morphine. The latter dose has been successfully used to manage pain after hip and knee surgery.[10]

Methods

The study was approved by the local Ethics Committees. Informed consent was obtained from each patient. Seventy-five patients, ASA 1–3, aged 52–86 yr and scheduled for total arthroplasty in either knee or hip, were randomized into three groups, Group A received spinal anaesthesia, Group B received epidural block with the catheter technique and Group C received combined spinal epidural (CSE) block. Premedication consisted of meperidine *im* in doses of 1 $mg \cdot kg^{-1}$ to patients <70 yr and 0.5 $mg \cdot kg^{-1}$ to patients >70 yr.

The blocks were performed with the patient in the sitting position. Patients in Group A received a spinal block through a 26 G spinal needle (Spinocan®, B.Braun Medical, Sweden), introduced at the L_{2-3} or L_{3-4} interspace. Depending on the height of patient 3.5–4 ml of isobaric bupivacaine 0.5% (17.5–20 mg) followed by 0.4 mg preservative-free morphine (1 ml) were injected. The patient was then placed in the supine or lateral position depending on the surgical procedure.

In patients in Group B an epidural catheter (Perifix®, B.Braun Medical, Sweden) was introduced through a cranially directed 18 G Tuohy needle (Perican®, B.Braun Medical, Sweden) in the L_{3-4} or L_{2-3} interspace. After negative aspiration for blood or spinal fluid a test dose of 3 ml bupivacaine 0.5% with epinephrine was given. With the patient still in the sitting position titrated doses of 0.5% bupivacaine (3 ml + 3 ml) were given. One to two minutes after the second dose, the patient was placed in the appropriate surgical position and additional 3 ml-doses of bupivacaine 0.5% were given through the catheter until a T_{10} sensory block was achieved. Preservative-free morphine in 10 ml saline, 4 mg, was then administered through the epidural catheter.

Patients in Group C underwent surgery with a combined spinal epidural (CSE) block with the needle-through-needle technique using a single interspace as described by Coates[4] and Rawal.[5] However, in this study we did not rotate the Tuohy needle between the spinal block and the insertion of the epidural catheter. Briefly the block consists of performing a spinal block via a long 26 G spinal needle (Spinocan® 120 mm, B.Braun Medical, Sweden) introduced through an 18 G Tuohy needle (Perican®) placed in the epidural space. The cranially directed Tuohy needle was introduced at the L_2–L_3 or L_3–L_4 interspace. After injecting 3.5–4 ml of bupivacaine 0.5% (17.5–20 mg) followed by 0.2 mg morphine intrathecally, the spinal needle was removed and an epidural catheter (Perifix®) was introduced into the epidural space through the Tuohy needle.

After being positioned on the surgical table the patients were given oxygen 2 $L \cdot min^{-1}$ through a nasal catheter. Arterial O_2-saturation (SpO_2) was monitored continuously by a pulse-oximeter (Novametrix® 505, Medical Systems Inc, USA). All patients had a urinary bladder catheter. The time from "start of anaesthesia" (i.e., skin infiltration of local anaesthetic) to the time for a T_{10} sensory block and the time to start of surgery (skin incision) were recorded. The level of sensory block was tested at one-minute intervals by pin-prick. After five minutes, it was tested at five-minute intervals until the start of surgery. Motor block was assessed using the Bromage scale (grade I:inability to move feet, II:able to move feet only, III:just able to move knees, IV:full flexion of knee and feet).[11] The time from start of anaesthesia to Bromage grade I was also noted. The ECG was monitored continuously and the blood pressure every five minutes.

The anaesthetist who performed the block was not involved in evaluation of the block.

Hypotension (defined as 25% decrease of systolic BP compared with preoperative control levels) was treated with 10 mg ephedrine *iv*. During surgery, patients were given *iv* sedatives (midazolam) and supplementary analgesics (fentanyl) on demand. The criterion for giving sedatives was when the patient reported discomfort and for giving analgesics when the patient complained of pain other than from the surgical site. A blinded nurse anaesthetist assessed surgical analgesia on a four-grade scale. Analgesia was rated as *excellent* when no supplementary sedatives or analgesics were considered necessary, *good* when only sedatives were given, *fair* when both sedatives and analgesics were given and *poor* when general anaesthesia (tracheal intubation) was necessary. The surgeon was asked to rate the surgical conditions (i.e., motor block) on a four-grade scale. Each patient rated analgesia and discomfort during surgery. The blocks were rated excellent, good, fair or poor following global assessment. Neither patient nor the surgeon was aware of the type of anaesthetic block performed.

