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DISCHARGE HOME IN THREE HOURS AFTER SELECTIVE SPINAL ANAESTHESIA

Studies on the quality of anaesthesia with hyperbaric bupivacaine for ambulatory knee arthroscopy

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Academic Dissertation

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Abstract

Recently several studies with low-dose bupivacaine for ambulatory knee arthroscopy have been conducted with varying failure rates and time to home-readiness. We tested the hypothesis that selective spinal anaesthesia (SSA) with bupivacaine (alone or together with fentanyl) is suited for outpatients undergoing knee arthroscopy.

Five prospective, randomized studies were conducted, consisting of 483 outpatients undergoing knee arthroscopy. We tested the suitability of selective spinal anaesthesia with low-dose hyperbaric bupivacaine alone (4 or 6 mg), or together with fentanyl (3 mg + 10 μg) for knee arthroscopy. Since itching was common after intrathecal fentanyl, one study was designed to answer the question "Does intravenous ondansetron prevent pruritus induced by intrathecal fentanyl". The 4th study was conducted to find out whether SSA can be achieved by injecting at the L3/4 interspace, and whether a 5 degree head down tilt of the vertebral column is needed to accomplish it. Finally, SSA was compared with desflurane-maintained general anaesthesia (GA). The quality of SSA (the spread and the recovery from sensory and motor block, and the side effects) was estimated in each study. A strictly standardized technique, consisting of low-dose, low-flow, low-volume, a lateral decubitus position for 10 min, with a carefully adjusted position of the vertebral column (horizontal or a head down tilt of 5 degrees, with the help of a spirit level) was used. Furthermore, the bevel of the needle was directed towards the nerves involved through a G-27 Quincke needle. The time spent in the postanaesthesia care unit and the time to home-readiness, as well as side effects were evaluated after SSA and GA (maintained with desflurane).

An identical spread and recovery of the sensory block was seen when an identical dose and technique were used. The head-down tilt of 5 degrees left the sacral segments significantly more often intact compared to the horizontally positioned patients, producing a clearly segmental block often seen during epidural block. The failure rate was 2% and 3% after the 6 mg and 4 mg doses of bupivacaine, and 4% after 3 mg of bupivacaine + 10 μg of fentanyl when injected at L2/3 interspace with the vertebral column in a horizontal position. Four mg injected at the L3/4 level together with a head down tilt resulted in a 2.5% failure rate, whereas 12% failed when the vertebral column was in a horizontal position.

The median time in the postanaesthesia care unit was 36 min after the combination (3 mg of bupivacaine and fentanyl) and 55 min after 4 mg of bupivacaine (P=0.005). Increasing the dose to 6 mg caused a further 30-min delay in the PACU: 64 versus 94 min, after 4 mg and 6 mg of bupivacaine (P<0.001), respectively. No difference in the PACU stay was seen after SSA (4 mg of bupi-

vacaine) and GA (desflurane). Home-readiness was equal after SSA with 3 mg of bupivacaine and fentanyl, with 4 mg of bupivacaine, and after GA maintained with desflurane: 178 min, 186 min and 192 min, respectively. The 6 mg dose prolonged the fulfilment of the home discharge criteria by 30 min when compared with the 4 mg dose of spinal bupivacaine. After spinal anaesthesia, 5% of the patients suffered from PDPH and 1% needed an epidural blood patch. 75% of the patients receiving i.t. fentanyl developed pruritus, which was not preventable with i.v. ondansetron. Pain, PONV and somnolence were more frequent after GA than after SSA, whereas TNS occurred equally. None of the patients needed catheterization to pass urine.

In conclusion, a standardized selective spinal anaesthesia technique with a 4 mg dose of hyperbaric bupivacaine produced a highly predictable spread of spinal block and home-readiness 3 hours after injection. Furthermore, a small change in the dose, injection at a different vertebral site, and positioning the patient's vertebral column differently at the time of injection, altered the spread, the recovery (and the reliability) of the spinal anaesthesia. Although home-readiness was similar after selective spinal anaesthesia and desflurane-maintained general anaesthesia, a higher number of side effects was associated with general anaesthesia. The use of a 27-G Quincke spinal needle resulted in a high incidence of PDPH.

List of Original Publications

This thesis is based on the following original articles, which are referred to in the text by their Roman numerals I-V.

I Valanne JV, Korhonen A-M, Jokela RM, Ravaska P. Korttila K: Selective spinal anesthesia: A comparison of hyperbaric bupivacaine 4 mg versus 6 mg for outpatient knee arthroscopy. Anesth Analg 2001: 93:1377-9

II Korhonen A-M, Valanne J, Jokela R, Ravaska P, Korttila K: Intrathecal hyperbaric bupivacaine 3 mg +fentanyl 10µg for outpatient knee arthroscopy with tourniquet. Acta Anaesthesiol Scand 2003: 47:342-6

III Korhonen A-M, Valanne J, Jokela R, Ravaska P, Korttila K: Intravenous ondansetron does not prevent pruritus induced by low-dose intrathecal fentanyl. Acta Anaesthesiol Scand 2003:47:1292-7

IV Korhonen A-M, Valanne J, Jokela RM, Ravaska P, Volmanen P, Korttila K: Influence of the injection site (L2/3 or L3/4) and the posture of the vertebral column on selective spinal anesthesia for ambulatory knee arthroscopy. Acta Anaesthesiol Scand; in press

V Korhonen A-M, Valanne JV, Jokela R, Ravaska P, Korttila K: A comparison of selective spinal anesthesia with hyperbaric bupivacaine and general anesthesia with desflurane for outpatient knee arthroscopy. Anesth Analg 2004; in press

Abbreviations

$5\text{-}HT_3$	5-hydroxytryptamine-$_3$
ASA	American Society of Anesthesiologists
ASU	Ambulatory surgery unit
BIS	Bispectral Index of Electroencephalogram
BMI	Body mass index
BPM	Beats per minute
CI	Confidence interval
CIA	Confidence interval analysis
CO_2	Carbon dioxide
CSF	Cerebrospinal fluid
ECG	Electrocardiogram
EO	End of operation
EPI	Epidural
FDA	United States Food and Drug Administration
G	Gauge
GA	General anaesthesia
IA, i.a.	Intra-articular
i.t.	Intrathecal
i.v.	Intravenous
L2/3, L3/4	Lumbar 2/3 or 3/4 interspace
LA	Local anaesthetic
LMA	Laryngeal mask airway
MAC	Monitored anaesthesia care
MAP	Mean arterial pressure
MRI	Magnetic resonance imaging
N	Number
N_2O	Nitrous oxide
NA	Not applicable
NIBP	Non-invasive blood pressure
NSAID	Non-steroidal anti-inflammatory drug
OR	Operating room
P	Probability
PACU	Postanaesthesia care unit
PDPH	Postdural puncture headache
p.o.	Per os
PONV	Postoperative nausea and vomiting
RA	Regional anaesthesia
SA	Spinal anaesthesia
SAP	Systolic arterial pressure
SD	Standard deviation
SpO_2	Peripheral oxygen saturation
SSA	Selective spinal anaesthesia
TES	Transcutaneous electrical stimulation
TNS	Transient neurological symptoms
TOF	Train of four
TRI	Transient radicular irritation
VeAS	Verbal analogue scale
VAS	Visual analogue scale

Introduction

A wide category of anaesthetic techniques can and have been used for outpatient knee arthroscopy. The patients receiving regional anaesthesia are more alert and suffer less from nausea and pain in the postanaesthesia care unit, compared with patients undergoing general anaesthesia (Mulroy and McDonald 2003). On the other hand, side effects like postdural puncture headache, transient neurological symptomes, back pain and difficulties in voiding are sometimes associated with neuraxial techniques (Mulroy and McDonald 2003). General anaesthesia can produce faster induction compared with regional techniques (not performed in an induction area) (Wong et al. 2001). The use of modern general anaesthetics, effective anti-emetic treatment and laryngeal mask airway have made the recovery times after general anaesthesia and regional anaesthesia equal.

Selective spinal anaesthesia (SSA) is a practice of using minimal doses of intrathecal agents so that only the nerve roots supplying a specific area and only the modalities that need to be anaesthetized are affected (Vaghadia 1998). Depending on the type of surgical procedure, the SSA can be either a bilateral or a unilateral block. Extremely low doses have been applied in SSA for gynaecological laparoscopies: 10 mg of lidocaine together with 10 μg of sufentanil provided a significantly faster early stage recovery and ability to ambulate, compared with general anaesthesia either with propofol (Stewart et al. 2001) or desflurane (Lennox et al. 2002b). Without a specific injection technique, the failure rate after low-dose bupivacaine in knee arthroscopy patients has been as high as 24% decreasing to 0% when low-dose bupivacaine and fentanyl are combined (Ben-David et al. 1997).

The purpose of the present series of studies was to produce reliable SSA with bupivacaine for outpatients undergoing knee arthroscopy. The specific aim was to compare the recovery times after SSA with different doses of bupivacaine (alone or together with fentanyl) and after desflurane-maintained general anaesthesia (GA), as well as to compare the time in the postanaesthesia care unit. Furthermore, the purpose was to evaluate the effects of a certain modification in the spinal anaesthesia technique, such as injection site (L2/3 or L3/4) and the position of the vertebral column (horizontal or tilted head down) on the spread of spinal anaesthesia. Finally, the incidence of side effects after SSA and GA, and the possibility of preventing intrathecal fentanyl-induced pruritus with intravenous ondansetron were evaluated.

Review of the Literature

Anaesthesia techniques used in outpatient knee arthroscopy

Knee arthroscopy is a common procedure performed in an ambulatory setting. Arthroscopic exploration of the knee may last only up to 10-15 min, whereas the operations on meniscus, capsules and ligaments, on synovia of the knee or operation for osteochondritis last significantly longer. Whether muscle relaxation and / or tourniquet are required, depends mainly on the surgeon.

Regional anaesthesia

Peripheral blocks like femoral and sciatic nerve block have been used for knee arthroscopy. The preparation time of combined sciatic-femoral block was slightly longer than that of general anaesthesia, 16 versus 13 min (Casati et al. 2002). After a combined sciatic-femoral block, a greater number of patients could bypass the postanaesthesia care unit (PACU) compared to general anaesthesia (GA) with propofol-remifentanil, but readiness to discharge home was prolonged signifincanly after peripheral block (Casati et al. 2002) (Table 1). In more recent studies, the time to home-readiness was equal after GA (propofol + N_2O), spinal anaesthesia (SA) (bupivacaine 6 mg + fentanyl 15 µg) and psoas block (600 mg mepivacaine) (Jankowski et al. 2003). Intra-articular (i.a.) local anaesthetic has been used alone, or in combination with peripheral nerve blocks and monitored anaesthesia care. The operation conditions and postoperative pain scores were equal after an i.a. local anaesthetic with or without femoral nerve block in knee arthroscopy patients (Goranson et al. 1997). In another study, 180 of 400 patients underwent elective knee arthroscopy with an i.a. local anaesthetic. Although the authors concluded that elective knee arthroscopy is performable under i.a. local anaesthesia in 92% of the patients, they found that in 16% (29/180) of the patients, the technique was not considered optimal by the surgeon (Jacobson et al. 2000). More often, i.a. drugs are used for postoperative pain (Kalso et al. 1997; Kalso et al. 2002).

Neuraxial anaesthesia (i.e. spinal or epidural) is popular for outpatient knee arthroscopy. SA is easy to perform, rapid in onset (Mulroy 2002b) and cheap (Dahl et al. 1997; Lennox et al. 2002a), whereas epidural anaesthesia (EPI) is technically more difficult to perform. It is, however, possible to titrate the extent of epidural anaesthesia through the catheter, thus decreasing the need for supplementary medication, if the surgical procedure is prolonged (Mulroy 2002a). In a

Table 1. A comparison of different anaesthesia techniques used in outpatients undergoing knee arthroscopy. Prospective, randomized clinical trials.

Reference	No.	Anaesthetic technique	Failure (%)	Fast-tracking (%)	PACU time (min)	Time to ambulate (min)	Ready to discharge (min)	Comments/Other results
(Jankowski et al. 2003)	60	**Psoas block** 600mg mepivacaine	0	95	233[1]	NA	110 [35-330]	Home readiness time from the EO. Voiding was required.
		SA: 6mg bupivacaine + 15µg fentanyl	5	100	0		129 [72-262]	[1] One patient was admitted to PACU: bilateral block due to protocol violation, received GA as well
		GA: propofol +N_2O, fentanyl	–	35 P<0.001	46 [3-69]		131 [48-187] NS	
(Pollock et al. 2003)	63	**SA:** lidocain 25mg+ fentanyl 20 µg	9	0	85±5	NA	142 ±5	40-42% had additional propofol infusion in both groups. PACU time= time in Phase I + Phase II unit.
		EPI: chloroprocaine 15-20 ml	10	0	87±4		152 ±5	
(Casati et al. 2002)	40	**Sciatic-femoral:** 500 mg mepivacaine	5	50	5 [5-20]	NA	277[2] [140-480]	[2] The time in the ambulatory surgery unit.
		GA: propofol+remifentanil	–	5 P=0.003	23 [10-95] P=0.001		170 [100-400] P=0.005	
(Ben-David et al. 2001)	100	**SA:** 20 mg lidocaine + fentanyl 20 µg	0	100	0	NA	45 [28-180]	Ready to home from the EO, neither voiding nor walking required.
		IA +LA lidocaine + propofol infuusion	6	98	0		43 [22-139] NS	
(Jacobson et al. 2000)	400	**IA+LA** 0.5 % prilocaine 40-70 ml **SA:** lidocaine 60-90 mg **GA:** propofol + alfentanil	16 % of LA not optimal	NA	NA	NA	NA	90 %, 81 % and 97 % were satisfied with the anaesthesia in IA, SA and GA groups (NS)
(Mulroy et al. 2000)	48	**EPI:** chloroprocaine 15-20 ml	56[3]	0	NA	NA	92±18*	[3]% of the patients needed propofol infusion. Discharge time from arrival to PACU, voiding required in EPI and SA groups.
		SA: procaine 75mg + 20µg fentanyl	25[3]	0			146±52	
		GA: propofol/N_2O; BIS 40-60	-	0			104 ±31** *P=0.0006 EPI vs. SA **P=0.008 GA vs. SA	
(Goranson et al. 1997)	60	**IA:** 100mg lidocaine **+ LA**	0	NA	NA	NA	117±47	Discharge from entering the recovery room until discharge home. Intraoperative pain VAS varied from 3.3-4.9± 2.7 (NS).
		FNB: 400mg chloroprocaine	5				149±43	
		FNB 400mg chloroprocaine **+ IA**: 100mg lidocaine	0				162±98	

Time values (min) are either median [range] or mean ± SD.

EO = end of operation, PACU = Postanaesthesia care unit. SA = spinal anaesthesia, EPI = epidural anaesthesia, IA = intra-articular; LA = local anaesthesia, GA = general anaesthesia, FNB = femoral nerve block

study by Mulroy and co-workers, the discharge times after EPI (20 mg/ml chloroprocaine) and GA (propofol) were comparable, whereas SA (procaine and fentanyl) was associated with a longer discharge time (Mulroy et al. 2000). On the contrary, two other studies found no difference in the time to home-readiness after SA (lidocaine and fentanyl) and EPI (2-chloroprocaine) (Pollock et al. 2003), or after IA lidocaine together with propofol infusion and SA (lidocaine and fentanyl) (Ben-David et al. 2001). A comparison of GA and/or different regional anaesthetic (RA) techniques used in recent studies for ambulatory knee arthroscopy patients is given in Table 1.

General anaesthesia

The ambulatory anaesthetic agent should provide a smooth and rapid induction, optimal surgical conditions, and fast recovery with no or minimal side effects. In a comparison of different GA techniques for patients undergoing knee arthroscopy, the use of inhalation anaesthetic (desflurane or sevoflurane) was associated with faster early stage recovery (Dolk et al. 2002) and reduced drug costs (Heidvall et al. 2000; Dolk et al. 2002) compared to anaesthesia maintained with propofol.

Monitored anaesthesia care

In monitored anaesthesia care (MAC), sedative/anxiolytic drugs are used in addition to a local anaesthetic or regional anaesthesia (or for sedation when unpleasant diagnostic procedures are done). The anaesthetic state can vary from conscious sedation to deep sedation without airway control (Tesniere and Servin 2003). A great variety of i.v. drugs are used to achieve MAC. An i.a. local anaesthetic has been used solely or in combination with MAC for knee arthroscopy (Goranson et al. 1997; Hirshorn 2001).

Postoperative recovery and discharge

An outpatient should be a carefully selected patient who is undergoing a non-emergency procedure and all its constituent elements (admission, surgical procedure and discharge home) on the same day (Korttila 1995). An extended stay (i.e. 23 hours or overnight) should not be considered ambulatory surgery (McGrath and Chung 2003). Recovery can be divided into three phases: early, intermediate and late recovery (Korttila 1995). In the early stage of recovery, the patient emerges from anaesthesia and is usually looked after in the abundantly equipped and manned postanaesthesia care unit (PACU) or phase I unit. Modern short-acting drugs in GA and techniques in RA have made the early stage recovery so fast that some patients can be safely fast-tracked, i.e. bypass PACU (Apfelbaum et al.

2002). The ambulatory surgery unit (ASU) or phase II unit is a less expensive unit than the regular PACU; thus fast-tracking means savings in costs (Song et al. 1998; Apfelbaum et al. 2002). In most studies, the modified Aldrete scoring system (Appendix 1) has been used to determine fast-track eligibility (Aldrete and Kroulik 1970; Aldrete 1995; Song et al. 1998). For patients undergoing GA, the new fast-tracking criteria (White and Song 1999) are more suitable, since they also take into consideration the common side effects, nausea and pain (Appendix 2).

During the stage of intermediate recovery, the patient achieves the criteria for home discharge (Korttila 1995; Marshall and Chung 1999). The discharge time (total recovery time) has been used as a measure of efficacy when comparing anaesthetic agents or techniques (Valanne 1992). However, several elements may cause confusion when comparing the home-readiness. It has been demonstrated that many non-anaesthetic related factors had an effect on discharge time, postoperative nursing care being the single most important reason (Pavlin et al. 1998). A validated postanaesthesia discharge scoring system has been created by Chung and co-workers (1995) basing on stable vital signs, ability to walk, no or minimal pain, no or minimal postoperative nausea and vomiting, absence of severe bleeding, and ability to tolerate fluids, and void (Appendix 3). Various criteria are nevertheless used.

During the past few years, the home discharge criteria have been changed. Mandatory drinking has been eliminated from the Practice Guidelines for Postanaesthetic Care (The American Society of Anesthesiologists 2002) and, according to these guidelines, the routine requirement of voiding before discharge has also been recommended to be necessary only for selected patients (i.e. high-risk patients). After GA, local or peripheral nerve block, urinary retention affected 0.5% of the patients who were categorized as low-risk patients (non-pelvic surgery or outpatient gynaecological surgery), whereas in high-risk patients (hernia or anal surgery or a history of retention) the incidence was 5%. The rate of re-retention after anal surgery was as high as 50% (Pavlin et al. 1999). The patients should be informed to seek immediate medical help if they are unable to void 6-8 hours after discharge (McGrath and Chung 2003).

In most studies, ambulating without help has been mandatory before being judged home-ready, whereas in other studies, only the ability to stand or walk with crutches was required (Ben-David et al. 2001; Borghi et al. 2003). In GA studies, the time to reach home-readiness is usually measured from the end of surgery, whereas in RA studies it is measured from the beginning of the injection of the local anaesthetic. The lack of identical fast-tracking and home-readiness criteria between studies makes the evaluation of the efficacy of different anaesthetic agents and techniques difficult.

In late recovery, the patient returns to the preoperative physiological state (Marshall and Chung 1999). Despite its subjective nature, patient satisfaction has been included in outcome studies. Overall satisfaction with low-dose spinal

anaesthesia ranges from 92-99% of the patients (Chung and Mezei 1999; Kuusniemi et al. 2000a; Kaya et al. 2004).

Spinal anaesthesia in ambulatory surgery

Unilateral spinal anaesthesia

As long as 40 years ago, Tanasichuk and co-workers (1961) used a "spinal hemianalgesia" technique, by which they tried to limit the spread of spinal block to one side of the body by using a hyperbaric solution, a pencil-point needle and a lateral decubitus position. Several words such as restricted, asymmetric or unilateral spinal anaesthesia are used to describe the spinal anaesthesia developing mainly on one side of the body. Most often the criteria for unilateral spinal block have been described as absence of sensory and motor block on the nondependent side, but some investigators have determined also the degree of sympathetic block i.e., strictly unilateral spinal anaesthesia (Tanasichuk et al. 1961; Meyer et al. 1996; Enk et al. 2001).