After surgery all patients were nursed in the Intensive Care Unit (ICU) during the first 24 hr. The ECG was

monitored continuously, respiratory rate and blood pressure were noted every ten minutes during the first hour, then every 30 min until discharge from ICU. During surgery and up to 24 hr after the onset of block the SpO_2 was monitored continuously with a pulse oximeter. All patients received 2 L · min^{-1} oxygen through a nasal catheter. Every episode of SpO_2 below 90% was noted. Respiratory depression was defined as a respiratory rate below 10 · min^{-1} and/or $SpO_2 < 85\%$.

Postoperative pain was assessed every hour using a 10-grade visual analogue scale (VAS). All patients with VAS values above 3 received 5 mg *im* ketobemidone (a synthetic opioid which is equipotent with morphine).[12] When the patient was asleep no VAS-assessments were made and a VAS score of 0 was given. The time to the first injection of ketobemidone was noted. The total dose of ketobemidone during the first 24 hr after the start of anaesthesia was recorded. Side effects such as itching, nausea and hypotension were also recorded.

Statistical methods

Kruskall Wallis nonparametric analysis of variance was used for statistic analysis of differences between the groups in quality and block levels, ANOVA analysis for times and drug doses and Chi-square test for differences in frequencies. A value of $P < 0.05$ was considered significant.

Results

The three groups were similar regarding age, height, sex distribution and ASA status; however, the distribution of knee arthroplasties was uneven among the groups (Table I).

In patients receiving epidural anaesthesia (Group B) one patient (4%) required general anaesthesia due to inadequate analgesia and motor block and in two additional patients the block was supplemented with local anaesthetics other than bupivacaine through the epidural catheter to achieve acceptable muscle relaxation. In the epidural group the block was assessed as good or excellent by the 21 patients (84%). However, only 16 blocks (64%) were rated good or excellent by the nurse anaesthetist. The requirement of concomitant analgesics and sedatives is shown in Table II. Nine patients (36%) in the epidural group required supplementary bupivacaine (dose range 10–30 mg) for adequate perioperative analgesia (Figure, Table III).

The number of patients that had complete muscle relaxation (Bromage grade I) differed among the groups. In Groups A (spinal block) and C (CSE block) all patients reached Bromage grade I, but in Group B (epidural block) only three patients (12%) reached Bromage grade I ($P < 0.05$). In four patients (16%) in the CSE

TABLE I Demographic data

	Group A Spinal block (n = 25)	*Group B Epidural block (n = 25)*	*Group C CSE block (n = 25)*	
Sex F/M	14/11	11/14	11/14	NS
Age (yr)	69.9 ± 1.5	72.3 ± 1.5	71.0 ± 1.3	NS
Height (cm)	166.8 ± 9.6	166.6 ± 8.8	167 ± 7.2	NS
Duration of surgery (min)	132 ± 5.7	145 ± 6.0	143 ± 5.2	NS
Knee arthroplasty (*n*)	8	4	5	NS
Hip arthroplasty (*n*)	17	21	20	NS

Values are mean ± SEM. NS = not significant.

TABLE II Requirement of supplementary sedatives and analgesics during surgery

	Spinal block (n = 25)	*Epidural block (n = 25)*	*CSE block (n = 25)*	
Fentanyl				
n	2(8%)	8(32%)*	2(8%)	
Dose (mg)	0.05 ± 0	0.1 ± 0.02	0.1 ± 0	NS
Midazolam				
n	17(68%)	21(84%)	17(68%)	NS
Dose (mg)	3.9 ± 0.6	4.1 ± 0.6	3.7 ± 0.6	NS

Values are mean ± SEM. NS = not significant.
*$P < 0.05$ vs spinal and CSE block.

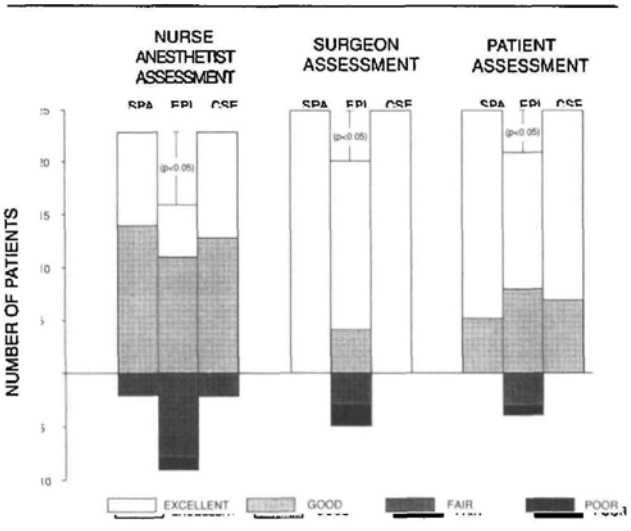

FIGURE Assessment of surgical analgesia (nuse anaesthetist), motor blockade (surgeon) and global assessment of block (patient) during surgery. Ratings by all three categories of assessors were significantly lower ($P < 0.05$) for epidural block (EDA) than for spinal (SPA) and combined spinal epidural (CSE) block.

TABLE III Doses of bupivacaine to achieve T_{10} sensory block

	Spinal block (n = 25)	*Epidural block (n = 25)*	*CSE block (n = 25)*
Preoperative dose (mg)	19.8 ± 0.1	71.6 ± 3.6*	22.9 ± 3.5
Patients requiring bupivacaine during surgery (n)	0†	9(36%)	3(12%)
Dose during surgery (mg)	0†	20.0 ± 2.7	25.0 ± 5.0

Values are mean ± SEM.
*$P < 0.01$ vs spinal and CSE block.
†$P < 0.05$ vs epidural and CSE block.

TABLE IV Time from start of anaesthesia to T_{10} sensory block and to start of surgery

	Spinal block (n = 25)	*Epidural block (n = 25)*	*CSE block (n = 25)*
Time to T_{10} sensory block (min)	11.8 ± 1.1	35.9 ± 3.9*	14.9 ± 2.2
Time to start of surgery (min)	59.5 ± 2.1	79.6 ± 4.5†	63.9 ± 2.2

Values are mean ± SEM.
*$P < 0.01$ vs spinal and CSE block.
†$P < 0.01$ vs spinal and CSE block.

TABLE V Requirement of concomitant analgesics during 24 hr after surgery

	Spinal block (n = 25)	*Epidural block (n = 25)*	*CSE block (n = 25)*	
Duration of epidural/spinal analgesia (hr)	13.1 ± 1.4	15.3 ± 1.3	11.4 ± 1.6	NS
Patients requiring additional analgesia (*n*)	17(68%)	13(52%)	14(56%)	NS
Dose of concomitant ketobemidone (mg)	7.9 ± 1.3	6.7 ± 0.9	10.5 ± 1.8	NS

Values are mean ± SEM.
NS = not significant.

group the spinal block was inadequate, in one of these only a T_{10}–L_1 block was achieved. Administration of bupivacaine (dose 20–90 mg) in the epidural catheter provided satisfactory block in all these patients (Table III).

The upper level of sensory block was different among the three groups. The median level in patients receiving epidural block was T_8 (range T_3–T_{12}), in patients receiving spinal blocks T_8 (range T_4–T_{10}) and in patients receiving CSE blocks T_6 (range T_3–T_{10}) ($P < 0.05$). No differences were noted among the groups regarding the incidence of hypotension or the number of patients requiring ephedrine.

The time from the start of anaesthesia to a T_{10} sensory block and to the start of surgery differed among the groups as shown in Table IV.

There were no differences among the groups with regard to the number of patients requiring ketobemidone during the first 24 hr after surgery (Table V). The frequency of side effects was similar in all groups.

In this study no respiratory depression was noted; however, three patients in the epidural group who required fentanyl due to inadequate surgical analgesia showed perioperative desaturation ($SpO_2 < 80\%$) soon after *iv* fentanyl injection. None of the patients developed post dural puncture headache.

Discussion

In the present study intraoperative analgesia and motor block were better in patients receiving spinal or CSE block than in those receiving epidural block. The lack of complete muscle relaxation with epidural bupivacaine is consistent with the findings of Cousins[13] and of Nydahl *et al.*[14] Using a quantitative method of measuring isometric strength in the muscles of the lower limb the latter group demonstrated incomplete motor block in eight of nine patients (89%) when bupivacaine 0.5% was administered epidurally. It is noteworthy that although only three patients (12%) in the epidural group reached Bromage grade I in our study, the surgical conditions were rated as excellent by the surgeon in 16 patients (64%) in this group.

The time taken to a T_{10} sensory block and, consequently, to the start of surgery was similar in the groups receiving spinal or CSE blocks. The extra time required for insertion of the epidural catheter with the CSE technique did not affect the time of onset of analgesia or delay the start of surgery. On the contrary, the advantage of an epidural catheter in the CSE group was demonstrated in the four patients in whom inadequate spinal block was converted to an adequate (T_{10}) block by the administration of bupivacaine through the epidural catheter.