According to Enk (Enk 1998; Enk et al. 2001), it is possible to inject a local anaesthetic solution i.t. in such a way that the hyperbaric anaesthetic forms a layer below the cerebrospinal fluid (CSF) enabling thus, a strictly unilateral spinal anaesthesia. Injection of an anaesthetic with high outflow velocity through a small-bore spinal needle causes turbulence and further mixing up with the CSF, compared with a slow injection flow (Enk et al. 2001). Today, smaller needles are used to avoid the risk of postdural puncture headache (PDPH). Halving of the diameter of the needle results in a fourfold flow velocity within the spinal needle. Thus, the smaller the needle, the slower the injection should be to avoid turbulence (Enk 1998). With an indermediate amount of 5 mg/ml hyperbaric bupivacaine (1.4 to 1.7 ml) Enk and co-workers (2001) were able to produce a unilateral sensory spinal block to 48% versus 10.5% of the patients ($P<0.05$), when they compared a low-flow (0.5 ml/min) injection (27-G Whitacre) with conventional flow (7.5 ml/min), respectively. On the other hand, Casati and co-workers (1998c) found the incidence of unilateral sensory block to be equal, when they injected 8 mg of hyperbaric bupivacaine (1.6 ml) either at a low flow of 0.02 ml/s (1.2 ml/min) or a high flow of 0.25 ml/s (15 ml/min) (25-G Whitacre), 56% vs. 43%, respectively. However, the low-flow was over twofold faster (1.2 ml/min vs. 0.5 ml/min) and the maintenance of the lateral decubitus was shorter (15 vs. 30 min) in the latter study.

Selective spinal anaesthesia

In selective spinal anaesthesia (SSA), minimal doses of intrathecal agents are used, so that only the nerve roots supplying a specific area, and only the modalities that

need to be anaesthetized, are affected (Vaghadia 1998). Most often the term SSA has been used of spinal anaesthesia produced for gynaecological laparoscopies (bilateral block), whereas the name unilateral spinal anaesthesia is used more often of the block developing mainly to one side of the body. In both techniques, however, low doses of local anaesthetics are administered.

Compared with a conventional dose of lidocaine 75 mg, SSA with 25 mg of lidocaine together with 25 µg of fentanyl enabled faster recovery from motor and sensory blocks, as well as a 40 min shorter time to meet home discharge criteria after laparoscopy (Vaghadia et al. 1997). The comparison of SSA with three low-dose solutions showed that either 20 mg of hypobaric lidocaine combined with 25 µg fentanyl, or 10-20 mg lidocaine combined with 10 µg sufentanil can be used for ambulatory laparoscopy, but the combination of 10 mg of lidocaine and 10 µg of sufentanil was associated with the fastest recovery from sensory block. The recovery times from motor block were equal after all three solutions (Vaghadia et al. 2001). The laparoscopy patients had significantly faster early stage recovery and ability to ambulate after SSA with 10 mg of lidocaine together with 10 µg sufentanil, compared with GA with either propofol (Stewart et al. 2001) or desflurane (Lennox et al. 2002b). For anorectal surgery, the SSA was produced by using 5 mg of hypobaric bupivacaine for the patients in a prone, jack-knife position. The median level of upper sensory level was L1 and no patient developed motor block. The postoperative analgesia lasted up to 340 min (Maroof et al. 1995).

The advantages of unilateral or selective versus conventional SA are: better haemodynamic stability (Tanasichuk et al. 1961; Pittoni et al. 1995; Vaghadia et al. 1997; Fanelli et al. 2000), faster motor and sensory recovery (Vaghadia et al. 1997; Vaghadia 1998; Fanelli et al. 2000) and decreased risk of urinary retention (Ben-David et al. 1996; Ben-David et al. 1997; Ben-David et al. 2000; Kuusniemi et al. 2000a; Mulroy et al. 2002). The patients' satisfaction with the unilateral techniques has been high, too (Pittoni et al. 1995; Kuusniemi et al. 1997; Kuusniemi et al. 2000a).

The quality of spinal anaesthesia

The spread of spinal anaesthesia

Greene reported 25 factors that could affect the distribution of the local anaesthetic in the cerebrospinal fluid (Greene 1985), but not all of them have clinical relevance. These factors can be classified into 4 subgroups: characteristics of the patient and of the CSF, characteristics of the local anaesthetic agent, and the injection technique used (Table 2). Besides the drug dosage, the position of the patient at the time of injection and thereafter, together with the baricity of the anaesthetic, are the most important factors affecting the level of spinal anaesthesia (Stienstra and Greene 1991; Connolly and Wildsmith 1998; Enk 1998).

Table 2. Elements influencing the spread of spinal anaesthesia in addition to the injection technique.

Element	Influence	Reference
Patient characteristics		
patient position	major importance	(Greene 1985; Enk 1998)
increasing age	no clear correlation	(Pitkänen et al. 1984; Pitkänen 1987)
height	not within normal variation	(Pitkänen 1987)
BMI	higher spread with increased BMI	(Pitkänen 1987; Taivainen et al. 1990)
pregnancy	higher spread	(Hirabayashi et al. 1995b)
gender	no	(Greene 1985)
Cerebrospinal fluid (CSF)		
volume	decreasing volume increases the sensory spread; 2-3 -fold variety in the volume of CSF between individuals	(Hogan et al. 1996; Carpenter et al. 1998; Higuchi et al. 2004)
density	a higher sensory spread after plain solution when the density of CSF increases	(Schiffer et al. 2002; Higuchi et al. 2004)
Anaesthetic agent		
dose	major importance	(Greene 1985; Enk 1998)
baricity	major importance	(Greene 1985; Enk 1998)
concentration	only minor effects	(Casati et al. 1998b)
Injection technique	major importance	See text.

BMI = body mass index

Anatomy

The spinal cord, covered by a bony vertebral column, extends from the level of the atlas vertebra downward, ending as the conus medullaris, which is usually situated between the 1st and 2nd lumbar vertebrae. The spinal cord is situated in the middle of the spinal canal, where it is surrounded by 3 connective tissue membranes: the pia mater, the arachnoid mater and the dura mater. Between the pia and arachnoid mater is the subarachnoid, i.e. the intrathecal space, filled with cerebrospinal fluid (CSF). The 31 pairs of spinal nerves exit the spinal canal through each intervertebral foramen. Each spinal nerve supplies a specific area of the skin (i.e. dermatomes) and a specific number of muscles (i.e. myotomes), although there is overlapping between the segmental distribution. The nerves below the conus form the cauda equina, and they are situated inside the dural sac surrounded by CSF. Intrathecally administrated local anaesthetic agents are injected into the CSF below the level of the conus, where the nerves are devoid of perineural tissue. Thus, there is only little resistance to the action of local anaesthetic, which explains the rapid onset of spinal anaesthesia (Kahle et al. 1986; Mulroy 2002b).

Injection technique of unilateral or selective spinal anaesthesia

In creating a unilateral or selective spinal anaesthesia with low doses of intrathecal agents, the injection technique becomes especially important. Enk (1998) concluded the importance of "low-dose, low-volume and low-flow" for produc-

ing unilateral spinal anaesthesia. The extent of hyperbaric spinal anaesthesia influences the duration of the block. When a significantly higher sensory spread followed after the injection of the same dose of lidocaine, a faster recovery of sensory and motor block, and earlier fulfilment of home-readiness were seen compared to a lower sensory block (Urmey et al. 1997). It was also demonstrated that with the same dose of hyperbaric bupivacaine, the duration of both sensory and motor block is longer in patients with restricted block (Kooger Infante et al. 2000). This might explain the high failure rate with low-dose i.t. anaesthetic in some studies (Ben-David et al. 1997): if the spread is not restricted, the risk of inadequate spinal block may increase.

As mentioned earlier, the position of the patient (sitting, lateral decubitus position, prone) is essential with respect to the baricity of the local anaesthetic. The maintenance of the selected position affects the spread of anaesthesia. After 7.5 or 10 mg of i.t. hyperbaric bupivacaine the sensory and motor blocks were more unilateral, when the patients were kept 10 or 15 min in the lateral decubitus position compared with 5 min time. With a higher dose of hyberbaric bupivacaine, i.e. 12.5 mg, 90-100% of the patients developed a bilateral block when the lateral decubitus position was maintained for 5 to 10 min, and even with 15 minutes spent in the lateral decubitus position, 50% of the patients had bilateral block (Esmaoglu et al. 1998). When the influence of 20 versus 30 min time spent in the lateral decubitus position on the possibility to develop unilateral block was evaluated, both the level of sensory block and the incidence of unilateral sensory block were similar with 6.12 mg of hypobaric bupivacaine. Although the unilateral motor block was achieved more often after 30 min in the lateral decubitus position, the longer time spent in this position did not have an effect on motor recovery (Kuusniemi et al. 1997).

The earlier finding that hyperbaric rather than hypobaric bupivacaine can facilitate the development of unilateral block (Kuusniemi et al. 2000a), was confirmed in a recent study comparing hyperbaric and hypobaric i.t. bupivacaine (Kaya et al. 2004). All the patients were kept in a lateral decubitus position for 15 min before turning them supine. At 15 min, the incidence of unilateral block was equal, 80% versus 76% of the patients, respectively. But 15 min after the patients had been turned supine, 68% of the patients in the hyperbaric group compared with 24% in the hypobaric group, had unilateral block. The maximum level of the sensory block on the operative side did not spread higher after the patient had been turned supine. With conventional doses of bupivacaine (i.e. 15 mg plain/hyperbaric), the change in position as late as 80-115 min after spinal injection increased the level of sensory block by 1 to 4 segments (Povey et al. 1989; Niemi et al. 1993).

The injection site is one factor influencing the intrathecal spread. Unfortunately, the ability of an anaesthetist to predict a certain lumbar interspace has been shown to be poor: 59-85% of anaesthetists failed to identify lumbar interspaces correctly (Van Gessel et al. 1993; Broadbent et al. 2000). A higher level of

sensory block was noted when 3 ml of plain bupivacaine was injected at the L2/3 interspace compared to the L4/5 interspace (Tuominen et al. 1989). On the other hand, when a higher dose (4 ml) of plain bupivacaine, was injected either at L2/3 or L3/4 interspace, no effect was found on sensory block level (Olsen et al. 1990). The use of a large dose and the 2-min time in the sitting position might have had an influence on the overall spread.

Finally, the needle type affects the spread of spinal anaesthesia as well as the direction of the spinal injection. As early as in 1961, Tanasichuk found a higher incidence of spinal hemianalgesia with the use of a pencil-point needle (Whitacre) compared to a non-directional (Pitkin) needle: 67% versus 30% of the patients, respectively (Tanasichuk et al. 1961). In a more recent study, 66% of the patients had a unilateral sensory block with a Whitacre needle compared to 16% of the patients with a Quincke needle (Casati et al. 1998a). When 60 mg of plain lidocaine was injected through a Whitacre needle, either with the aperture of the needle cephalad or caudally oriented, a higher sensory spread was found with the cephalad-oriented injection than with the caudally directed injection: Th3.4 ± 1.3 versus Th6.6 ±2.8 ($P<0.001$), respectively (Urmey et al. 1997).

Spinal anaesthetic agents

Local anaesthetics

A local anaesthetic agent inhibits neural transmission by blocking the conductance of sodium into the cell and thus making depolarization impossible. In Finland, all intrathecally administered local anaesthetics, including lidocaine, mepivacaine, bupivacaine, ropivacaine and levobupivacaine, are amino-amides. Amino-esters such as short-acting procaine and long-acting tetracaine are used for spinal anaesthesia elsewhere.

Since 1948, hyperbaric *lidocaine* has been widely used as a spinal agent for procedures of short duration. Both serious neurological injury (cauda equina syndrome) (Rigler et al. 1991; Schell et al. 1991) and transient neurological symptoms (TNS) (Schneider et al. 1993) were reported after the use of lidocaine in the beginning of 1990. Later, the incidence of TNS after short-acting lidocaine and mepivacaine has been 16-37% (Hampl et al. 1996; Hiller and Rosenberg 1997; Salmela and Aromaa 1998; Hiller et al. 1999; Pollock et al. 1999; Pollock 2003). These observations guided the researcher to look for other suitable spinal agents for outpatients.

The incidence of TNS after long-acting *bupivacaine* has been shown to be considerably lower, 0-3% (Hiller and Rosenberg 1997; Kuusniemi et al. 1997; Keld et al. 2000; Kuusniemi et al. 2000a), making the use of bupivacaine an attractive option for SA. In a dose-response study of hyperbaric bupivacaine (3.75 – 11.25 mg) in volunteers, each additional mg of bupivacaine increased the time to home readiness by 21 min (Liu et al. 1996). In clinical studies, bupivacaine

(after a dose reduction from a conventional dose) has been shown to be suitable for outpatients. For ambulatory patients undergoing knee arthroscopy, both low doses of bupivacaine (4-6 mg) (Kuusniemi et al. 1997; Kuusniemi et al. 2000a; Borghi et al. 2003) and medium-low doses (6-8 mg) (Casati et al. 1998b; Fanelli et al. 2000; Enk et al. 2001; Borghi et al. 2003; Kaya et al. 2004) have been used successfully.

Ropivacaine, the S-isomer of the propyl homologue of bupivacaine (Whiteside et al. 2001) has approximately 50% of the potency of bupivacaine at equal doses, when administered i.t. (Gautier et al. 1999; McDonald et al. 1999). The incidence of TNS has been 0-6% after spinal ropivacaine (Gautier et al. 1999; McDonald et al. 1999; Buckenmaier et al. 2002). For ambulatory knee arthroscopy, the use of ropivacaine has not offered benefits over bupivacaine. The sensory and motor blocks recovered faster after a 10 mg dose of i.t. ropivacaine than after 8 mg of bupivacaine, but the quality of intraoperative analgesia was also significantly lower with ropivacaine (Gautier et al. 1999). Increasing the dose of ropivacaine to 12 mg, the recovery from SA was similar to that after 8 mg of bupivacaine (Gautier et al. 1999). The combination of 8 mg of ropivacaine and 15 µg of clonidine provided better analgesia for knee arthroscopy than 8 mg of ropivacaine alone and a recovery times suitable for outpatients (De Kock et al. 2001). Surprisingly few studies have been done with low-dose i.t. ropivacaine and opiods.

Levobupivacaine is the S-enantiomer of bupivacaine with a lower degree of cardiotoxicity compared to racemic bupivacaine (Whiteside and Wildsmith 2001). Cardiotoxicity is not relevant with the bupivacaine doses (up to 20 mg) used in spinal anaesthesia. No difference was found between the spinal block after i.t. bupivacaine or levobupivacaine (Alley et al. 2002).

Adjuncts

Vasoconstrictors (adrenaline, phenylephrine), alpha-2-agonists (clonidine), acetylcholine esterase inhibitors (neostigmine) and opioids (morphine, fentanyl and sufentanil) have been used as additives, with local anaesthetics for SA (Table 3). Because the use of i.t. adjuncts mainly aims to prolong the anaesthetic action, only a few of them are suitable for outpatients.

Low doses of i.t. opioids improve intraoperative analgesia (Abouleish et al. 1988; Liu and McDonald 2001) and the quality of anaesthesia (Ben-David et al. 1997; Goel et al. 2003). The effects on motor recovery and discharge are controversial, however. Most of the studies with a combination of low-dose local anaesthetic and fentanyl have found no delays on discharge (Vaghadia et al. 1997; Ben-David et al. 2000; Ben-David et al. 2001; Vaghadia et al. 2001; Lennox et al. 2002b; Jankowski et al. 2003), whereas Goel and co-workers showed a significant prolonging of motor block when 5 mg of bupivacaine was administered together with 10–12.5 µg of fentanyl compared to a 7.5 µg dose (Goel et al.

Table 3. Effects of certain adjuncts on the spinal anaesthesia with ambulatory patients.

Adjunct	Time of recovery	Quality	Side effects	Reference
Adrenaline				
0.2 mg and 7.5 mg bupivacaine versus bupivacaine alone	delayed	prolonged toleration of TES	NA	(Moore et al. 1998)
Clonidine				
15 µg and ropivacaine 8 mg	delayed, but suitable for outpatients	improved	–	(De Kock et al. 2001)
45-75 µg and ropivacaine 8mg versus ropivacine alone	delayed		hypotension, sedation	(De Kock et al. 2001)
Neostigmine				
6.25 µg – 50 µg + bupivacine 7.5mg versus bupivacaine alone	delayed	no effect/ prolonged toleration of TES	nausea, vomiting, sedation	(Liu et al. 1999)
Low-dose Opioid				
morphine	delayed	improved	PONV, respiratory depression, dysuria, pruritus	See text.
fentanyl, sufentanil	controversial	improved	PONV, pruritus	See text.

TES = transcutaneous electrical stimulation, PONV = postoperative nausea and vomiting

2003). This study was conducted in a single-blinded fashion. However, with higher doses (bupivacaine 10 mg and fentanyl 25 µg compared to bupivacaine 10 mg alone), a similar effect was found (Kuusniemi et al. 2000b). Hydrophilic morphine as an i.t. adjunct has been shown to produce long-lasting (24 h) post-operative analgesia (Abboud et al. 1988). The slow onset time, long duration of action, and a rare, but dangerous complication of late respiratory depression (Liu and McDonald 2001) limits the use of spinal morphine to inpatients. Even a mini-dose of i.t. morphine (50 µg) together with bupivacaine caused a 3-4 h delay in the ability to void, when compared with bupivacaine-fentanyl or bupivacaine alone, respectively (Gürkan et al. 2004).

Lipophilic opioids have a shorter duration of action than morphine, and the risk of respiratory depression is small with low-dose fentanyl (10-25 µg) (Liu and McDonald 2001). The use of i.t. fentanyl 10-25 µg together with a low dose of lidocaine or bupivacaine, is common in day surgery. The minimum effective dose of fentanyl is 10 µg (Liu and McDonald 2001). Sufentanil 10µg has been used successfully together with low-dose lidocaine 10-20 mg in producing SSA for gynaecological laparoscopy (Vaghadia et al. 2001), whereas i.t. 20 µg of sufentanil alone was unsuitable for the procedure (Henderson et al. 2001).

Failure of spinal anaesthesia

In a study of 1891 patients, the overall failure rate of conventional SA was found to be 3.1% after i.t. lidocaine or bupivacaine (Tarkkila 1991). In a recent study of 2603 orthopedic patients undergoing spinal anaesthesia, only 1% of the blocks failed after conventional SA with bupivacaine (Puolakka et al. 2000). When different needles were compared, the incidence of failure varied from 5.5 to 8.5% in orthopaedic inpatients with a 27-gauge pencil-point (Whitacre) or cutting needle (Quincke), respectively (Lynch et al. 1994) and from 7 to 7.7% in gynaecological inpatients when using either an Atraucan (26-gauge) or Whitacre (25-gauge) needle (Pan et al. 2002).

With low-dose (not unilateral) spinal bupivacaine 5 mg, a failure rate as high as 24% was reported, but when 5 mg of bupivacaine was combined with 10 µg of fentanyl, the failure rate fell to 0% (Ben-David et al. 1997). After bupivacaine 5 mg combined with either 10 or 7.5 µg of fentanyl in ambulatory urological patients, 13-27% of the blocks failed, whereas with a fentanyl dose of 12.5 µg, no failures occurred (Goel et al. 2003). Other investigators have reported a lower incidence of failure with (unilateral) low-dose spinal bupivacaine for patients undergoing knee arthroscopy. Plain or hyperbaric bupivacaine 4–8 mg resulted in a 0% incidence of failure (Kuusniemi et al. 2000a; Kuusniemi et al. 2001; Borghi et al. 2003; Kaya et al. 2004), after 5-12 mg of hyperbaric bupivacaine (dose adjusted to the height of the patient) 2.5% failed (Pittoni et al. 1995) and finally, a failure rate of 6% after 8 mg of hyperbaric bupivacaine either with unilateral or bilateral SA technique was noted (Fanelli et al. 2000). After a low dose of lidocaine (20 mg) together with fentanyl (20–25 µg) for knee arthroscopy, no failures were reported (Ben-David et al. 2000; Ben-David et al. 2001). When SSA was produced for gynaecological procedures with lidocaine and fentanyl or sufentanil, 20-50% of the patients needed intravenous opioids because of shoulder pain, but the need to convert to general anaesthesia was low or nonexistent (Vaghadia et al. 1997; Vaghadia et al. 2001; Lennox et al. 2002b).