The time taken to provide a T_{10} sensory block and to the start of surgery was longer in patients undergoing surgery with epidural block than in the patients receiving spinal or CSE block, since the onset of analgesia and motor block was slower using the epidural block with catheter technique. In our study this resulted in a saving of at least 15 min in patients in the spinal and CSE groups.

Not surprisingly, intrathecal administration of bupivacaine, whether in the spinal group or in the CSE group, provided a more rapid and more reliable block than did the epidural administration of bupivacaine. This is also reflected in the use of concomitant analgesics, sedatives and general anaesthesia.

The differences in the upper level of sensory block among the groups may have been influenced by the time that the patients in the CSE group remained sitting after injection of local anaesthetic through the spinal needle. In this group the patients remained sitting for three to four minutes longer to allow introduction of the epidural catheter. Kalso *et al.* have shown that plain bupivacaine 0.5% administered in the sitting position results in a higher block if patients remain sitting for 2.5 min or longer.[15] However, it should be noted that the higher upper level of block in the CSE group was not associated with any negative effects such as hypotension or respiratory depression.

Recently, epidural and intrathecal opioid administration for the management of postoperative pain has gained widespread acceptance.[16] The commonest opioid for epidural or intrathecal administration is morphine.[17] Although different doses have been studied the usual epidural dose of morphine for hip and knee surgery is 4–5 mg[10] while the intrathecal dose is 0.3–0.5 mg.[18] Although 4–5 mg morphine doses are considered adequate by most workers equianalgesic intrathecal morphine doses have not yet been defined.

A ratio of 1:10 to 1:16 intrathecal to epidural morphine has been proposed based on the use of morphine after Caesarean section in a retrospective study.[19] To our knowledge, no controlled trial has been performed to study equianalgesic doses of epidural versus intrathecal morphine in a standardized group of patients. Our study did not demonstrate any difference in postoperative pain relief provided by 0.2 or 0.4 mg doses of intrathecal morphine. However, our study has shown that 0.2 mg morphine intrathecally provides as effective analgesia as that provided by 4 mg morphine epidurally. Since respiratory depression appears to be dose-dependent[20] there seems to be no benefit in giving intrathecal doses larger than 0.2 mg for pain relief in patients undergoing hip or knee replacement surgery. This dose has also been shown to provide excellent post-Caesarean section analgesia.[21] Thus, our results demonstrate that for effective analgesia after hip and knee surgery the ratio between intrathecal and epidural morphine appears to be in the range of 1:20 to 1:10.

Based on data from large surveys it is believed that the risk of late onset respiratory depression is higher if morphine is administered by the intrathecal than by the epidural route.[20,22] Although intrathecal morphine provides as good or better analgesia than epidural morphine, a possible disadvantage is the stricter surveillance requirement since this has to be organized once intrathcal morphine has been administered.[3,22] If the CSE technique is selected the catheter in the epidural space provides the flexibility of morphine administration if and when considered necessary.

It may be argued that a continuous spinal technique will provide all the advantages of CSE block. However, there is an increased risk of post dural puncture headache with the technique.[23] Although very fine diameter catheters may decrease the risk of this complication, problems such as kinking, breakage and failure to aspirate have been reported with the currently available catheters.[24] Furthermore recently Rigler *et al.* have reported the more serious complication of cauda equina syndrome after continuous spinal anaesthesia[25] and this lead to the FDA Safety alert of May 1992 on the use of small-bore catheters in continuous spinal anaesthesia.

In conclusion, this controlled study showed that combined spinal epidural block is a useful technique for major orthopaedic surgery on the lower limb. The CSE technique rapidly produced a reliable spinal block. In four patients the flexibility with the CSE technique was demonstrated when supplementary local anaesthetic could be administered through the epidural catheter to achieve appropriate surgical analgesia.

Acknowledgements

The authors wish to thank Wivan Ersson for excellent secretarial assistance in preparing this manuscript.

References

1 *Modig J, Hjelmstedt Å, Sahlstedt B, Maripuu E.* Comparative influences of epidural and general anaesthesia on deep venous thrombosis and pulmonary embolism after total hip replacement. Acta Chir Scand 1981; 147: 125–30.

2 *Rosberg B, Fredin H, Gustafson C.* Anesthetic techniques and surgical blood loss in total hip arthroplasty. Acta Anaesthesiol Scand 1982; 26: 189–93.