Side effects of spinal anaesthesia

Hypotension

Hypotension occurs in 8.2 - 33% of the patients receiving SA, but as many as 81% of the patients develop episodes of hypotension when the peak sensory block exceeds Th5 (Tarkkila and Kaukinen 1991; Carpenter et al. 1992; Tarkkila and Isola 1992). SA causes sympathetic block, which results in arteriolar dilatation and venous pooling (decreasing systemic vascular resistance) and further hypotension. The venous pooling reduces venous blood return to the heart and can decrease cardiac output and cause hypotension (Carpenter et al. 1992). The level of the sympathetic block (Tarkkila and Isola 1992), the intravascular volume

status, as well as age, affect the extent of decrease in blood pressure (Pitkänen et al. 1984; Tarkkila and Isola 1992).

Bradycardia

The overall incidence of bradycardia after SA is 8.9-13% (Tarkkila and Kaukinen 1991; Carpenter et al. 1992; Tarkkila and Isola 1992), but may be as high as 75% when peak sensory block extends > Th5. If the sympathetic cardio-accelerator fibres from Th1 to Th5 are blocked, the vagal parasympathetic tone predominates, resulting in mild to moderate bradycardia (Salinas et al. 2003). Bradycardia may occur after decreased venous return or stimulus such as traction on the peritoneum, but it can remain unexplained, too (Mulroy 2002b). Risk factors for bradycardia (heart rate < 50 bpm.) are baseline heart rate < 60 bpm, the use of β-blockers, ASA physiological status I (Liu and McDonald 2001).

Cardiac arrest resulting from severe hypotension and bradycardia is an infrequent side effect of SA. In a prospective survey in France, 41000 spinal blocks were performed during a 10-month follow-up: 10 cardiac arrests occurred (2.7/10000) after SA (Auroy et al. 2002), whereas in a Finnish study, 2 out of 550000 SA patients developed cardiac arrest (Aromaa et al. 1997).

Since the SA-induced hypotension is related to the level of sensory block, it is reasonable to try to restrict the spread of SA. Decreased haemodynamic changes after unilateral and selective spinal anaesthesia techniques have been demonstrated in several studies (Tanasichuk et al. 1961; Kuusniemi et al. 1997; Vaghadia et al. 1997; Kuusniemi et al. 1999; Fanelli et al. 2000; Kuusniemi et al. 2000a).

Neurological sequelae

Serious permanent neurological injury after SA is rare, but when it occurs, it is a catastrophic complication (Dripps and Vandam 1954; Vandam 2004). In an important study by Dripps and Vandam (Dripps and Vandam 1954), early and late effects of SA were studied after 10098 spinal blocks: after a 6-month follow-up only one case of serious neurological injury was found, affecting a patient with an asymptomatic meningioma. Case-reports of cauda equina syndrome after continuous SA with lidocaine in 1991 (Rigler et al. 1991; Schell et al. 1991) aroused concern against both the continuous i.t. technique and the neurotoxicity of i.t. lidocaine. More recently, seven cases, in which the conus medullaris was damaged following spinal anaesthesia, were described: Bupivacaine was used through an atraumatic needle, injected at L2/3 interspace, and all patients reported pain on insertion of the needle. Six of the patients were obstetric, and one was obese (Reynolds 2001). Aromaa and co-workers (1997), however, found the incidence of serious neurological complications to be low: 0.003% following SA and 0.002% following EPI, based on patients

claims in Finland during the years 1987–1993. Auroy and co-workers (2002) reported the incidence of serious neurological injury to be 0.01% after spinal, and 0.003% after epidural anaesthesia.

The term transient neurological symptoms (TNS) is described today as unilateral or bilateral pain in the anterior or posterior thighs with or without extension into the legs and back after recovery from SA (Pollock 2003). The first studies used the name transient radicular irritation (TRI), but it was replaced by TNS, because a definitive aetiology was lacking and, it described these symptoms better, as they had a possible neurological origin, but were more musculoskeletal in nature (Rowlingson 2000; Faccenda and Finucane 2001; Pollock 2003). TNS were first described as late as 1993, by Schneider and co-workers after a single-shot spinal anaesthesia with 5% lidocaine (Schneider et al. 1993). Since then, a number of randomized, controlled studies have been conducted to determine the incidence and aetiology of TNS after spinal anaesthesia. Although the exact mechanism remains unclear, it is now known that the highest incidence of TNS occurs after lidocaine SA (10-37%) compared to other local anaesthetics, and in patients undergoing knee arthroscopy (18–22%) or surgery in the lithotomy position (30–36%) (Pollock 2003). Neither the dilution of lidocaine (Pollock et al. 1999) nor the use of isobaric rather than hyperbaric solution have decreased the occurrence of TNS significantly (Eberhart et al. 2002). After a reduced dose of lidocaine (1% hypobaric) 50 mg, TNS occurred in 33% of the patients, but with a mini dose of lidocaine 20 mg together with fentanyl 25 µg, only 4% of the patients developed TNS (Ben-David et al. 2000).

Although the aetiology of TNS remains unclear, some authors have recommended to avoid the use of i.t. lidocaine in unilateral spinal anaesthesia (Enk 1998) and in certain patient groups (ambulatory knee arthroscopy and procedures where nerve stretching is possible, like lithotomy position), because of the high risk of TNS in these patients (de Jong 1994; Pollock 2003).

Postdural puncture headache

Intense headache after SA was reported after the first spinal anaesthesias given, and Bier himself was affected by this headache when the spinal block was administered to him in 1898 (Spencer 1998). By that time, up to 66 % of the patients developed postdural puncture headache (PDPH), due to the use of large gauge, cutting spinal needles (Turnbull and Shepherd 2003). Today, the incidence of PDPH is less than 3% (Mulroy and McDonald 2003), when smaller-gauge and pencil-point needles are used. Although it is known that the dural puncture leads to CSF leakage through a needle-induced dural hole, and further to lower CSF pressure, the actual mechanism behind the PDPH remains unclear (Turnbull and Shepherd 2003).

PDPH can be described as a headache appearing within the first three days or even a week after a certain or possible dural puncture, worsened by an upright

position and relieved when lying down. It lasts over 24 hours, being usually a frontal or occipital headache, but it can be associated with photophobia, neck stiffness, tinnitus and/or nausea. The majority of the patients with PDPH recover spontaneously in 5 to 10 days (Horlocker 2000). Mild to moderate symptoms can be treated conservatively with bed rest, hydration, analgesics and caffeine. However, in the case of severe symptoms, an epidural blood patch is the treatment of choice with a success rate of over 90% (Horlocker 2000).

Several risk factors for PDPH have been identified. The incidence of PDPH decreases in patients older than 40-50 years of age (Mulroy and Wills 1995; Eriksson et al. 1998). Women have been considered to have an increased risk for PDPH (Dripps and Vandam 1954; Despond et al. 1998; Eriksson et al. 1998), although an opposite result has been found, too (Seeberger et al. 1996). The most important factor is the type and the size of the needle. A recent study with 529 outpatients showed the incidence of PDPH to be higher when using a 27-G Quincke vs. a 27-G Whitacre needle: 2.7% versus 0.37% ($P<0.05$), respectively (Santanen et al. 2004). In a meta-analysis, a reduction in the incidence of PDPH was seen when a small-gauge spinal needle vs. a large needle of the same type, and when a non-cutting rather than a cutting spinal needle was used (Halpern and Preston 1994). The risk of PDPH increases also if repeated dural punctures are required. After a single puncture vs. multiple punctures, the incidence of PDPH was found to be 1.6% compared to 4.2% ($P < 0.02$), respectively (Seeberger et al. 1996).

Difficulties in voiding

The incidence of postoperative urinary retention is controversial. After a conventional dose of i.t. bupivacaine, the incidence of urinary retention was as high as 30% (Mulroy et al. 2002). On the other hand, a certain type of surgery (hernia or anal surgery), or a history of retention increased significantly the risk of urinary retention in patients receiving GA, local or peripheral nerve block compared to patients undergoing non-pelvic procedures (Pavlin et al. 1999). When long-lasting local anaesthetics, even at reduced doses, are used i.t., their effects on voiding should be taken into consideration. The detrusor block after SA with long-acting bupivacaine (10 mg hyperbaric) lasted much longer than after short-acting lidocaine (100 mg hyperbaric), 462 min versus 233 min ($P=0.0002$), whereas the motor block lasted only 148 versus 144 min, respectively (Kamphuis et al. 1998). The abilty to void was 40 min shorter after lidocaine 60 mg, than after levobupivacaine 10 mg or ropivacaine 15 mg: 245 min versus 284 and 285 min, respectively ($P < 0.05$) (Breebaart et al. 2003). Because the delayed return of bladder function may lead to overdistension and further to urinary retention (Mulroy et al. 2002), ambulatory patients have been required to void before discharge.

On the other hand, several researchers have reported a very low frequency of urinary problems associated with low-dose SA or EPI either after a local anaes-

thetic solution alone or in combination with a low dose of lipophilic opioid (Ben-David et al. 1996; Ben-David et al. 1997; Ben-David et al. 2000; Kuusniemi et al. 2000a; Mulroy et al. 2000; Mulroy et al. 2002). Since discharge is often delayed because of the requirement of voiding (Mulroy et al. 2002), it has been suggested that the requirement of urination before discharge should be mandatory only in selective patients (Ben-David et al. 2000; 2002; Mulroy et al. 2002). Finally, in a study of Mulroy and co-workers this practice was evaluated by performing a bladder ultrasound to those patients who did not void spontaneously. The authors concluded that voiding could be omitted before discharge home in outpatients after spinal anaesthesia when using a short-acting spinal anaesthetic or hyperbaric bupivacaine < 7mg in patients with low risk of urinary retention (Mulroy et al. 2002).

Backache

Non-radiating backache has been reported in 33% of the patients undergoing SA (lidocaine) and in 20% of the patients receiving GA (Hiller et al. 1999). One important factor affecting postoperative back pain is the duration of surgery, and it is not related to the anaesthesia method (i.e. GA, SA, EPI) used (Faccenda and Finucane 2001). The incidence of backache rises from 18%, with surgery lasting less than 1 h, up to 50% when the operation time exceeds 4 h (Faccenda and Finucane 2001). Schwabe and Hopf investigated persistent back pain after SA and found that after 5 days 11% and after 3 months 12% of the patients had back pain, but 99.2% of these patients had suffered from back pain already before spinal anaesthesia. They concluded that the incidence of a new backache after SA was 0.8% (Schwabe and Hopf 2001). The type of needle affected the incidence of backache, being 21% after Quincke (G25 -27) and 17% after Whitacre (G22 – 27) needles ($P<0.05$). Also the number of skin punctures influenced the incidence of back pain: after one puncture it was 17% and after multiple punctures 27% ($P<0.01$) (Eriksson et al. 1998).

Pruritus

The incidence of pruritus induced by i.t. opioids is high even after low doses: 60-85% with i.t. or epidural morphine (Yeh et al. 2000; Kjellberg and Tramèr 2001), 50-68% with i.t. fentanyl (Vaghadia et al. 1997; Ben-David et al. 2001; Vaghadia et al. 2001) and 40-80% with i.t. sufentanil (Vaghadia et al. 2001; Lennox et al. 2002b; Waxler et al. 2004). Although annoying, the pruritus induced by i.t. fentanyl or sufentanil is seldom severe (Ben-David et al. 1997; Kuusniemi et al. 2000b; Buckenmaier et al. 2002). After i.t. morphine, the pruritus may last up to 13 h (Yeh et al. 2000), but after i.t. lipophilic opioids the duration of pruritus has not been reported. Several drugs, like propofol (Warwick et al. 1997; Beilin et al. 1998; Yeh et al. 2000), 5-hydroxytryptamine$_3$ (5-HT$_3$) receptor antagonists

(Borgeat and Stirnemann 1999; Yeh et al. 2000; Gürkan and Toker 2002) and droperidol (Kjellberg and Tramèr 2001) have been studied in treating or preventing pruritus, but with contradictory results. The μ-receptor antagonists, naloxone, naltrexone and nalbuphine, have been shown to be effective, suggesting therefore the involvement of the μ-receptors in the mechanism of intrathecal opioid induced pruritus. Naloxone is widely used for the treatment of opioid-induced pruritus, but the possibility of reversing the analgesic effect of the i.t. opioids limits the use of naloxone during surgery (Kjellberg and Tramèr 2001).

Postoperative nausea and vomiting (PONV)

PONV is traditionally considered to be one of the most frequent side effects after general anaesthesia, and the literature concerning PONV has focused on patients undergoing GA (Borgeat et al. 2003). Nausea is, however, a common side effect associated with SA, too (Tarkkila and Kaukinen 1991; Carpenter et al. 1992; Tarkkila and Isola 1992). Female sex increased the risk of nausea, as did a higher sensory level of the block, and opioid premedication (Tarkkila and Kaukinen 1991; Tarkkila and Isola 1992). In a recent review (not systematic) by Borgeat and co-workers (2003), the authors concentrated on PONV after RA and concluded that female gender might be a risk factor for PONV also after RA, but other patient-related risk factors should be further investigated. Crocker and Vandam (1959) found that hypotension increased the risk of nausea or vomiting in patients undergoing SA. The incidence of hypotension after unilateral spinal anaesthesia (5-7%) (Kuusniemi et al. 1999; Kuusniemi et al. 2000a) and SSA (0%) (Chilvers et al. 1997; Vaghadia et al. 1997) has been low when compared with conventional SA (15-33%) (Carpenter et al. 1992; Tarkkila and Isola 1992), but findings on the frequency of nausea and vomiting have been controversial.

Borgeat and co-workers (2003) reported that spinal morphine induced PONV dose-dependently, whereas lipophilic opioids, fentanyl and sufentanil, had no or only little effect on PONV. This is in contrast with recent studies in outpatients undergoing SA with low-dose local anaesthetics together with i.t. opioids. Already a dose of 50 μg of i.t. morphine together with 6 mg of bupivacaine induced nausea to 35% of the patients compared to 0% with i.t. bupivacaine alone (Gürkan et al. 2004) and furthermore, the incidence of nausea was 20-27% after i.t. fentanyl 20-25 μg (Ben-David et al. 2001; Pollock et al. 2003) and up to 30% after i.t. sufentanil 10 μg (Vaghadia et al. 2001; Lennox et al. 2002b). On the other hand, in the studies with low-dose i.t. fentanyl, the risk of PONV decreased: 5-7% of the patients suffered from PONV after low-dose bupivacaine combined with 7.5–15 μg of fentanyl (Goel et al. 2003; Jankowski et al. 2003). Other adjuncts, such as neostigmine, have been shown to cause PONV, too. Even a low dose of i.t. neostigmine (6.25 mg) together with bupivacaine 7.5 mg induced PONV to 33% of the volunteers compared to 0% of the volunteers with the same dose of bupivacaine alone (Liu et al. 1999).

Management of general anaesthesia in ambulatory surgery

Equipment in general anaesthesia

Special monitoring

Depth-of-hypnosis monitoring has been developed to prevent awareness during anaesthesia (Chikungwa and Smith 2003). Many devices are already in use and several others are under development, but the bispectral index of EEG (BIS) seems to be the most frequently used at the moment. The bispectral index is a value derived from electroencephalography (EEG) (Sigl and Chamoun 1994). A single number of BIS (ranging from 100 to 0) decreases when the depth of anaesthesia increases. A BIS value < 60 is associated with "a very low probability to recall" (Rosow and Manberg 2001). In ambulatory anaesthesia, the use of a BIS monitor has resulted in faster emergence and decreased consumption of propofol (Gan et al. 1997), sevoflurane and desflurane (Song et al. 1997). A wide variation of BIS index levels has been used, but in studies concerning fast-tracking, the BIS index levels have commonly been kept between 55-65 during the maintenance of anaesthesia (Song et al. 1997; Tang et al. 2001) or a higher level of BIS, 60-75, has been used towards the end of surgery (Gan et al. 1997). Song and co-workers concluded that in outpatients, a BIS value as high as 75 at the end of propofol or desflurane anaesthesia was needed to achieve faster PACU discharge criteria and PACU bypass eligibility (Song et al. 1998).

Laryngeal mask airway versus intubation

A laryngeal mask airway (LMA) is used as often as a tracheal tube in elective ambulatory surgery (Joshi 2003). Since a LMA can be inserted without muscle relaxation or laryngoscopy, no neuromuscular reversal drugs are required at the end of surgery. Most studies in patients breathing spontaneously through a laryngeal mask have been done with sevoflurane or propofol. Also desflurane has been used with LMA in patients breathing spontaneously (Tang et al. 2001; Dolk et al. 2002).

Anaesthetic agents used in general anaesthesia for ambulatory surgery

Propofol has a fast recovery profile, making it the hypnotic drug of choice for induction of anaesthesia in outpatients. As a non-irritant volatile anaesthetic, sevoflurane allows also rapid and smooth induction and can be used as an alternative to i.v. propofol/muscle relaxant induction (Joshi 2003). GA maintained with propofol is associated with a lower incidence of PONV (Sneyd et al. 1998) but a longer time to early stage recovery compared to anaesthesia maintained

with desflurane or sevoflurane (Dolk et al. 2002). The highest fast-tracking percentages were obtained with desflurane compared with sevoflurane and propofol (90% versus 75% and 26%) after gynaecological laparoscopy (Song et al. 1998). The maintenance of anaesthesia with a modern, short-acting i.v. anaesthetic agent (propofol) (Erhan et al. 2003) or inhaled anaesthetics (desflurane and sevoflurane) renders recovery and home discharge times comparable to those after RA (Li et al. 2000; Lennox et al. 2002b).

Opioids

Analgesia during surgery is mainly produced with opioids (White 2002). The use of high doses of perioperative opioids increases the risk of complications, like PONV, sedation, ventilatory depression and delayed home discharge (White 2002). Fentanyl is a common opioid in ambulatory surgery and during MAC. With low doses, 25-100 μg i.v., cumulation is not a problem, and recovery is not delayed. Fentanyl is also suitable for postoperative use in the PACU as a rescue medication (Tesniere and Servin 2003). Compared to fentanyl, alfentanil has a faster onset of action (time to peak effect 4 min versus 1.5 min, respectively). In outpatients, the incidence of PONV was lower after alfentanil than after fentanyl (Langevin et al. 1999). Remifentanil is an ultra-short-acting opioid having a similar onset as alfentanil, but a very short context-sensitive half-life that does not depend on the duration of remifentanil infusion. It lacks the residual opioid effect, which has to be remembered when planning the postoperative pain management (Tesniere and Servin 2003).

Neuromuscular blocking agents

In ambulatory surgery, the neuromuscular blocking agents should have a short duration of action (Schlaich et al. 2000). Mivacurium is a short-acting non-depolarizing muscle relaxant, providing rapid spontaneous recovery from neuromuscular block. Rocuronium at a dose of 0.6 mg/kg, is an intermediate-acting relaxant which provides a faster onset of action than mivacurium (Tang et al. 1996). By reducing the dose of rocuronium to 0.45 mg/kg the onset time was prolonged by 60 s compared to a dose of 0.6 mg /kg ($P<0.05$), but the intubating conditions remained excellent to good in 29 out of 30 patients. The duration to reach a train-of-four (TOF) ratio 0.8 decreased from 60 to 45 min (NS), with the reduced dose (Schlaich et al. 2000). To decrease the risk of residual muscle relaxation, objective neuromuscular monitoring should be used when administering non-depolarizing muscle relaxants (Gätke et al. 2002; Eriksson 2003). Earlier, a TOF ratio <0.7 (<0.8) was considered as an indication of residual paralysis (Gätke et al. 2002; Eriksson 2003). However, since the patient's ability to protect the airways (an important factor when considering postoperative pulmonary complications) has been shown to diminish when the TOF ratio is <0.9, the safety limit

of residual muscle paralysis has been set to a TOF ratio ≥ 0.9 (Eriksson 2003). In day-surgery, the fast recovery of muscle relaxation, and thus the possibility to avoid neuromuscular blocking reversal agents, is beneficial when considering the possibility of PONV induced by the reversal drugs (Tang et al. 1996).

Side effects after general anaesthesia

Postoperative pain

Postoperative pain is often the reason for delayed home readiness and unplanned hospital admission (Chung and Mezei 1999; White 2002). A balanced or multimodal technique (smaller doses of opioids in combination with local anaesthetics and nonsteroidal anti-inflammatory drugs, NSAID) can provide effective pain relief throughout the perioperative period, decrease the adverse effects of opioids and thus, enable fast-tracking and earlier discharge home (White 2002). In a systematic review, the use of i.a. local anaesthetic (bupivacaine) after knee arthroscopy was shown to be effective in controlling pain during the first 1-4 postoperative hours (Moiniche et al. 1999). In another systematic review, it was concluded that i.a. morphine at a dose of 5 mg achieved postoperative pain relief for up to 24 hours after knee arthroscopy (Kalso et al. 2002).

Postoperative nausea and vomiting

The incidence of postoperative nausea and vomiting (PONV) after general anaesthesia is 30% (Kovac 2000) and PONV is associated with delayed home discharge (Gold et al. 1989; Chung and Mezei 1999). It seems to be cost-effective to recognise the patients at high PONV risk and to provide prophylaxis to them (Watcha and Smith 1994; Apfel et al. 2004). A simplified risk score for PONV, consisting of female sex, history of PONV or motion sickness, non-smoker, and the use of postoperative opioids (Apfel et al. 1999) was developed to guide the management of PONV. Several drugs, like traditional metoclopramide and droperidol (Jokela and Koivuranta 1999; Henzi et al. 2000; Jokela et al. 2002), 5-HT_3 receptor antagonists (Jokela and Koivuranta 1999; Jokela et al. 2000; Jokela et al. 2002) and, dexamethasone (Henzi et al. 2000) have been studied, either alone or in combinations, to prevent PONV.

A recent multicentre trial of 5199 patients, with factorial design (Apfel et al. 2004) showed a similar efficacy for each of the three antiemetics, i.e. droperidol, dexamethasone and 5-HT_3 receptor antagonists, in preventing PONV. No double prophylaxis was superior to any other combination in preventing PONV. The patients with a low/moderate risk for PONV can be anaesthetised by using either a volatile anaesthetic together with antiemetic prophylaxis, or with propofol without the prophylaxis. For the patients at high risk (>40%), a multimodal approach (propofol maintained anaesthesia, with double antiemetic prophylaxis with droperi-

dol, dexamethasone) should be chosen. The best cost-benefit choice is to use droperidol and dexamethasone in prophylaxis and reserve the 5-HT_3 receptor antagonists for rescue medication (Apfel et al. 2004). On the other hand, the use of droperidol became troublesome after the FDA (United States Food and Drug Administration) "black-box" warning in 2001 indicating the possible association with torsades des pointes ECG changes. It has not been shown, however, whether the antiemetic doses prolong the QT-time, leading to this situation (Dershwitz 2002). Furthermore, the delay in recovery when using a dose of 0.014 mg/kg of droperidol should be taken into consideration (Valanne and Korttila 1985).

Studies comparing spinal anaesthesia and general anaesthesia in outpatients

SA and GA are both useful methods for ambulatory knee arthroscopy patients with respect to patient safety and operating conditions. Patient satisfaction with a certain technique may be related to the control of side effects, which have been discussed earlier. The total cost of an anaesthetic method is more difficult to evaluate. When only the costs of the drugs and disposables were calculated, the perioperative costs were lower after lidocaine SA than after propofol-maintained GA, USD 6.5 versus USD 30, respectively (Dahl et al. 1997). Although the time after surgery to readiness to leave the OR has been shown to be shorter after SA (lidocaine) than after GA (propofol or isoflurane), the preparation time corresponded conversely, and home-readiness was equal (Dahl et al. 1997; Wong et al. 2001). In a study with low-dose SA (lidocaine and fentanyl) and propofol-maintained GA, the patient satisfaction, intraoperative and postoperative efficiency, as well as discharge were comparable (Ben-David et al. 2001). Only a few studies comparing ambulatory SA with bupivacaine to GA in patients undergoing knee arthroscopy have been conducted. SA with 10 mg of bupivacaine resulted in prolonged time to home-readiness compared with intravenous anaesthesia with propofol and remifentanil (Danelli et al. 2002). On the other hand, 6 mg of bupivacaine together with 15 µg of fentanyl i.t. resulted in equal home discharge time compared with GA maintained with propofol (129 versus 131 min, respectively) (Jankowski et al. 2003). Not only the drugs during anaesthesia, but also the different times of recovery, as well as the costs of treating or preventing side effects (pain, PONV, PDPH) should be taken into consideration when cost is being evaluated (Dahl et al. 1997). In one recent study, these were evaluated after SSA (lidocaine and sufentanil) and after GA (desflurane) in gynaecological patients. The mean cost of the drugs and disposals and nursing was significantly lower after SSA than GA, whereas the costs of preparation and recovery were equal. The number of patients in this study was, however, relatively low (i.e. 20) (Lennox et al. 2002a).

Aims of the Study

The purpose of the thesis was to study the best possible anaesthesia for outpatients undergoing knee arthroscopy, with special reference to reliability, recovery times, side effects and the use of hospital facilities. The specific aims of the present series of studies were:

1. To compare the quality of spinal anaesthesia and the time to home-readiness after selective spinal anaesthesia produced by different doses of intrathecal hyperbaric bupivacaine with (II, III) or without low-dose fentanyl (I, II, IV, V) and after general anaesthesia maintained with desflurane (V).

2. To evaluate the possibility of a shorter stay in the post anaesthesia care unit (PACU), or bypassing PACU altogether after spinal anaesthesia when using intrathecal hyperbaric bupivacaine alone (I, II, IV, V) or in combination with fentanyl (II, III) and after general anaesthesia maintained with desflurane (V).

3. To evaluate the spread of spinal block after different doses of bupivacaine alone or in combination with fentanyl (I-IV), as well as the effect of the injection site (L2/3 or L3/4) and the posture of the vertebral column on selective spinal anaesthesia (IV).

4. To compare the side effects after selective spinal anaesthesia with bupivacaine, or a combination of bupivacaine and fentanyl (II, III, V), and after general anaesthesia maintained with desflurane (V), and furthermore, to find out whether intravenously administrated ondansetron can prevent low-dose intrathecal fentanyl-induced pruritus compared to placebo (III).

Patients and Methods

Ethical aspects and patients

All studies were approved by the Ethics Committee of Lapland Central Hospital. Studies III-V were also approved by the National Agency for Medicines. The written informed consent of all patients was obtained. In total, 483 ASA I-III ambulatory knee arthroscopy patients were investigated in 5 separate studies. The studies were conducted during the years 2000-2003 in Lapland Central Hospital, Rovaniemi, Finland.

Design of the original studies

Studies I-V were all prospective, controlled and randomised; Studies I-IV were also double-blinded. A placebo-control was used in Study III. A sealed envelope technique, with computer-generated random numbers was used to randomise the patients. The study designs are given in Table 4.

Table 4. Study designs.

	I	II	III	IV	V
Number of patients	106	100	90	123	64
Study design	prospective, randomized, double-blind	prospective, randomized, double-blind	prospective, randomized, double-blind, placebo-controlled	prospective, randomized, double-blind	prospective, randomized
Bupivacaine mg	4 or 6	4 alone or 3	3	4	4
Dose of fentanyl µg	0	10	10	0	0
Vertebral interspace	L2/3	L2/3	L2/3	L2/3, L3/4	L2/3
Intervention group	bupivacaine 4 mg i.t.	bupivacaine 3 mg + fentanyl 10 µg i.t.	ondansetron 4 or 8 mg i.v.	injection site L3/4 with/without a 5 degree head down tilt	GA with desflurane
Control group	bupivacaine 6 mg i.t.	bupivacine 4 mg i.t.	placebo i.v.	injection site L2/3, horizontal	SSA with 4 mg
Primary endpoint	home readiness	home readiness	incidence of pruritus	produce SSA at L3/4 level with/ without head down tilt of the vertebral column	home readiness and time in PACU

SSA = selective spinal anaesthesia, PACU = postanaesthesia care unit

Methods

Premedication and monitoring

Before their arrival to the operating room, the patients received either ketoprofen 100 mg p.o. (I), nimesulid 100 mg p.o. (II) or ibuprofen 600 mg p.o. (Studies III-V), or if contraindicated: paracetamol 1000 mg p.o. Intraoperatively, the patients who had SA were given midazolam up to 2 mg i.v. and/or alfentanil up to 0.5 mg (Studies IV-V) and up to 1 mg (Studies I-III) i.v. if needed. An intravenous infusion of 0.9% saline was started before the lumbar puncture or the induction of general anaesthesia. Standard monitoring (ECG, NIBP and pulse oximetry) was used for all of the patients. Bradycardia was treated with glycopyrrolate (<50 beats per minute) and with atropine (<40 b.p.m) and hypotension (<90 mmHg or SAP falling more than 50 mmHg from the baseline) was treated with etilephrine i.v. Furthermore, the BIS-index, the adductor pollicis TOF ratio (by using kinemyographic measurement with Datex-Ohmeda MechanoSensor®), the inspired and end-tidal concentrations of oxygen, CO_2, desflurane and N_2O were also monitored in the GA group. A tourniquet around the thigh, inflated 300-350 mmHg, was used in the operative extremity.

Spinal anaesthesia

In Studies II-V, a spirit level was used before the spinal puncture to ensure that the posture of the vertebral column was horizontal (in Studies II-V) or tilted 5 degrees "head down" (in Study IV, in the group L3/4T). In Studies I-III and in the spinal group in Study V, the injection site was L2/3. In Study IV, one third of the patients were injected at the L2/3 interspace, with the vertebral column horizontal (control group), one third at the L3/4 interspace, with the vertebral column tilted 5 degrees head down, and one third at the L3/4 interspace with the vertebral column horizontal. Technically, the spirit level was placed along the lower thoracal and all lumbar spinosus processes while the patient was lying sideways, the operative side dependent. After that the inclination of the vertebral column was set to 0 or 5 degrees head down tilted, depending on the study group, by turning the operating table to a proper position.

The dural puncture was performed with a 27-G Quincke needle (Becton-Dickinson Yale Spinal®) either with a median or lateral approach with or without an introducer. At the time of injection, the patient was in a lateral decubitus position, the operative side dependent: the position was maintained for 10 min from the beginning of the injection, in all studies. At 7 min, an additional head down or head up tilt was used for 3 min, if the sensory block was inadequate (i.e. the upper level of the sensory block was < L1 or the lower level was > L5).

Hyperbaric 5 mg/ml bupivacaine (Marcain® spinal tung, Astrazeneca) was used in all studies, either alone or in combination with fentanyl (Fentanyl B.

Brown 50 µg/ml, Brown Medical). In Study I, either 4 mg (0.8 ml) or 6 mg (1.2ml) of hyperbaric bupivacaine was injected i.t. In Study II, the study drug was either 4 mg of hyperbaric bupivacaine or 3 mg of bupivacaine in combination with 10 µg of fentanyl (the volume of both solutions was 0.8 ml). In Study III, all the patients received a combination of 3 mg of bupivacaine and 10 µg of fentanyl (0.8 ml). In Studies IV and V the dose of bupivacaine was 4 mg (0.8 ml). The study drug was injected over a 2-min period (i.e. 0.4 ml/min, except the patients receiving 6 mg in Study I, the rate was 0.6ml/min) in the studies. The aperture of the needle was turned laterally towards the nerve roots involved. To ensure good needle placement, a gentle aspiration of 0.1 ml was used. A 1-ml syringe (divided into 0.1-ml sections) was used in Studies II-V.

The specific gravities (= the ratio of the density of the solution at a specified temperature to the density of water at the same temperature) of 5 mg/ml Marcain® spinal tung and the solution (0.6 ml of hyperbaric bupivacaine and 0.2 ml of fentanyl) used in Studies II-III, were calculated by the pharmacists of the Lapland Central Hospital. The specific gravity of the commercial 5 mg/ml bupivacaine glucose mixture, Marcain® spinal tung was measured to have a specific gravity of 1.031 at 20°C (according to Pharmaca Fennica, the specific gravity of the Marcain® spinal tung is 1.026 at 20°C) and the specific gravity of the solution containing Marcain® spinal tung and fentanyl (3:1) was measured to have a specific gravity of 1.026 at 20°C, being thus hyperbaric relative to the CSF.

Evaluation of the sensory, sacral and motor blocks

The sensory block of the thoracic and lumbar nerves as well as the first sacral nerve (S1, measured form the little toe) was recorded on each side by using cold stimulus (acetone drop) to the respective dermatomes at 7, 12 and 30 min after the beginning of the injection, at the end of the operation, and every 20 min thereafter until recovery of dermatome L2 or discharge home. At 30 min, S1 was not tested because of existing surgical drapes at that time. If the dermatomes L1-L5, (L1 – L4 in studies I-II) on the operative side were not blocked at 12 min, the block was considered to have failed, and the patient received a general anaesthesia. The motor block on each side was assessed according to a modified Bromage scale (Kuusniemi et al. 1999) at 12-15 min after the beginning of the injection, postoperatively, and every 20 min thereafter, until complete recovery. Five myotomes were tested: L2 = hip flexion, L3 = knee extension, L4 = ankle dorsiflexion, L5 = great toe dorsiflexion, S1 = ankle plantar flexion. The score of each myotome was recorded as no block = 0 or complete block =1 point. Both sides were tested separately, and the maximum score on each side was 5 out of 5 points.

General anaesthesia

In Study V, half of the patients received general anaesthesia (GA). The risk of postoperative nausea and vomiting (PONV) was assessed, and the patients with ≥2 risk factors (female, non-smoker, history of PONV or motion sickness) were given prophylactic dexamethasone 5 mg i.v. after induction and a 5-HT_3 antagonist (ondansetron 4 mg) i.v. at the end of surgery. Rescue medication for PONV was provided by metoclopramide 10 mg i.v. for the patient who had received the prophylaxis, and ondansetron 4 mg i.v. for the patient without prophylaxis. GA was induced with propofol 2-3 mg/kg, 0.1 mg fentanyl and rocuronium 0.4 mg/kg i.v. Anaesthesia was maintained with desflurane 2-6% and 50% N_2O in O_2 titrated to keep the BIS index value towards the end of the operation between 50 and 60. For the first 6 min after intubation, a high-flow of 5 L/min of fresh gas was used, followed by a low-flow of 0.7 L/min for the rest of the anaesthesia. Additional fentanyl 0.05 mg i.v. was allowed when clinically indicated (blood pressure or heart rate more than 15% above the baseline values). All patients were mechanically ventilated to maintain an end-tidal CO_2 concentration of 4.5–5.5 kPa. A bolus dose of rocuronium (0.1mg/kg i.v.) was administered if required (high peak inspiratory pressure values or coughing). Neuromuscular reversal drug was used if the TOF ratio was less than 0.8 at the end of the operation. When the tourniquet was released, desflurane and N_2O were discontinued. The patients were extubated when fully awake.

Criteria for fast-tracking, PACU discharge and home-discharge

The time in the postanaesthesia care unit (PACU) was recorded as the time from admission to the PACU until transfer to the ambulatory surgery unit (ASU). After SSA, the criteria to transfer to ASU were full recovery from motor block, sensory block not above Th12, and stable vital signs. If the criteria mentioned above were fulfilled at the end of the operation, the patient bypassed PACU (i.e. was fast-tracked). After the release of the tourniquet, and every 20 min thereafter, the sensory and motor blocks were evaluated until the transfer to the ambulatory surgery unit (ASU). In Study V, after SSA the PACU discharge was evaluated by using both the new fast-tracking scoring system (White and Song 1999) and furthermore, complete recovery from motor block, sensory block not above Th12, and ability to sit up. The patient was fast-tracked to ASU, if the latter criteria were fulfilled at the end of surgery, considering that the new fast-tracking criteria were fulfilled, too. In the GA group, the recovery status was assessed after extubation and every 20 min thereafter by using the new fast-track scoring system (White and Song 1999). A minimum score of 12 out of 14 with no zero scores was required for the patient to be fast-tracked. Before transferring to ASU the patient had to be able to sit up, and patients with vertigo, somnolence, or those who

wanted to lie down, were kept in the PACU, even though their fast-tracking score was ≥12.

The home-discharge criteria consisted of: stabile vital signs, absence of PONV, no or minimal pain (VAS < 4), no bleeding, and ability to walk. A physiotherapist tested the ability to stand and ambulate, and gave the training instructions to the patients in the ASU. Voiding was required before home-discharge in Studies I-IV. The times of walking, voiding and home-readiness were measured from the time of spinal injection, in Studies I-IV. In Study V, voiding was not required before home-readiness, but the time to void was recorded if the patient had not yet left the hospital (for example no escort arrived). The times of walking and home-readiness were measured from the time of releasing the tourniquet (Study V).

In Study V, the anaesthesia preparation time (APT) was recorded as the time from ensuring the posture of the vertebral column until the end of the 10 min required for the patient to maintain the lateral decubitus position, in the SSA group. In the GA group, the APT was considered as the time from the beginning of injection of the induction drugs until connection of the patient to a respirator. Immediate recovery time from anaesthesia was recorded as the time from release of the tourniquet until extubation and orientation. The APT together with the immediate recovery time were considered as the anaesthesia-related time.

Postoperative follow-up and patient satisfaction

In the PACU and ASU, symptoms like PONV and pain were recorded in all studies. Pruritus was evaluated in Studies II and III. Home-readiness was assessed as described above. Postoperative pain was evaluated with a verbal analogue scale (VeAS) from 0 = no pain to 10 = the worst pain imaginable (Ben-David et al. 2001) or with a visual analogue scale (VAS) from 0 = no pain to 10 = the worst pain imaginable. Severe postoperative pain (VeAS or VAS >7) was treated with fentanyl i.v. (up to 0.1 mg), and moderate pain (3< VeAS/VAS<8) with a combination of paracetamol and codein (1g of paracetamol and 60 mg of codein) p.o., or if contraindicated, with tramadol (100 mg) i.v./p.o. Mild pain (VeAS/VAS <4) was treated with ketoprofen (50 mg) i.v. or propacetamol (2 g) i.v. If the pain relief was still insufficient, the patients received i.v. oxycodone (3-5 mg i.v. repeatedly until the pain relieved) and were admitted to the hospital. In Studies II and III, the pruritus was treated with naloxone 0.004–0.01 mg i.v., when needed.

A telephone interview was conducted within 4-7 days to elucidate the side effects and patient satisfaction. In Studies I-IV the interviewer was blinded to the method used. The patients were asked about headache (positional headache was considered as postdural puncture headache, PDPH), backache, TNS, difficulties in voiding, pain and post-discharge nausea or vomiting. TNS was defined as pain radiating to the buttocks or legs and/or sensory disturbances in areas not related to the surgery. In Studies II and V, the pain in the operated knee was asked by

using a verbal analogue scale from 0 to 10. In Study II, the pruritus was evaluated on a scale of mild, moderate or severe in the hospital, and in Study III, by using a verbal analogue scale (from 0 = no pruritus to 10 = the worst pruritus imaginable) in the hospital and at home.

The patient's opinion of the anaesthesia given was asked by using the alternatives superior, equal or worse than anticipated. Their willingness to choose the same type of anaesthesia for a similar operation in future was also asked.

Statistical analysis

For all studies, a power-analysis was performed with a power of 0.80 and a significance level of 0.05. In Studies I-II, the sample sizes (of 52 and 44, respectively) were calculated to detect a 25% reduction in the time of recovery from motor block after two different doses of i.t. anaesthetic drug (with 45% SD in Study I, and 50 min SD in Study II). In Study III, the incidence of i.t. fentanyl-induced pruritus was assumed to decrease 50% when using prophylactic ondansetron: 75% without and 37.5% with ondansetron. The sample size of 24 per treatment group was raised to 30 because of possible dropouts. In Study IV, the level of sensory block was assumed to reach 2 segments lower in 30% of the patients when the i.t. drug was injected at the L3/4 interspace with a horizontal position of the vertebral column compared to the sensory block in patients injected at the L3/4 interspace with a 5 degree head down tilt of the vertebral column, or in patients injected at L2/3 level with a horizontal position. The calculation resulted in a sample size of 36 patients per treatment group. In Study V, the sample size of 28 per group was calculated to detect a 20% difference in home-readiness, assuming the time to be 110 min and 140 min after SSA and GA maintained with desflurane, respectively.

The Statistical Package for Social Sciences (SPSS®) for Windows (Versions 9.0, 10.0, 11.0.1 and 12.0) was used for statistics in all studies (SPSS Inc., Chicago, IL, USA). The Confidence Interval (CI) analyses were performed with the CIA program (Gardner and Altman 1989) in Studies III-IV to compare the outcomes by calculating the 95% confidence interval for the differences in proportions. When comparing categorical data, χ^2 and Fisher's exact tests were used, whereas for nonparametric data the tests were Kruskal-Wallis, Mann-Whitney U and Student's t-tests. A two-tailed P-value below 0.05 was considered as statistically significant in all studies.