3 *Johnson A, Bengtsson M, Merits H, Löfström JB.* Anesthesia for major hip surgery. A clinical study of spinal and general anesthesia in 244 patients. Reg Anesth 1986; 11: 83–8.

4 *Coates MB.* Combined subarachnoid and epidural techniques (Letter). Anaesthesia 1982; 37: 89–90.

5 *Rawal N.* Single segment combined subarachnoid and epidural block for Caesarean section (Letter). Can Anaesth Soc J 1986; 33: 254–5.

6 *Rawal N, Schollin J, Wesström G.* Epidural versus combined spinal epidural block for cesarean section. Acta Anaesthesiol Scand 1988; 32: 61–6.

7 *Carrie LES.* Extradural, spinal or combined block for obstetric surgical anaesthesia. Br J Anaesth 1990; 65: 225–33.
8 *Tadoori P, Ravella R, Doss N, Gintautas J, Abadir AR.* Combined epidural spinal (ESP) anesthesia for cesarean section using lidocaine 1.5% with 1:200,000 epinephrine. Reg Anesth 1991; 15: suppl 13: 84.
9 *Vandermeersch E, Kick O, Möllmann M, de Gouw N, Van Aken H.* Combined spinal and epidural anesthesia. Reg Anaesth 1991; 14: 108–12.
10 *Stenseth R, Sellevold O, Breivik H.* Epidural morphine for postoperative pain: experience with 1085 patients. Acta Anaesthesiol Scand 1985; 29: 148–56.
11 *Bromage PR.* A comparison of the hydrochloride and carbon dioxide salts of lidocaine and prilocaine in epidural analgesia. Acta Anaesthesiol Scand Suppl 1965; 16: 55–69.
12 *Tamsen A, Bondesson U, Dahlström B, Hartvig P.* Patient-controlled analgesic therapy, Part III: pharmacokinetics and analgesic plasma concentrations of keotbemidone. Clin Pharmacokinet 1982; 7: 252–65.
13 *Cousins MJ.* Epidural neural blockade. *In:* Cousins MJ, Bridenbaugh PO (Eds.). Neural Blockade in Clinical Anesthesia and Management of Pain. Philadelphia: JB Lippincott, 1988: 310–11.
14 *Nydahl P-A, Axelsson K, Philipson L, Leissner P, Larsson PG.* Motor blockade and EMG recordings in epidural anaesthesia. A comparison between mepivacaine 2%, bupivacaine 0.5% and etidocaine 1.5%. Acta Anaesthesiol Scand 1989; 33: 597–604.
15 *Kalso E, Tuominen M, Rosenberg PH.* Effect of posture and some C.S.F. characteristics on spinal anaesthesia with isobaric 0.5% bupivacaine. Br J Anaesth 1982; 54: 1179–84.
16 *Cousins MJ.* The spinal route of analgesia. Acta Anaesthesiol Belg, Suppl 2, 1988; 39: 71–82.
17 *Gustafsson LL, Wiesenfeld-Hallin Z.* Spinal opioid analgesia: a critical update. Drugs 1988; 35: 597–603.
18 *Bengtsson M, Löfström JB, Merits H.* Postoperative pain relief with intrathecal morphine after major hip surgery. Reg Anesth 1983; 8: 139–43.
19 *Chadwick HS, Ready LB.* Intrathecal and epidural morphine sulphate for post-cesarean analgesia – a clinical comparison. Anesthesiology 1988; 62: 925–9.
20 *Etches RC, Sandler AN, Daley MD.* Respiratory depression and spinal opioids. Can J Anaesth 1989, 36: 165–85.
21 *Abouleish E, Rawal N, Fallon K, Hernandez D.* Combined intrathecal morphine and bupivacaine for Cesarean section. Anesth Analg 1988; 67: 370–4.
22 *Rawal N, Arnér S, Gustafsson LL, Allvin R.* Present state of extradural and intrathecal opioid analgesia in Sweden – a nationwide follow-up survey. Br J Anaesth 1987; 59: 791–9.
23 *Gielen M.* Post dural puncture headache (PDPH): a review. Reg Anesth 1989; 14: 101–6.
24 *Hurley RJ, Lambert DH.* Continuous spinal anesthesia with a microcatheter technique: preliminary experience. Anesth Analg 1990; 70: 97–102.
25 *Rigler ML, Drasner K, Krejcie TC, et al.* Cauda equina syndrome after continuous spinal anesthesia. Anesth Analg 1991; 72: 275–81.