Results

Patients, failures and reliability

The number of patients and their characteristics in Studies I-V and within subgroups are given in Tables 5 and 6. Because of a failed block, 4 patients in Study I, one patient in Study II, and 4 patients in Study III received GA for the surgical procedure and these patients were excluded from all analyses. In Study IV, there was one failure (2.5%) in the group L3/4T, 2 failures (5%) in the group L2/3 and 5 (12%) in the group L3/4H. These patients were included in the analyses of both the sensory and motor block (in order to estimate the effects of using a lower interspace on the level of the block), but were excluded from the analyses

Table 5. Number of patients in Studies I-V, within different subgroups, protocol violation and failures.

	I		II		III			IV			V		Total	
	B4	B6	B3F	B4	O4	O8	P	L2/3	L3/4T	L3/4H	SSA	GA	SSA	GA
Number of patients														
– randomized	106		100		90			123			64		451	32
– protocol violation or impossible dural puncture	3	0	1	0	0	1	0	3	1	0	0	0	9	0
– total	103		99		89			119			64		442	32
– within groups	51	52	49	50	30	29	30	38	40	41	32	32		
– failures	3	1	1	0	2	2	0	2	1	5	2	0	19	0
	(6)	(2)	(2)		(6.7)	(6.9)		(5.3)	(2.5)	(12.2)	(6.3)		(4.3)	
– final within groups	48	51	48	50	28	27	30	36	39	36	30	32	423	32

Values are n (%).

Table 6. Patient characteristics in Studies I-V.

	I	II	III	IV	V
Number of patients	99	98	85	111	62
Gender; female/male	46/53	51/47	36/49	52/67	29/33
Age (years)	45±15 46 [15-82]	43±14 45 [18-73]	47±15 47 [19-76]	45±14 46 [19-73]	42±14 43 [19-76]
BMI (kg/m2)	26±3 25 [18-32]	26±4 25 [19-33]	26±3 26 [18-34]	26±3 26 [18-33]	26±3 26 [18-32]
Duration of surgery (min)	26±11 23 [8-62]	29±17 24 [7-80]	33±15 30 [9-75]	29±15 26 [4-92]	33±21 26 [8-114]
Duration of anaesthesia at the end of surgery (min)	62±13 60 [33-105]	62±18 58 [37-120]	67±15 65 [39-111]	66±16 63 [38-26]	71±21 69 [40-134]

BMI = body mass index = weight kg/ (height m^2); values are mean ±SD or median [range].

concerning the time in PACU and home discharge, because they received general anaesthesia for the operation. In Study V, in the spinal group 2 failures (6%) resulted in exclusion. In the GA group, 3 patients had to stay overnight in hospital, and were excluded from the analyses concerning ambulating, voiding and home-discharge. The overall incidence of failure was 4% (19 patients) after SSA. The final number of patients receiving successful SSA was 423, and 32 patients were randomized to receive GA (Study V).

The quality of the anaesthesia is shown in Table 7. One patient in Studies I and V, and 4 patients in Study III received also propofol. One patient felt anxious already before the operation started, 5 others felt pain or discomfort during the procedure, and they received propofol aproximatley 45 min after the spinal injection. In 4 out of 6 cases, the injection had been technically difficult. In all studies, the three most common arthroscopic procedures (involving 63-95% of the patients) were partial excision of meniscus, operation for osteochondritis and exploration of the knee joint. The surgeon evaluated the quality of motor block to be good or satisfactory in 86 %, 98 % and 97 % of the patients after i.t. bupivacaine 3 mg + fentanyl 10 µg, bupivacaine 4 mg and general anaesthesia, respectively. The number of the patients with unilateral motor, sensory and sacral segment block, or no sacral (S1) block at all is given in Table 7.

Table 7. The quality of the anaesthesia.

	I		II		III			IV			V	
	B4	B6	B3F	B4	O4	O8	P	L2/3	L3/4T	L3/4H	SSA	GA
Number of patients	51	52	49	50	30	29	30	38	40	41	32	32
Failed block	3 (5.9)	1 (1.9)	1 (2)	0 (0)	2 (6.7)	2 (6.9)	0 (0)	2 (5.3)	1 (2.5)	5 (12.2)	2 (6.3)	N.A. N.A.
Additional opioids during surgery	2 (4)	1 (2)	5 (10)	7 (14)	7 (24)	6 (23)	6 (20)	5 (14)	5 (13)	4 (11)	3 (10)	24 (75)
Quality of motor block[1]												
good/ satisfactory/poor	N.A.	N.A.	36/ 8/4	43/ 5/2	22/ 1/4	13/ 7/6	19/ 5/4	34/ –/–	36/ –/1	29/ 4/1	27/ 1/0	30/ 1/1
Motor block unilateral			48 (100)	44 (88)	26 (93)	24 (89)	30 (100)	34 (94)	34 (87)	33 (92)	N.A.	N.A.
Sensory block unilateral	10 (21)	4 (8)	7 (15)	11 (22)	8 (29)	4 (15)	7 (23)	15 (42)	7 (18)	11 (31)		
Sacral (S1) block unilateral			38 (79)	41 (82)	17 (61)	24 (89)	24 (80)	30 (83)	26 (67)	27 (75)		
No S1 block at all			3(6)	5(10)	2(7)	0	3(10)	1(3)	4(10)	0		

Values are n (%). S1 = sacral segment block. [1]Asessed by the surgeon.

Sensory block and sacral segment block

In Study I, comparison of two doses, 4 and 6 mg of 5mg/ml hyperbaric bupivacaine injected at the L2/3 interspace, showed a significant difference in the upper level of the sensory block between the groups (Figure 1). On the operative side, the highest level of sensory block was seen 30 min after the injection, reaching Th7 (median) compared to Th10 after the 6 mg and 4 mg doses of bupivacaine, respectively. The sensory block was lower, but adequate, on the operative side after the 4 mg dose compared to 6 mg. The extension of sensory block decreased to L2 or lower after 120 versus 160 min after the 4 mg and 6 mg dose, respectively.

In Study II, the comparison of a 4 mg dose of hyperbaric bupivacaine to 3 mg of hyperbaric bupivacaine combined with 10 µg of fentanyl injected at the L2/3 interspace, gave no statistical difference in the development or recovery of sensory block. On the operative side, the sensory block reached the Th10 (median) after 4 mg of bupivacaine and Th11 after the combination at 30 min, and decreased to L1 level or lower after 120 min in both groups (Figure 1).

In Study III, all the patients received 3 mg of bupivacaine combined with 10 µg of fentanyl intrathecally. The upper sensory block reached the Th11 (median) dermatomy at 30 min, and the block faded to L2 level or below in 120 min (Figure 1).

In Study IV, the median level of the upper sensory block was significantly higher when the spinal drug was injected at the L3/4 interspace with the vertebral column tilted head down (L3/4T) compared to an injection at L2/3 (L2/3) or L3/4 (L3/4H) interspace with the vertebral column kept horizontal. At 30 min, the median upper level of the sensory block was Th8, Th10 and Th11 in the groups L3/4T, L2/3 and L3/4H, respectively (Figure 2). To achieve an adequate level of sensory block, 26% and 39% of the patients needed a modification of the posture (i.e. an additional head down tilt of the operation table for 3 min), in the groups L2/3 and L3/4H (NS), respectively. After this change in posture, 5% and 12% of the patients still had inadequate block for surgery (= failed block). On the other hand, when the same dose was injected at the L3/4 interspace tilting the vertebral column 5 degrees head down during the time of injection (up to 6 min), only 10% of these patients needed postural modification, and finally only 2.5% of the blocks failed.

When the L2/3 interspace and a horizontal position was used, an additional head down tilt at 7 min was needed in 16-25% of the patients after 4 mg of bupivacaine (Studies I-II), in 14% of the patients after 6 mg of bupivacaine (Study I) and in 23% of the patients with the combination of bupivacaine and fentanyl (3 mg + 10µg) (Study II).

The number of patients having unilateral sacral segment (S1) block or no sacral segment block on either side is given in Table 7. The 4 mg dose of bupivacaine and the combination (bupivacaine and fentanyl), produced either a unilateral or

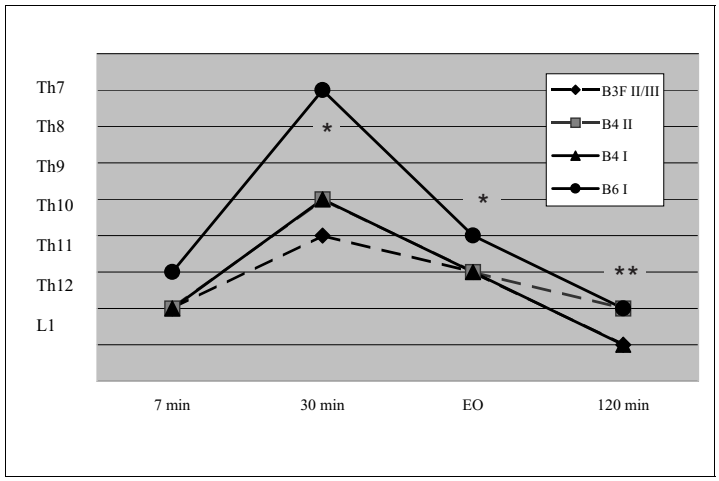

Figure 1. The median of the upper level of the sensory block at the operative side at different times and after different doses of hyperbaric bupivacaine or bupivacaine + fentanyl combination.

B3FII/III = Bupivacaine 3 mg + fentanyl 10 µg in Studies II and III. B4II = Bupivacaine 4 mg in Study II, B4I = bupivacaine 4 mg in Study I and B6I = bupivacaine 6 mg in Study I. *P < 0.01 between groups B6I and B4I, **P < 0.001 between groups B6I and B4I. EO= end of operation.

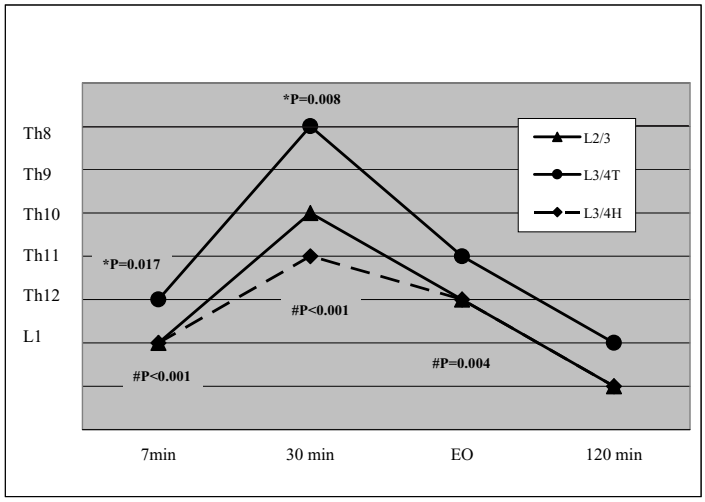

Figure 2. The median of the upper level of the sensory block at the operative side at different times with 4 mg of bupivacaine, after a different injection site and position of the vertebral column.

L2/3 = Injected at L2/3 level, with the vertebral column horizontal, L3/4T= injected at L3/4 level with the vertebral column tilted 5 degrees head down, L3/4H= injected at L3/4 level with the vertebral column horizontal. EO= end of operation.
*P values are between groups L2/3 and L3/4T and,
P values are between groups L3/4H and L3/4T.

an unaffected (i.e. the S1 not blocked on either side) sacral block to >75% of the patients when injected at L2/3 interspace. When the L3/4 level was used without a tilt, 75% of the patients had unilateral S1 block, but no one had an unaffected S1 block, whereas with the head down tilt 10% of the patients did not develop S1 block on either side. A significantly greater number of patients had S1 blocked at different time points in the L3/4 horizontal versus L3/4 tilt group (Figure 3).

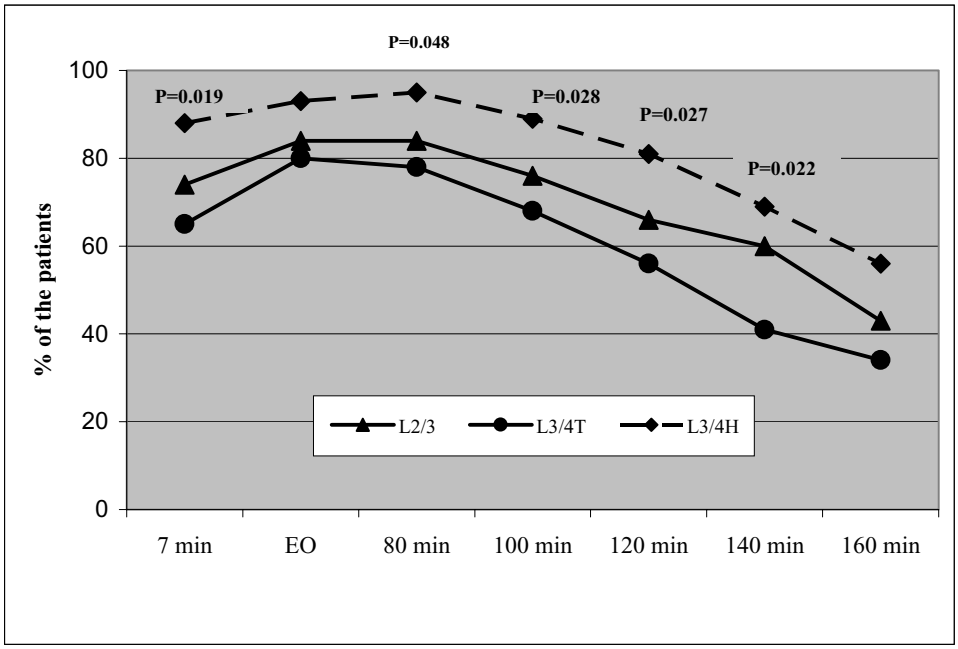

Figure 3. The proportions of patients having sacral segment (S1) block at different times on the operative side after spinal injection of 4 mg of hyperbaric bupivacaine.

The P values shown are between the groups L3/4T (T=vertebral column tilted head down for 6 min) and L3/4H (H= horizontal position). EO= end of operation.

Combining all the studies, the upper sensory level was equal after a 4 mg dose of bupivacaine injected at L2/3 interspace in Studies I-II and IV, and after combination of 3 mg of bupivacaine and 10 μg of fentanyl injected at L2/3 interspace in Studies II-III. On the other hand, the 6 mg dose injected at L2/3 interspace resulted in a similar upper level of the sensory block as the 4 mg dose injected at L3/4 level with the vertebral column 5 degrees tilted for the first 6 min. The lower level of the sensory block, i.e. the sacral segment block was mostly unilateral with a 4 mg dose injected at L2/3 or L3/4 level with a horizontally positioned patient, whereas injection at the L3/4 level with a head down tilt of the vertebral column left the sacral segments more often intact.

Motor block

In Study I, the maximal motor block, median [range], on the operative side was similar, 5 [1-5] and 5 [0-5] after 4 and 6 mg dose of bupivacaine, respectively. In Study II, the motor block on the operative side was 3 [1-5] and 2 [0-5], P<0.01, after 4 mg of bupivacaine and 3 mg of bupivacaine and 10 µg fentanyl, respectively. The recovery from motor block happened in the following order: 3 mg of bupivacaine + 10 µg fentanyl > 4 mg > 6 mg of bupivacaine, when injected at the L2/3 interspace (Figure 4).

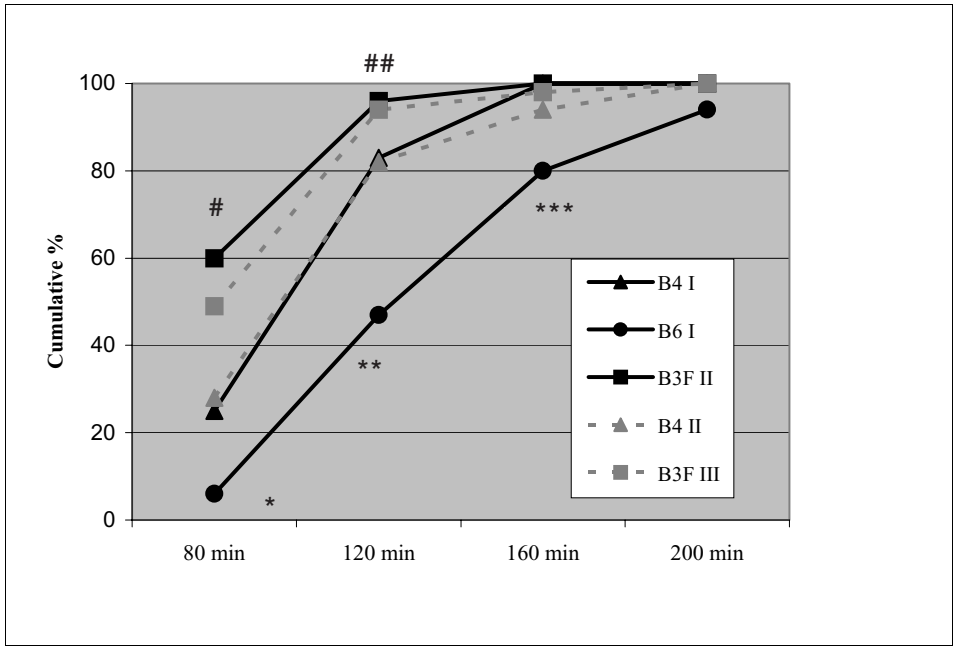

Figure 4. Cumulative percentages of patients needing 80 min, 120min, 160min, 200 min to recover from motor block on the operative side after spinal anaesthesia with different doses of bupivacaine or the combination of bupivacaine and fentanyl.

*P=0.01, **P<0.001, ***P=0.001 in Study I, between groups B4 and B6. #P=0.002, ##P=0.051 in Study II between groups B3F and B4. B4I=bupivacaine 4 mg in Study I, B6I=bupivacaine 6 mg in Study I, B3FII= bupivacaine 3 mg +10 µg fentanyl in Study II, B4II= bupivacaine 4 mg in Study II, B3FIII=all patients in Study III.

In Study IV, with the 4 mg dose of bupivacaine, the maximum motor block on the operative side was equal, when injected either at L2/3 interspace with the vertebral column horizontal or at L3/4 interspace with the vertebral column horizontal or tilted head down. The motor recovery was similar between the groups, and comparable to the recovery times after the 4 mg dose in Studies I-II.

At 12 min, the myotomes L2 (hip flexion) and L3 (knee extension) were mostly blocked, and the least affected was S1 (ankle plantar flexion), in all groups. The myotome L5 (great toe dorsiflexion) was blocked in 60% of the patients with the intrathecal injection at L3/4 level with the head down tilt versus in 88% of the patients (P=0.005) with the intrathecal injection at the L3/4 interspace without the tilt.

Combining Studies I-IV, the motor block (on a modified Bromage scale) was equal 15 min after spinal injection when using either 6 or 4 mg of hyperbaric bupivacaine, but a more profound motor block was seen after 4 mg of hyperbaric bupivacaine compared to a combination of 3 mg of hyperbaric bupivacaine together with 10 µg of fentanyl. The maximal motor block or the time of recovery from the motor block did not differ with the 4 mg dose of bupivacaine injected either at L2/3 or L3/4 level with or without the head down tilt. However, more selective motor block was seen when the injection site was at the L3/4 level with the head down position. In Studies II-IV, the motor block was highly unilateral in all groups (Table 7).

Haemodynamic changes

The number of patients with cardiovascular side effects is given in Table 8. The overall incidence of hypotension was 3% (12/423) and bradycardia 10% (44/423), after selective spinal anaesthesia. In Study V, none of the patients in the spinal group needed treatment for hypotension versus 7 (22%) patients in the general anaesthesia group (P=0.011), and 3 (10%) versus 8 (25%) received treatment for bradycardia (NS). In Study IV, none of the patients in the L3/4 tilt group needed treatment for cardiovascular side effects, although the upper level of sensory block reached higher than in the horizontal groups.

Table 8. Cardiovascular side effects.

	I		II		III			IV			V		Total
	B4	B6	B3F	B4	O4	O8	P	L2/3	L3/4T	L3/4H	SSA	GA	SSA
Hypotension	3 (6)	3 (6)	1 (2)	0	1 (4)	1 (4)	2 (7)	0	0	1 (3)	0	7 (22)*	12 (3)
etilefrine	3 (6)	3 (6)	1 (2)		1 (4)	1 (4)	2 (7)			1 (3)		7 (22)	
Bradycardia	7	16	3 (6)	5 (10)	3 (11)	1 (4)	1 (3)	4 (11)	0	1 (3)	3 (10)	8 (25)	44 (10)
glycopyrrolate	6 (13)	12 (24)	2 (4)	3 (6)	1 (4)	1 (4)	0	3 (8)			1 (3)	7 (22)	
atropine	1(2)	4 (8)	1(2)	3 (6)	2 (7)	0	1 (3)	1 (3)		1 (3)	2 (7)	1 (3)	

Values are n (%). *P=0.011 between GA and SSA groups in Study V.

Postoperative pain and PONV

In Study II, the postoperative pain at home was similar after spinal anaesthesia with 3 mg of bupivacaine and 10 µg of fentanyl (B3F) and after 4 mg of bupivacaine (B4) (Table 9). The pain VeAS score was at its highest in the evening of the operating day: 3.7 versus 3.1 in the B3F and B4 groups (NS) respectively. In Study V, the patients in the GA group had more pain in the hospital compared to the spinal anaesthesia group. The median VAS score in PACU was 5 (0-10) after GA and versus 0 (0-2) after SSA (P<0.001). At home, the pain was mild in both anaesthesia groups. In Study V, 41% of the patients in the general anaesthesia group received double PONV prophylaxis. In the hospital, the incidence of PONV was 19% compared to 0% (P = 0.024) in the general anaesthesia and spinal anaesthesia groups, respectively. At home, no difference was seen between the groups. In Studies II-IV, no one had PONV in the hospital after spinal anaesthesia. In Study III, 65% of the patients received ondansetron 4 or 8 mg i.v. before spinal anaesthesia.

Table 9. Postoperative pain and side effects.

	I		II		III			IV			V		Total
	B4	B6	B3F	B4	O4	O8	P	L2/3	L3/4T	L3/4H	SSA	GA	SSA
Pain VAS in PACU											0* [0-2]	5 [0-10]	
Pain VeAS at home 1st evening			3.7 [0-10]	3.1 [0-10]							2 [0-8]	3 [0-8]	
PONV in hospital	N.A.	N.A.	0	0	0	0	0	0	0	0	0**	6 (19)	0
PONV at home			6 (13)	5 (10)	5 (18)	2 (7)	0	1 (3)	5 (13)	0	2 (7)	4 (13)	
PDPH	2 (4)	2 (4)	2 (4)	2 (4)	3 (10)	1 (4)	2 (7)	3 (8)	2 (5)	1 (3)	1 (3)	–	22 (5)
Needed an epidural blood patch	0	0	0	1 (2)	1 (3)	1 (4)	0	0	0	0	1 (3)	–	4 (1)
TNS	1 (2)	2 (4)	3 (6)	0	0	1 (4)	0	1 (3)	1 (3)	1 (3)	1 (3)	2 (6)	11 (3)
Backache	6 (13)	5 (10)	9 (19)	6 (12)	1 (4)	1 (4)	2 (7)	8 (22)	3 (8)	7 (20)	4**** (14)	0	52 (12)
Dysuria	0	1 (2)	1 (2)	0	2 (7)	0	2 (7)	1 (3)	2 (5)	0	0	1 (3)	10 (2)
Pruritus	N.A.	N.A.	36# (75)	2 (4)	21 (75)	19 (70)	17 (57)	N.A.	N.A.	N.A.	N.A.	N.A.	
from mild to moderate			32	2	18	15	13						
severe			4	0	3	4	4						
Somnolence in ASU											0***	9 (28)	

Values are median [range]; n (%). #P<0.001 between B3F and B4 groups. *P<0.001, **P=0.024; ***P=0.002; **** P=0.049 between SSA and GA groups.

VAS = visual analogue scale, VeAS = verbal analogue scale, PACU = postanaesthesia care unit, PONV = postoperative nausea and vomiting, PDPH = postdural puncture headache, TNS = transient neurological symptoms, ASU = ambulatory surgery unit.

Fast-tracking and time in PACU

We found no difference in the number of patients who were fast-tracked between the groups in Studies II-V. In Study II, there was a trend towards a better possibility to bypass PACU with the combination of bupivacaine and fentanyl (3 mg + 10 µg) versus the 4 mg dose of bupivacaine: 35% versus 18% of the patients were fast-tracked (P=0.068), respectively. Furthermore, the time in PACU was significantly shorter with the combination (Table 10). When combining all the patients who received an equal amount of local anaesthetic agent, fast-tracking was achieved in 35% (47/133) and 12% (23/199) of the patients with 3 mg of bupivacaine and 10 µg fentanyl (Studies II-III) and 4 mg of bupivacaine (Studies II, IV-V), respectively. When SSA and GA were compared, no statistical difference was found in the fast-tracking possibilities or in the PACU time. In the SSA group (V), 12 patients were admitted to PACU instead of fast-tracking because of partial motor block on the operative side, although the new fast-tracking criteria were fulfilled, and 14 SSA patients stayed in PACU because of complete motor and/or sensory block above Th12 on the operative side. If we had followed the new fast-tracking criteria (where some weakness in the movement of the extremities is allowed if scores from the other six categories are sufficient) also in the spinal group, 12 additional patients with only partial motor block in the PACU could have been fast-tracked. Then 16 (53%) of the patients in the spinal anaesthesia group could have been fast-tracked compared to 7 (22%) in the GA group (P=0.017).

Home-readiness

In Study I, the standard home discharge criteria were fulfilled significantly faster after the use of 4 mg of hyperbaric bupivacine compared to 6 mg dose, after 181 min [115-319] and 209 min [147-377] (P<0.001), respectively (Table 10). In Study II, using the combination of 3 mg of bupivacine and 10 µg of fentanyl did not further shorten the time to home-readiness. In Study III, the home-readiness was achieved after 175 min [94-304] with 3 mg of bupivacaine and 10 µg of fentanyl.

In Study IV, the injection site (L2/3 or L3/4) or the posture of the vertebral column (horizontal or tilted 5 degrees cranially) did not affect home-readiness, but the overall recovery times were nevertheless longer than in the three earlier and in the one later study. The median home-readiness time was 212 [141-333] after injection at the L2/3 level, 197 min [131-243] at the L3/4 level with the horizontal posture of the vertebral column and 194 min [142-280] at the L3/4 interspace with the vertebral column tilted cranially.

In Study V, voiding was no longer required before home discharge, but it was recorded if the patient was still in hospital. When home readiness was adjusted from the time of induction or injection, the patients were home ready 192 min after GA and 183 min after spinal anaesthesia (NS).

Table 10. The time in PACU and until fulfilment of home discharge criteria after selective spinal and general anaesthesia.

	I		II		III			IV			V	
	B4	B6	B3F	B4	O4	O8	P	L2/3	L3/4T	L3/4H	SSA	GA
Time in PACU	64* [21-122]	94 [30-202]	36** [10-103]	55 [10-140]	21 [0-93]	24 [0-135]	20 [0-60]	48 [0-130]	45 [6-95]	44 [3-93]	40 [0-105]	30 [0-147]
Ambulating	166* [101-246]	196 [139-367]	158 [87-274]	166 [111-269]	147 [103-224]	152 [84-238]	151 [100-265]	195 [136-253]	186 [125-260]	179 [121-238]	180 [110-240]	175 [80-319]
Voiding	172* [115-319]	203 [122-377]	171 [99-395]	182 [111-311]	155 [103-256]	187 [94-252]	168 [103-304]	205 [125-285]	186 [124-278]	195 [126-243]	185 [115-280]	203 [108-319]
Home-readiness; *from the time of injection/ induction*	181* [115-319]	209 [147-377]	171 [111-279]	183 [111-316]	172 [103-256]	190 [94-266]	168 [103-304]	212 [141-333]	194 [142-280]	197 [131-243]	183 [115-245]	192 [83-319]

Times are minutes; median [range]. PACU= postanaesthesia care unit. *P<0.001 bupivacaine 4 mg versus 6 mg. **P=0.005 combination of bupivacaine 3 mg and fentanyl 10 µg versus bupivacaine 4 mg.

Side effects at home

The side effects are given in Table 9. The overall incidence of postdural puncture headache (PDPH) was 5% (22 patients), and 1% (4 patients) of the patients needed an epidural blood patch. 3 % of the patients (11/423) developed transient neurological symptoms after spinal anaesthesia and 6% (2 patients) after general anaesthesia. After spinal anaesthesia (all study groups), 2% of the patients developed some difficulties in voiding, but none of them needed medical help. The incidence of dysuria at home was 3%, in the patients undergoing general anaesthesia. In Study II, the incidence of pruritus was 75% after i.t. bupivacaine (3 mg) combined with 10 µg of fentanyl and 4% (P<0.001) after 4 mg dose of i.t. bupivacaine. 63 % of the patients considered the pruritus to be mild in the bupivacaine-fentanyl group. In Study III, all the patients received 3 mg of bupivacaine and 10 µg of fentanyl i.t.. Compared to placebo, the incidence of pruritus was equal to that after prophylactic i.v. ondansetron 4 or 8 mg, 57-75% of the patients developed pruritus. The median duration of the pruritus was 0.5-2.0 hours.

Patients' experience and satisfaction

The overall satisfaction with the anaesthesia was high (Table 11). The anaesthesia experience was judged to be equal or superior to expectations in 89-100% and 97% of the patients after SSA or GA, respectively. Similarly, 92–100 % and 78% of

the patients in the SSA and GA groups would choose the same anaesthesia also the next time.

In Study V, the patients' experience of the anaesthesia was mostly superior to their expectations in both groups, and they would choose the same anaesthesia technique also in future. Although not statistically different, a higher number of the patients in the GA group would prefer spinal anaesthesia the next time: 2 patients because of difficult side effects, PONV and dizziness, 2 would like to communicate with the surgeon during the operation, and 2 would like to try spinal anaesthesia. No one complained of insufficient pain relief in the GA group. In the SSA group, the one patient with PDPH would like to try general anaesthesia in the future.

Table 11. Patient satisfaction.

	I		II		III		IV			V		
	B4	**B6**	**B3F**	**B4**	**O4**	**O8**	**P**	**L2/3**	**L3/4T**	**L3/4H**	**SSA**	**GA**
Patients' experience												
superior	34(72)	31(62)	35(73)	43(88)	22(79)	22(82)	27(90)	30 (83)	34 (87)	27(77)	26(90)	23(74)
equal	11(23)	15(30)	10(21)	6 (12)	3 (11)	2 (7)	3 (10)	4 (11)	4 (10)	7 (20)	3 (10)	7 (23)
worse than anticipated	2 (4)	4 (8)	3 (6)	0	3 (11)	3 (11)	0	2 (6)	1 (3)	1(3)	0	1 (3)
Willingness to have same anaesthesia												
yes	46(98)	47 (94)	47 (98)	48(98)	26(93)	24(92)	30(100)	36(100)	39(100)	34(97)	28(97)	25(81)
no	1 (2)	3 (6)	1 (2)	1 (2)	2 (7)	2 (8)	0	0	0	1 (3)	1 (3)	6 (19)

Values are n (%).

Discussion

Methodology

Sensory and sacral segment block

In all five studies, the level of sensory and sacral segment block was assessed by using thermal stimuli, i.e. a cold acetone drop. Methods such as the loss of sharp pinprick, the loss of cold and the loss of touch sensations are used to test the level of sensory block. Some studies with lidocaine and bupivacaine and fentanyl showed that during spinal anaesthesia, the levels of analgesia (pinprick) and cold sensation were equal (White et al. 1998; Patterson et al. 2001). Furthermore, the level of anaesthesia was 3 dermatomes lower (caudad) than the levels of analgesia and cold sensation (White et al. 1998). Earlier Brull and Green found that the loss of sensation to pinprick is 2 dermatomes cephalad compared to loss of touch, after i.t. hyperbaric bupivacaine (Brull and Greene 1989). In studies with patients undergoing caesarean section, loss of both cold and pinprick sensations have poorly predicted the level of adequate anaesthesia (Alahuhta et al. 1990; Hirabayashi et al. 1995a), whereas in a recent study it was found that loss of touch would predict better the level of anaesthesia in these patients (Russell 2004), a result demonstrated already much earlier with surgical patients (Rocco et al. 1985).

On the other hand, Liu and Ware (1997) concluded in their study with volunteers, that after spinal anaesthesia with hyperbaric bupivacaine, the sensory block either to touch, pinprick or cold was a poor predictor for surgical anaesthesia and tourniquet pain. They used tolerance to transcutaneous electrical stimulation (TES) with an intensity of stimulation equivalent to surgical incision. However, the loss of cold sensation tested with a cold acetone drop is an easy and cheap method. Together with adequately tested motor block, they brought acceptable information of surgical anaesthesia in patients undergoing knee arthroscopy.

The sacral segment (S1) block was evaluated by using cold stimulus, too. The dermatome S1 was tested separately on both sides; this gave only a rough estimate of the true sacral block (the dermatomes S2-S4 where not tested). Together with an absence of motor block at the myotome S1 (= ankle plantar flexion), the lack of sacral block was more evident.

Motor block

The motor block was assessed by using a modified Bromage scale, where 5 myotomes (L2-S1) corresponding to a specific joint movement were tested separately on both sides (0= no block of a myotome and 1=myotome blocked) (Kuusniemi et al. 1997; Kuusniemi et al. 1999; Kuusniemi et al. 2000a). Although most

studies have used a Bromage scale from 0 to 3 (0= no motor block, 1=hip blocked, 2=hip and knee blocked, 3=hip, knee and foot blocked), we wanted to have a method, in which the 5 myotomes could be tested independently. This provided us with a possibility to estimate whether the site of injection or the posture of the vertebral column had an effect on motor block, by moving the blocked myotome cephalad (Study IV). Being simple to perform and easy for the patient, without special equipment, the modified Bromage scale offers a reliable method to test the onset and quality of motor block for the surgical procedure.

However, when evaluating the recovery from motor block, other methods than the Bromage scale might be more suitable. A quantitative method measuring isometric muscle strength showed that the actual recovery of motor strength after a high dose of bupivacaine was reached 1.5–2 h later than estimated when using the Bromage scale (Axelsson et al. 1985). The standard clinical tests of motor recovery were found to be poor predictors of functional balance after low-dose i.t. bupivacaine and fentanyl. Although 100% of the patients had regained gross motor functions (Bromage scale, joint position, leg raising, deep knee bending and heel-to-shin touch) 60 min after spinal injection, only 36% of the patients could stand, and 8% of the patients could walk without assistance at that time ($P < 0.01$). The majority, 96% of the patients, could walk adequately 150 min after spinal injection (Imarengiaye et al. 2003). Although the spinal block was bilateral in their study, and accordingly the disturbances of motor function, balance and postural stability were bilateral, a similar walking lag was observed in our studies: 96% of the patients after i.t. bupivacaine 3 mg + fentanyl 10 µg and 83% of the patients after i.t. bupivacaine 4 mg had recovered from motor block (assessed by a modified Bromage scale) 120 min after spinal block, but the ability to walk followed 30-40 min later (Studies I-III). As Imarengiaye and co-workers concluded, ambulation without assistance should be a major factor when determining home-readiness in outpatients (Imarengiaye et al. 2003).

The anaesthetic techniques used in spinal anaesthesia and general anaesthesia

The discharge time is used to estimate the efficacy of different anaesthesia techniques. Furthermore, fast-tracking results in a shorter stay in the postanaesthesia care unit (PACU) and thus, might save costs as a result of the decreased need of personnel in PACU (Marshall and Chung 1999). In Study V, focussing on the efficacy of selective spinal anaesthesia and general anaesthesia, the GA was maintained with desflurane, because earlier studies have shown the better fast-tracking eligibility after desflurane compared to sevoflurane and propofol (Song et al. 1998). Tracheal intubation was chosen instead of LMA, because in the study hospital the surgeons who performed the knee arthroscopies were mainly residents, and thus motor relaxation was required. Since the surgeon had considered the relaxation to be poor in 4% of the patients after the 4 mg dose and in up to

16% of the patients after the i.t. combination of 3 mg bupivacaine and 10 μg fentanyl (Studies II-III), we preferred to use the 4 mg dose in the SSA group and neuromuscular blocking agents in the GA group. To minimize the need for reversal drugs, a low-dose rocuronium was used with careful monitoring of muscle relaxation (adductor pollicis TOF ratio by using kinemyographic measurement with Datex-Ohmeda MechanoSensor®) in the GA group. The use of LMA instead of tracheal intubation could have shortened the time to extubation and orientation in the GA group. Whether the use of LMA would have influenced fast-tracking or home-readiness is more difficult to estimate: the factors which hindered the PACU bypass were pain, dizziness, sedation and shivering. However, it is possible that the use of tracheal intubation might have caused a bias in favour of SSA versus GA.

The risk for postoperative nausea and vomiting (PONV) was assessed before general anaesthesia (Apfel et al. 1999), and the patients with ≥2 risk factors (female, non-smoker, history of PONV or motion sickness) received double prophylaxis. This concept has been suggested also in a recent multicenter study, although the most preferable/cost-effective combination for preventing PONV would be dexamethason and droperidol (Apfel et al. 2004). However, droperidol may cause delayed recovery (Valanne and Korttila 1985), which is why we used dexamethason and ondansetron.

Study design

All studies were prospective, randomized clinical trials, and the size of each study group was based on power analysis. Studies I-IV were double-blinded, whereas in Study V the different nature of the anaesthesia techniques made the blinding of the study impossible, which may have biased the results.

Assessment of recovery and home-discharge criteria

When Study I was conducted (in 2000), fast-tracking was not used for outpatients undergoing neuraxial anaesthesia in the study hospital. The highest probability of PACU bypass was seen after the combination of bupivacaine and fentanyl (35% of the patients (47/133), Studies II-III) because of the shortest time to gross motor recovery. The protocol in the present studies to follow the patients in the PACU until complete motor recovery (Bromage), sensory block not above Th12 and vital signs resulted in only 12% (23/199) of the patients to be able to bypass PACU after 4 mg of bupivacaine (Studies II, IV, V). However, the ability to move the lower extremities fully is not required before discharge from PACU in the various PACU bypass criteria (Aldrete 1995; White and Song 1999).

In most studies, a modified Aldrete scoring (Appendix 1) system has been used when determining the possibility of fast-tracking, after either GA or SA. Since in these criteria pain and PONV are not included, White and Song developed a more suitable scoring system for PACU bypassing (Appendix 2) and found

that a higher percentage of the patients having been judged eligible for fast-tracking using a modified Alderete scoring system required more i.v. analgesics and antiemetics compared with assessing the ability of bypassing PACU by using the new criteria (White and Song 1999). The new criteria were, however, designed for outpatients undergoing general anaesthesia, not neuraxial anaesthesia. Furthermore, the level of sensory block has not been taken into account, which may increase the possibility of orthostasis when the patient rises to a sitting position. In Study V, the PACU discharge was evaluated by using both the new fast-tracking scoring system (all patients), and furthermore, complete recovery from motor block and sensory block not above Th12 (the patients undergoing spinal anaesthesia). In the spinal group, the PACU bypass was possible, if the later criteria were fulfilled at the end of surgery, but the fulfilment of the new fast-tracking criteria were recorded as well. In both groups, the patient had to be able to sit up (without any symptoms like dizziness, nausea) before being transferred to ASU. The different criteria used in Study V between SSA and GA, as well as in the literature between different methods, make the estimation of the fast-tracking possibility after a particular anaesthesia method difficult. In future, when comparing general and neuraxial anaesthesia, the PACU bypass criteria presented by Williams and co-workers might be the most useful, since they include also pain, PONV, shivering and orthostasis (Williams et al. 2000; Williams et al. 2002; Williams 2004; Williams et al. 2004) (Appendix 4). Their studies, however, were observational and retrospective.

In Studies I-IV, the home discharge criteria consisted of absence of PONV, no or minimal pain, no bleeding, and ability to walk and void. In Study V, the ability to void was no longer required, but the time to urinate was recorded, if the patient still remained in hospital (the escort arrived late).

Spinal anaesthesia

Spinal anaesthesia technique

The aim of the studies was to develop a selective spinal anaesthesia for ambulatory knee arthroscopy. Ideally, the SSA would be unilateral, with only minimal or no motor block left at the end of the operation. The sensory block of dermatomes L1-L5 would be essential. If the S1 dermatome is not blocked, some patients may sense discomfort from the tourniquet at the backside of their thigh. On the other hand, if the pelvic nerves (S2 – S4) are not blocked, the ability to void after spinal anaesthesia may be facilitated (Kamphuis et al. 1998).

In all the present studies, the basic elements of the injection technique were equal: low-dose (3–6 mg of bupivacaine), low-volume (0.8–1.2 ml) and minimal-flow (0.4–0.6 ml/min), the use of hyperbaric solution, and maintenance of the lateral decubitus position for 10 min. The horizontal posture (or the 5 de-

gree head down tilt of the vertebral column in one group in Study IV) of the vertebral column was ensured with the help of a spirit level in Studies II-V. When the table is horizontal, the position of the vertebral column of a laterally placed patient is usually tilted between –5 and +5 degrees depending on the build of the patient: in women the broad pelvis can cause a slight head-down position of the vertebral column already when lying sideways, and in men with wide shoulders the opposite is true. Hence, the posture of the vertebral column needs to be measured in order to have an exact spread of hyperbaric local anaesthetic. Furthermore, the L2/3 vertebral interspace was used in all studies, except in Study IV, where the L3/4 interspace was used in two out of three groups. The dural puncture was made with a Quincke type needle (G27) in all studies.

Although the spread of spinal anaesthesia has been claimed to be unpredictable (Connolly and Wildsmith 1998), an identical spread of sensory block was demonstrated in different studies (I-III) when the same dose of bupivacaine or the combination was used (Figure 1). Also the gross motor recovery was almost equal after the same dose (Figure 4). We believe that a strictly standardized injection technique together with a low dose of hyperbaric bupivacaine resulted in this predictable spread of SA. Furthermore, a significantly higher spread of spinal block was found after a 6 mg dose of i.t. bupivacaine compared to a 4 mg dose, when the L2/3 interspace was used, but if the 4 mg dose was injected at L3/4 interspace and the posture of the vertebral column was tilted 5 degrees head down at the same time, a similar upper dermatomal spread was seen as after the 6 mg dose at L2/3 interspace. The combination of 3 mg of bupivacaine and 10 µg of fentanyl injected at L2/3 interspace resulted in an equally low spread as the injection of 4 mg of bupivacaine at L3/4 interspace without the tilt, but the latter method resulted in too many failures (12%), whereas 3.5% of the blocks failed overall. Although the difference in the failure rate was not statistically significant, the trend towards a higher risk of failure is clinically important.

There are some points to be criticized with respect to the technique. First, the L2/3 vertebral interspace was mainly used. Broadbent and co-workers (2000) demonstrated a poor capability of anaesthetists to identify the actual vertebral interspace: only 29% of the anaesthesiologists in their study could identify the interspace correctly. More recently, in a study with cadavers, a higher percentage of the anaesthetists (49%) were able to identify the interspace correctly at the Th8 – L4 region. Unfortunately, this study confirmed the tendency of anaesthetists to estimate the interspace to be more caudal than it actually was (Lirk et al. 2004). One can assume that the risk to insert the needle at the L1/2 interspace (and thus possibly damage the conus) is higher, if the intended interspace is L2/3 rather than L3/4. On the other hand, the L2/3 interspace is widely used in both conventional and unilateral spinal anaesthesia techniques, and it is recommended in a fresh textbook of regional anaesthesia: "The L2/3 interspace is usually preferred because injection at this level will take maximum advantage of the lumbar

spinal curvature to encourage spread of the solution both cephalad and caudad" (Mulroy 2002b). Furthermore, in Study IV, the possibility of choosing the intented interspace incorrectly may have influenced the spread of the block and thus lowered the accuracy of the results.

Second, the injections were made with a 27-G Quincke needle (Becton-Dickinson Yale Spinal), not with a pencil-point needle. The Quincke needle is associated with higher risk of PDPH than a pencil-point needle (Santanen et al. 2004). Furthermore, Tanasichuk demonstrated a long time ago that the pencil-point needle resulted in more patients having spinal hemianalgesia compared with the use of a Pitkin needle (Tanasichuk et al. 1961). Later, Casati et al. achieved a more marked differential sensory block with a Whitacre spinal needle compared to a Quincke needle (Casati et al. 1998a). In future, a good practice would be to use a pencil-point needle at the L3/4 lumbar interspace with the vertebral column tilted 5 degrees head down for the first 6 min.

Selective spinal anaesthesia

Highly unilateral motor block (87-100% of the patients) and sacral segment (both dermatome and myotome S1) (61-90%) block were found in all studies, whereas sensory block was only moderately unilateral. Interestingly, in some patients the S1 dermatome remained unblocked on the dependent side (Table 7), and the myotome S1 was unaffected at the operative side in 73%, 80% and 66% of the patients in Studies II, III, IV. The sensory sacral segment (S1) was significantly less affected when injected at L3/4 level with a head down tilt compared to injection at the same site with horizontal position (Figure 3). Traditionally, spinal anaesthesia has been considered to "produce total neural blockade caudad to the site of injection" (Mulroy 2002b). We nevertheless found a spinal block resembling more or less a segmental epidural block, in some of the patients.

Reliability of spinal anaesthesia

In our studies, the overall incidence of failure was 4.3% after SSA (all groups), which is in accordance with both earlier findings with low-dose / unilateral spinal anaesthesia 0-6% (Pittoni et al. 1995; Fanelli et al. 2000; Kuusniemi et al. 2000a; Kaya et al. 2004), and with conventional spinal anaesthesia 1-3.1% (Tarkkila 1991; Puolakka et al. 2000). The overall incidence of failure diminishes to 3.5 % (14 patients out of 401), if the L3/4 horizontal group (Study IV), with an unacceptably high failure rate (12%) is excluded. In Table 12, the results from Studies I-III of the thesis are combined, and these results as well as the results from Study IV are compared to recent clinical trials of low-dose/unilateral spinal anaesthesia techniques.

A lighter motor block was achieved when using the combination of 3 mg of bupivacaine and 10 μg of fentanyl versus 4 mg of bupivacaine (Study II) and thus,

Table 12. A comparison of different low-dose/ unilateral spinal anaesthesia techniques used in outpatients undergoing knee arthroscopy. The results from recent prospective, randomized clinical trials, as well as from studies I-IV of the thesis.

Reference	No.	Anaesthetic technique	Lateral decubitus (min)	Failure (%)	Preparation time	Time to discharge (min, h)	Comments/Other results
(Kaya et al. 2004)	50	7.5 mg bupivacaine **hyperbaric** **hypobaric**	15	0	NA	NA	*68% vs. 24%* of the patients *had unilateral sensory block* after hyperbaric and hypobaric bupivacaine (P<0.05).
(Borghi et al. 2003)	90	**hyperbaric bupivacaine** 4 mg 6 mg 8 mg	15	0	NA	 ~ 100 ~ 150 ~ 160 P<0.05	*Unilateral block in 90, 93 and 77%* of the patients in the groups of 4, 6 and 8 mg. Walking with crutches was required, but not voiding.
(Fanelli et al. 2000)	100	8 mg hyperbaric bupivacaine **unilateral** **conventional**	 15 0	 6 6	 16 [15-30] 13 [5-25] P=0.0005	 264 ± 95 281 ± 83 NS	Voiding was required. *Need for vasopressors was higher in conventional* group: 11% vs. 0% of the patients (P = 0.02).
(Kuusniemi et al. 2000a)	60	6 mg of bupivacaine **plain** 0.5 % **hyperbaric** 0.5 %	20	0	NA	 4.9 ± 0.8 4.8 ± 1.0	*Unilateral motor and sensory blocks were found in 37% vs. 83%* of the patients (P<0.01) after plain and hyperbaric i.t. bupivacaine.
(Casati et al. 1998a)	30	8 mg hyperbaric bupivacaine **25G Whitacre needle** **25G Quincke needle**	15	 7[1] 7	NA	NA	*66% vs 13%* of the patients had *unilateral sensory block* in Whitacre and Quincke groups (P<0.05).
(Ben-David et al. 1997)	50	Diluted 0.17 % **bupivacaine 5 mg** **5 mg + 10 µg fentanyl**	 0 0	 24 0 P<0.05	NA	 187 ± 51 195 ± 49 NS	Voiding was required before discharge
(Ben-David et al. 2000)	110	1 % hypobaric **lidocaine 50mg** **lidocaine 20mg + fentanyl 25µg**	 0 0	 0 0	NA	 180 ± 31 145 ± 38 P=0.002	Voiding was required. TNS in 33 vs. 4% of the patients, in the lidocaine vs. combination group. (P<0.0001).
(Valanne et al. 2001, Korhonen et al. 2003) Studies I-III	291	**Hyperbaric bupivacaine** 3 mg + fentanyl 10 µg 4 mg 6 mg	10	 4 3 2	NA	 178 ± 39 186 ± 39* 218 ± 41* *P<0.001	Voiding was required. *Shorter time in PACU after the combination* than after 4 mg dose, but 75% developed pruritus after i.t. fentantyl.
(Korhonen et al. 2004 Study IV)	119	Hyperbaric bupivacaine 4 mg **L2/3 horizontal** **L3/4 tilt** **L3/4 horizontal**	10	 5 2.5 12	NA	 213 ± 41 198 ± 33 195 ± 30	*A more segmental nature of the block,* when L3/4 was used with a head down tilt for 6 min compared to a horizontal position

Time values (min, h) are either median [range] or mean ± SD, [1]The one patient in the Whitacre group needed no GA, but needed additional analgesia and sedation 60 min after dural puncture.

faster gross motor recovery. In this study, the quality of motor block assessed by a surgeon was considered mostly "good" in both groups, whereas in Study III, the quality of motor block was judged to be "poor" in 16% of the patients.

The overall need for additional opioids during surgery after SSA was 12% (51/423), which is in accordance with earlier studies with low-dose unilateral SA (Kuusniemi et al. 1997; Kuusniemi et al. 1999; Kuusniemi et al. 2000b; Kuusniemi et al. 2001).

As low a dose as 3 mg of bupivacaine together with fentanyl 10 μg or 4 mg of bupivacaine alone provided an equally reliable block for knee arthroscopy, a finding confirmed in a recent study (Kiran and Upma 2004). The combination did not, however, offer benefits over a 4 mg dose, because 75% of the patients in the fentanyl group developed pruritus and no earlier fulfilment of home discharge criteria. On the other hand, a significant reduction in the failure rate was found when 10–12.5 μg of fentanyl was combined with 5 mg of bupivacaine (Ben-David et al. 1997; Goel et al. 2003). Perhaps the high failure rate (12%) after i.t. injection of 4 mg of bupivacaine at the L3/4 interspace without a head down tilt (Study IV) might have been reduced by combining a low dose i.t. fentanyl.

Side effects after selective spinal anaesthesia

Cardiovascular

Low-dose spinal anaesthesia causes less hypotension than SA induced with a conventional dose, 4% (Kuusniemi et al. 1997; Kuusniemi et al. 1999; Kuusniemi et al. 2000a; Kuusniemi et al. 2001) versus 33% (Carpenter et al. 1992), respectively. In our studies, the overall incidence of hypotension was low: 3%, whereas the number of patients needing treatment for bradycardia 44/423 (11%) is equal to the number after a conventional dose, 9-13% (Tarkkila and Kaukinen 1991; Carpenter et al. 1992). Young age (Tarkkila and Kaukinen 1991), as well as the ASA physical status I (Liu and McDonald 2001) have been found to correlate with bradycardia following spinal anaesthesia, which might explain the high frequency of bradycardia in our material. The discomfort due to a noxious stimulus during surgery may cause a vasovagal reaction, but is an unlikely explanation in the present studies, because only 5 (11%) of the patients who received medication for bradycardia needed additional opioids.

Transient neurological symptoms (TNS), postdural puncture headache (PDPH) and backache

The overall incidence of TNS was 3% after SSA with low-dose bupivacaine or the combination of bupivacaine and fentanyl, which is in accordance with earlier studies (Hiller and Rosenberg 1997; Kuusniemi et al. 1997; Keld et al. 2000; Kuusniemi et al. 2000a). Hiller and co-workers (1999) raported TNS after GA,

which was confirmed in Study V: two patients (6%) in the GA group fulfilled our TNS criteria, which supports the hypothesis of the musculoskeletal origin of these symptoms (Rowlingson 2000; Faccenda and Finucane 2001) and the finding that patients undergoing knee arthroscopy are at risk of developing TNS (Pollock 2003). Five percent of the patients suffered from PDPH. Today, the incidence of PDPH is shown to be less than 3%, when pencil-point needles are used. The percentage of PDPH could probably be diminished by changing the Quincke needle to a pencil-point needle (Santanen et al. 2004). Twelve percent of the SSA patients had non-radiating backache, which is comparable with earlier studies (Hiller et al. 1999; Faccenda and Finucane 2001).

Difficulties in voiding

Dysuria at home was reported by a few patients after all doses of i.t. bupivacaine (alone or together with fentanyl) and after GA, but none of the patients needed catheterization. This, together with the finding of unilateral sacral block supports the idea of home readiness without voiding requirements after knee arthroscopy when short-acting agents or bupivacaine less than 7 mg are used (Mulroy et al. 2002). We agree that the high-risk patients should urinate before home discharge and, furthermore, attention should be paid particularly with increasing doses of bupivacaine. The prolonged detrusor block (462 min) after 10 mg of i.t. bupivacaine (Kamphuis et al. 1998), speaks against a 10 mg dose of bupivacaine in day-surgery. The 8 mg dose has been used in either conventional or unilateral spinal anaesthesia for knee arthroscopy, with a home-discharge time of 4 to 4.5 hours (voiding required) (Casati et al. 1998b; Fanelli et al. 2000). Using a conventional technique in volunteers, Liu and co-workers demonstrated that every additional mg of bupivacaine delays home-readiness by 21 min (Liu et al. 1996). Although the delay per mg with unilateral/selective spinal technique may differ (the restricted block prolongs recovery, on the other hand, the one-sided sacral segment block can facilitate the ability to void), the importance of reducing the dose becomes clear.

Pruritus

Pruritus was a common side effect after mini-dose i.t. fentanyl. In earlier studies, ondansetron could partly prevent pruritus induced by i.t. morphine (Yeh et al. 2000) and by higher dose of i.t. fentanyl (Gürkan and Toker 2002). We, however, found no difference in the incidence of pruritus, when prophylactic ondansetron was compared to placebo. It is possible, that the mild and short-acting pruritus induced by low-dose fentanyl (10 µg) in our study, made the evaluation of the level of the pruritus more difficult. A similar result, however, was found in a recent study with prophylactic ondansetron and i.t. sufentanil (10 µg) (Waxler et al. 2004).

Spinal anaesthesia in ambulatory surgery

The time to home-readiness in the present studies is compared with the results of other clinical trials in Table 12. The different subgroups (bupivacaine 3 mg and fentanyl 10 µg, bupivacaine 4 mg and 6 mg) in Studies I-III are combined in this table. The time to home-readiness after 3 mg of bupivacaine and 10 µg of fentanyl or 4 mg of bupivacaine is comparable to the home discharge time after 50 mg of lidocaine or after 5 mg of bupivacaine in the studies of Ben-David and co-workers (Ben-David et al. 1997; Ben-David et al. 2000). They were able to reduce the time to home readiness significantly when combining 20 mg of lidocaine and 25 µg of fentanyl (Ben-David et al. 2000). With equal doses of hyperbaric bupivacaine (4, 6 or 8 mg), the fulfilment of home discharge criteria were gained significantly earlier than in our studies. However, the authors concluded that the different home-discharge criteria might be the explanation (walking with crutches instead of without assistance), between their and our studies (Borghi et al. 2003).

In Study IV, the time to home-readiness was longer in all groups, than in our other studies. Since this time was prolonged by 30 min also in the control group (L2/3 group), reasons other than related to the spinal technique were considered, too. It appeared that when Study IV was conducted, the overall number of ambulatory patients had rapidly grown, while there was a temporary shortage of personnel (only one physiotherapist) in the ASU. This might have influenced the time to home readiness.

Selective spinal anaesthesia versus general anaesthesia in outpatients

In Study V, the possibility of PACU bypass and the times in the PACU and until home readiness were similar after both SSA with 4 mg of bupivacaine and GA maintained with desflurane. A significantly higher number of patients suffered from side effects such as pain, somnolence and PONV (despite the double prophylaxis) and needed more postoperative opioids after desflurane-maintained GA than after SSA, whereas PDPH and backache were seen more after SSA. On the other hand, an intra-articular local anaesthetic together with morphine might have been beneficial in lowering the pain scores in the GA group (Kalso et al. 2002), and further in reducing the risk of PONV. Perhaps a higher percentage of the patients in the GA group could also have been fast-tracked, if this method had been included in the study protocol. In a study where locally and IA bupivacaine was administered by a surgeon (Jankowski et al. 2003), 35% of the patients after GA (propofol infusion, NO_2, LMA) could bypass PACU compared to our 22%. In Study V, similar home discharge times were seen between the SSA and GA groups, being comparable with the results of Jankowski and co-workers.

After SSA for gynaecological laparoscopy (10 mg of lidocaine and 10 μg of sufentanil), the patients could ambulate 3 min after surgery, but their time to discharge after the end of surgery, 112 min (Lennox et al. 2002b), is comparable with our 114 min (Study V).

The overall anaesthesia-related time (ART) was 1.5 min longer in the SSA than in the GA group (V). Although the difference was statistically significant, such a short time has no clinical relevance. In the SSA group, the ART consisted only of the preparation time (17 min), because all the patients were awake and orientated at the time of tourniquet release. A similar preparation time (16 min) was demonstrated after unilateral spinal anaesthesia with 8 mg of hyperbaric bupivacaine, and readiness for surgery required 13 min after conventional bilateral block (Fanelli et al. 2000). In the SSA group, a 17 min reduction in the OR time could have been achieved, if an induction room had been used. However, this imposes other costs and requirements in terms of both physical plant and personnel. On the other hand, had we used the LMA and spontaneous ventilation in the GA group, a reduction in anaesthesia-related time in the OR might have been achieved in the GA group, too. When the GA patients in Study V were extubated and orientated 7.5 min after the release of the tourniquet, in other studies 3.4 – 4 min time to orientation was noted after GA maintained with desflurane and LMA (Tang et al. 2001; Dolk et al. 2002).

Conclusions

The following conclusions can be drawn from the present studies:

1. All study doses of hyberbaric bupivacaine (3 mg of bupivacaine together with 10 µg of fentanyl, 4 mg or 6 mg of bupivacaine) injected at the L2/3 interspace produced a reliable SSA, with readiness to discharge home suitable for ambulatory knee arthroscopy. However, a significantly shorter time to home readiness was achieved when using either the combination of bupivacaine and fentanyl (3 mg+10 µg) or 4 mg of bupivacaine compared to the 6 mg dose. Time to home-readiness was similar after SSA with 4 mg of bupivacaine and GA maintained with desflurane.
2. Although the faster recovery of gross motor functions resulted in better fast-tracking possibilities after spinal injection of 3 mg bupivacaine + 10 µg fentanyl compared to the 4 mg dose of bupivacaine, no earlier discharge home was found. No difference in PACU bypass rate was seen between the SSA and GA groups.
3. A strictly standardised spinal anaesthesia technique including the use of a spirit level to ensure the desired position of the vertebral column resulted in a predictable spread of spinal block with the same dose of hyperbaric bupivacaine injected at L2/3 interspace. When using a L3/4 interspace for injection, a measured head down tilt of the vertebral column moved the blocked dermatomes and myotomes cephalad thus producing a true segmental block. A trend towards an increased risk of failure was seen in patients injected at L3/4 interspace with the vertebral column horizontal at the time of injection.
4. Postoperatively, nausea and vomiting, pain and somnolence were more frequent after general than after spinal anaesthesia, whereas the risk of postdural puncture headache was quite high after spinal anaesthesia when a 27-G Quincke needle was used. Pruritus was a common side effect after i.t. fentanyl, and ondansetron 4 or 8 mg i.v. could not prevent it. The low incidence of transient neurological symptoms was similar to earlier studies with bupivacaine and TNS occurred equally after SSA and GA. A higher number of SSA patients had backache compared to GA patients. Only a few patients, after both SSA (all doses) and GA, developed minor difficulties in voiding, but no one needed catheterization.

Clinical Considerations

Selective spinal anaesthesia with a 4 mg dose of hyperbaric bupivacaine produces reliable anaesthesia for knee arthroscopy with tourniquet lasting up to 80-100 min, with a home readiness 3 hours after the spinal injection.

Maintenance of the lateral decubitus position for 10 min is sufficient to restrict the spread of the selective spinal anaesthesia with hyperbaric bupivacaine.

Also residents with limited experience in spinal anaesthesia may administer selective spinal anaesthesia. However, knowledge of the selective spinal technique and a thorough understanding of the factors affecting the spread of spinal block are essential.

Although the failure rate after SSA in the present studies is similar to that after a conventional dose of spinal anaesthetic: 3.5% versus 1-3.1%, respectively, one should aim at 100% success. Adjusting the position of the vertebral column carefully – horizontal if injecting at L2/3 interspace or tilting 5 degrees head down if injecting at the L3/4 interspace – diminishes the risk of failure, which may be further decreased by using a combination of i.t. bupivacaine 4 mg and fentanyl 10 μg, but then, 75% of the patients would develop mild pruritus.

To avoid the high risk of postdural puncture headache it might be reasonable to choose another type of needle instead of the G-27 Quincke needle used in these studies. The use of L3/4 interspace with a 5 degree head down tilt of the vertebral column is recommended for increased neurological safety.

For the patients not suitable for neuraxial anaesthesia, desflurane-maintained general anaesthesia provides equally fast home-readiness as SSA with 4 mg of bupivacaine, after knee arthroscopy. Backache was more frequent after SSA, but the incidence of TNS was similar after both methods. On the other hand, higher pain VAS scores, greater need for postoperative opioids, more PONV and somnolence were observed in the patients undergoing general anaesthesia. However, adding intra-articular local anaesthetic and/or morphine to their treatment would probably decrease the pain, the need for opioids, and thus PONV, as well.

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Anna-Maija Korhonen, MD

Appendices

Appendix 1

Postanesthesia Recovery Score (Modified Aldrete Score)

Consciousness		**Circulation**	
Fully awake and orientated (name, place, date)	2	Blood pressure ± 20% of preanaesthetic level	2
Arousable on calling	1	Blood pressure ± *20-49% of preanaesthetic level*	1
Not responding	0	Blood pressure ± 50% of preanaesthetic level	0
Activity		**Oxygen saturation**	
Moves all 4 extremities voluntarily or on command	2	*SpO_2 >92% on room air*	2
Moves two extremities voluntarily or on command	1	*Supplemental required to maintain SpO_2 >90%*	1
Unable to move extremities	0	*SpO_2 <90% with supplementation*	0
Respiration			
Breathes deeply and coughs freely	2		
Dyspnoea, limited breathing, or tachypnea	1		
Apneic or on mechanical ventilation	0	**Maximum score**	**10**

(Aldrete and Kroulik 1970; Aldrete 1995)

Appendix 2

The New Fast-Tracking Criteria

Level of consciousness score		**Oxygen saturation status**	
Awake and oriented	2	*Maintains value >90% on room air*	2
Arousable with minimal stimulation	1	*Requires supplemental oxygen (nasal prongs)*	1
Responsive only to tactile stimulation	0	*Saturation <90% with supplemental oxygen*	0
Physical activity		**Postoperative pain assessment**	
Able to move all extremities on command	2	*None or mild discomfort*	2
Some weakness in movement of extremities	1	*Moderate to severe pain controlled with IV analgesics*	1
Unable to voluntarily move extremities	0	*Persistent severe pain*	0
Haemodynamic stability		**Postoperative emetic symptoms**	
NIBP decreased <15% of baseline MAP	2	*None or mild nausea with no active vomiting*	2
NIBP decreased 15%–30% of baseline MAP	1	*Transient vomiting or retching*	1
NIBP decreased >30% below baseline MAP	0	*Persistent moderate to severe nausea and vomiting*	0
Respiratory stability			
Able to breathe deeply	2		
Tachypnoea with good cough	1	**Total Score**	**14**
Dyspneic with weak cough	0	*A minimum score of 12 (with no zeros) is required to bypass PACU*	

(White and Song 1999)

Appendix 3

Post Anaesthetic Discharge Scoring System (PADS)			
Vital signes		**Surgical bleeding**	
Within 20% of preoperative value	2	*Minimal*	2
20-40% of preoperative value	1	*Moderate*	1
> 40% of preoperative value	0	*Severe*	0
Activity and mental status		**Intake and output**	
Oriented × 3 AND has a steady gait	2	*Has had p.o. fluids AND voided*	2
Oriented × 3 OR has a steady gait	1	*Has had p.o. fluids OR voided*	1
Neither	0	*Neither*	0
Pain, nausea and/or vomiting			
Minimal	2		
Moderate	1	**Total PADS score**	**10**
Severe	0	*Considered fit for discharge*	*≥9*

(Chung et al. 1995)

Appendix 4

A Post-Anaesthetic Discharge Scoring System			
Movement		**Respiratory effort**	
Purposeful movement of (at least) one lower and one upper extremity	2	*Coughs and deep breathes freely, and/or on command*	2
Purposeful movement of at least one upper but neither lower extremity	1	*Able to cough involuntarily, not on command, maintains airway without support*	1
No purposeful movement	0	*Tachypnoea, dyspnoea, or apnoea, and/or requiring maintenance*	0
Blood pressure (Sitting position assessment required after a supine assessement)		**Pulse oximetry score**	
Within 20% of preoperative baseline, without orthostatic changes	2	*SpO_2 ≥95% on room air*	2
Between 20-40% of preoperative baseline, without orthostatic changes	1	*SpO_2 ≥95% with face mask or nasal cannula*	1
Less than 40% of preoperative baseline, and/or orthostatic changes	0	*SpO_2 <95%*	0
Level of consciousness			
Awake, follows commands, easily aroused when called	2		
Arousable to stimuli, with protective reflexes, with/without following commands	1	**Total score**	**10**
Obtunded or persistently somnolent, with or without protective reflexes	0	*The minimum score to qualify for PACU bypass*	**8**

Patients considered for PACU bypass should not require interventions for pain, postoperative nausea and vomiting, or shivering. Patient pain scores should not exceed 2-3 (out of 10) at the time of PACU bypass or PACU discharge. **(Williams et al. 2004)**

References

Abboud TK, Dror A, Mosaad P, Zhu J, Mantilla M, Swart F, Gangolly J, Silao P, Makar A, Moore J, et al. (1988) Mini-dose intrathecal morphine for the relief of postcesarean section pain: safety, efficacy, and ventilatory responses to carbon dioxide. Anesth Analg 67:137-43

Abouleish E, Rawal N, Fallon K, Hernandez D (1988) Combined intrathecal morphine and bupivacaine for cesarean section. Anesth Analg 67:370-4

Alahuhta S, Kangas-Saarela T, Hollmen AI, Edström HH (1990) Visceral pain during caesarean section under spinal and epidural anaesthesia with bupivacaine. Acta Anaesthesiol Scand 34:95-8

Aldrete JA (1995) The post-anesthesia recovery score revisited. J Clin Anesth 7:89-91

Aldrete JA, Kroulik D (1970) A postanesthetic recovery score. Anesth Analg 49:924-34

Alley EA, Kopacz DJ, McDonald SB, Liu SS (2002) Hyperbaric spinal levobupivacaine: a comparison to racemic bupivacaine in volunteers. Anesth Analg 94:188-93

Apfel CC, Korttila K, Abdalla M, Kerger H, Turan A, Vedder I, Zernak C, Danner K, Jokela R, Pocock SJ, Trenkler S, Kredel M, Biedler A, Sessler DI, Roewer N (2004) A factorial trial of six interventions for the prevention of postoperative nausea and vomiting. N Engl J Med 350:2441-51

Apfel CC, Läärä E, Koivuranta M, Greim CA, Roewer N (1999) A simplified risk score for predicting postoperative nausea and vomiting: conclusions from cross-validations between two centers. Anesthesiology 91:693-700

Apfelbaum JL, Walawander CA, Grasela TH, Wise P, McLeskey C, Roizen MF, Wetchler BV, Korttila K (2002) Eliminating intensive postoperative care in same-day surgery patients using short-acting anesthetics. Anesthesiology 97:66-74

Aromaa U, Lahdensuu M, Cozanitis DA (1997) Severe complications associated with epidural and spinal anaesthesias in Finland 1987-1993. A study based on patient insurance claims [see comment]. Acta Anaesthesiol Scand 41:445-52

ASA (2002) Practice guidelines for postanesthetic care: a report by the American Society of Anesthesiologists Task Force on Postanesthetic Care. Anesthesiology 96:742-52

Auroy Y, Benhamou D, Bargues L, Ecoffey C, Falissard B, Mercier FJ, Bouaziz H, Samii K, Mercier F (2002) Major complications of regional anesthesia in France: The SOS Regional Anesthesia Hotline Service. Anesthesiology 97:1274-80

Axelsson KH, Widman GB, Sundberg AE, Hallgren S (1985) A double-blind study of motor blockade in the lower limbs. Studies during spinal anaesthesia with hyperbaric and glucose-free 0.5% bupivacaine. Br J Anaesth 57:960-70

Beilin Y, Bernstein HH, Zucker-Pinchoff B, Zahn J, Zenzen WJ (1998) Subhypnotic doses of propofol do not relieve pruritus induced by intrathecal morphine after cesarean section. Anesth Analg 86:310-3

Ben-David B, DeMeo PJ, Lucyk C, Solosko D (2001) A comparison of minidose lidocaine-fentanyl spinal anesthesia and local anesthesia/propofol infusion for outpatient knee arthroscopy. Anesth Analg 93:319-25, 2nd contents page

Ben-David B, Levin H, Solomon E, Admoni H, Vaida S (1996) Spinal bupivacaine in ambulatory surgery: the effect of saline dilution. Anesth Analg 83:716-20

Ben-David B, Maryanovsky M, Gurevitch A, Lucyk C, Solosko D, Frankel R, Volpin G, DeMeo PJ (2000) A comparison of minidose lidocaine-fentanyl and conventional-dose lidocaine spinal anesthesia. Anesth Analg 91:865-70

Ben-David B, Solomon E, Levin H, Admoni H, Goldik Z (1997) Intrathecal fentanyl with small-dose dilute bupivacaine: better anesthesia without prolonging recovery. Anesth Analg 85:560-5

Borgeat A, Ekatodramis G, Schenker CA (2003) Postoperative nausea and vomiting in regional anesthesia: a review. Anesthesiology 98:530-47

Borgeat A, Stirnemann HR (1999) Ondansetron is effective to treat spinal or epidural morphine-induced pruritus. Anesthesiology 90:432-6

Borghi B, Stagni F, Bugamelli S, Paini MB, Nepoti ML, Montebugnoli M, Casati A (2003) Unilateral spinal block for outpatient knee arthroscopy: a dose-finding study. J Clin Anesth 15:351-6

Breebaart MB, Vercauteren MP, Hoffmann VL, Adriaensen HA (2003) Urinary bladder scanning after day-case arthroscopy under spinal anaesthesia: comparison between lidocaine, ropivacaine, and levobupivacaine. Br J Anaesth 90:309-13

Broadbent CR, Maxwell WB, Ferrie R, Wilson DJ, Gawne-Cain M, Russell R (2000) Ability of anaesthetists to identify a marked lumbar interspace. Anaesthesia 55:1122-6

Brull SJ, Greene NM (1989) Time-courses of zones of differential sensory blockade during spinal anesthesia with hyperbaric tetracaine or bupivacaine. Anesth Analg 69:342-7

Buckenmaier CC, 3rd, Nielsen KC, Pietrobon R, Klein SM, Martin AH, Greengrass RA, Steele SM (2002) Small-dose intrathecal lidocaine versus ropivacaine for anorectal surgery in an ambulatory setting. Anesth Analg 95:1253-7

Carpenter RL, Caplan RA, Brown DL, Stephenson C, Wu R (1992) Incidence and risk factors for side effects of spinal anesthesia. Anesthesiology 76:906-16

Carpenter RL, Hogan QH, Liu SS, Crane B, Moore J (1998) Lumbosacral cerebrospinal fluid volume is the primary determinant of sensory block extent and duration during spinal anesthesia. Anesthesiology 89:24-9

Casati A, Cappelleri G, Berti M, Fanelli G, Di Benedetto P, Torri G (2002) Randomized comparison of remifentanil-propofol with a sciatic-femoral nerve block for out-patient knee arthroscopy. Eur J Anaesthesiol 19:109-14

Casati A, Fanelli G, Cappelleri G, Aldegheri G, Leoni A, Casaletti E, Torri G (1998a) Effects of spinal needle type on lateral distribution of 0.5% hyperbaric bupivacaine. Anesth Analg 87:355-9

Casati A, Fanelli G, Cappelleri G, Borghi B, Cedrati V, Torri G (1998b) Low dose hyperbaric bupivacaine for unilateral spinal anaesthesia. Can J Anaesth 45:850-4
Casati A, Fanelli G, Cappelleri G, Leoni A, Berti M, Aldegheri G, Torri G (1998c) Does speed of intrathecal injection affect the distribution of 0.5% hyperbaric bupivacaine? Br J Anaesth 81:355-7
Chikungwa M, Smith I (2003) Controversial issues in ambulatory anesthesia. Anesthesiol Clin North America 21:313-27
Chilvers CR, Vaghadia H, Mitchell GW, Merrick PM (1997) Small-dose hypobaric lidocaine-fentanyl spinal anesthesia for short duration outpatient laparoscopy. II. Optimal fentanyl dose. Anesth Analg 84:65-70
Chung F, Chan VW, Ong D (1995) A post-anesthetic discharge scoring system for home readiness after ambulatory surgery. J Clin Anesth 7:500-6
Chung F, Mezei G (1999) Factors contributing to a prolonged stay after ambulatory surgery. Anesth Analg 89:1352-9
Connolly C, Wildsmith JA (1998) Intrathecal drug spread. Can J Anaesth 45:289-92
Crocker JS, Vandam LD (1959) Concerning nausea and vomiting during spinal anesthesia. Anesthesiology 20:587-92
Dahl V, Gierloff C, Omland E, Raeder JC (1997) Spinal, epidural or propofol anaesthesia for out-patient knee arthroscopy? Acta Anaesthesiol Scand 41:1341-5
Danelli G, Berti M, Casati A, Albertin A, Deni F, Nobili F, Torri G (2002) Spinal block or total intravenous anaesthesia with propofol and remifentanil for gynaecological outpatient procedures. Eur J Anaesthesiol 19:594-9
de Jong RH (1994) Last round for a "heavyweight"? Anesth Analg 78:3-4
De Kock M, Gautier P, Fanard L, Hody JL, Lavand'homme P (2001) Intrathecal ropivacaine and clonidine for ambulatory knee arthroscopy: a dose-response study. Anesthesiology 94:574-8
Dershwitz M (2002) Droperidol: should the black box be light gray? J Clin Anesth 14:598-603
Despond O, Meuret P, Hemmings G (1998) Postdural puncture headache after spinal anaesthesia in young orthopaedic outpatients using 27-g needles. Can J Anaesth 45:1106-9
Dolk A, Cannerfelt R, Anderson RE, Jakobsson J (2002) Inhalation anaesthesia is cost-effective for ambulatory surgery: a clinical comparison with propofol during elective knee arthroscopy. Eur J Anaesthesiol 19:88-92
Dripps RD, Vandam LD (1954) Long-term follow-up of patients who received 10,098 spinal anesthetics: failure to discover major neurological sequelae. J Am Med Assoc 156:1486-91
Eberhart LH, Morin AM, Kranke P, Geldner G, Wulf H (2002) [Transient neurologic symptoms after spinal anesthesia. A quantitative systematic overview (metaanalysis) of randomized controlled studies]. Anaesthesist 51:539-46
Enk D (1998) Unilateral spinal anaesthesia: gadget or tool? Curr Opin Anaesthesiol 11:511-515
Enk D, Prien T, Van Aken H, Mertes N, Meyer J, Brüssel T (2001) Success rate of unilateral spinal anesthesia is dependent on injection flow. Reg Anesth Pain Med 26:420-7

Erhan E, Ugur G, Anadolu O, Saklayan M, Ozyar B (2003) General anaesthesia or spinal anaesthesia for outpatient urological surgery. Eur J Anaesthesiol 20:647-52
Eriksson AL, Hallén B, Lagerkranser M, Persson E, Sköldefors E (1998) Whitacre or Quincke needles – does it really matter. Acta Anaesthesiol Scand Suppl 113:17-20
Eriksson LI (2003) Evidence-based practice and neuromuscular monitoring: it's time for routine quantitative assessment. Anesthesiology 98:1037-9
Esmaoglu A, Boyaci A, Ersoy O, Güler G, Talo R, Tercan E (1998) Unilateral spinal anaesthesia with hyperbaric bupivacaine. Acta Anaesthesiol Scand 42:1083-7
Faccenda KA, Finucane BT (2001) Complications of regional anaesthesia Incidence and prevention. Drug Saf 24:413-42
Fanelli G, Borghi B, Casati A, Bertini L, Montebugnoli M, Torri G (2000) Unilateral bupivacaine spinal anesthesia for outpatient knee arthroscopy. Italian Study Group on Unilateral Spinal Anesthesia. Can J Anaesth 47:746-51
Gan TJ, Glass PS, Windsor A, Payne F, Rosow C, Sebel P, Manberg P (1997) Bispectral index monitoring allows faster emergence and improved recovery from propofol, alfentanil, and nitrous oxide anesthesia. BIS Utility Study Group. Anesthesiology 87:808-15
Gardner M, Altman D (1989) calculating confidence intervals for proportions and their differences. In: Gardner M, Altman D (eds) Statistics with confidence: confidence intervals and statistical guidlines. BMJ, London, pp 29-30
Gautier PE, De Kock M, Van Steenberge A, Poth N, Lahaye-Goffart B, Fanard L, Hody JL (1999) Intrathecal ropivacaine for ambulatory surgery. Anesthesiology 91:1239-45
Goel S, Bhardwaj N, Grover VK (2003) Intrathecal fentanyl added to intrathecal bupivacaine for day case surgery: a randomized study. Eur J Anaesthesiol 20:294-7
Gold BS, Kitz DS, Lecky JH, Neuhaus JM (1989) Unanticipated admission to the hospital following ambulatory surgery. Jama 262:3008-10
Goranson BD, Lang S, Cassidy JD, Dust WN, McKerrell J (1997) A comparison of three regional anaesthesia techniques for outpatient knee arthroscopy. Can J Anaesth 44:371-6
Greene NM (1985) Distribution of local anesthetic solutions within the subarachnoid space. Anesth Analg 64:715-30
Gürkan Y, Canatay H, Özdamar D, Solak M, Toker K (2004) Spinal anesthesia for arthroscopic knee surgery. Acta Anaesthesiol Scand 48:513-7
Gürkan Y, Toker K (2002) Prophylactic ondansetron reduces the incidence of intrathecal fentanyl-induced pruritus. Anesth Analg 95:1763-6, table of contents
Gätke MR, Viby-Mogensen J, Rosenstock C, Jensen FS, Skovgaard LT (2002) Post-operative muscle paralysis after rocuronium: less residual block when acceleromyography is used. Acta Anaesthesiol Scand 46:207-13
Halpern S, Preston R (1994) Postdural puncture headache and spinal needle design. Metaanalyses. Anesthesiology 81:1376-83
Hampl KF, Schneider MC, Pargger H, Gut J, Drewe J, Drasner K (1996) A similar incidence of transient neurologic symptoms after spinal anesthesia with 2% and 5% lidocaine. Anesth Analg 83:1051-4

Heidvall M, Hein A, Davidson S, Jakobsson J (2000) Cost comparison between three different general anaesthetic techniques for elective arthroscopy of the knee. Acta Anaesthesiol Scand 44:157-62

Henderson CL, Schmid J, Vaghadia H, Fowler C, Mitchell GW (2001) Selective spinal anesthesia for outpatient laparoscopy. III: sufentanil vs lidocaine-sufentanil. Can J Anaesth 48:267-72

Henzi I, Walder B, Tramèr MR (2000) Dexamethasone for the prevention of post-operative nausea and vomiting: a quantitative systematic review. Anesth Analg 90:186-94

Higuchi H, Hirata J, Adachi Y, Kazama T (2004) Influence of lumbosacral cerebro-spinal fluid density, velocity, and volume on extent and duration of plain bupivacaine spinal anesthesia. Anesthesiology 100:106-14

Hiller A, Karjalainen K, Balk M, Rosenberg PH (1999) Transient neurological symptoms after spinal anaesthesia with hyperbaric 5% lidocaine or general anaesthesia. Br J Anaesth 82:575-9

Hiller A, Rosenberg PH (1997) Transient neurological symptoms after spinal anaesthesia with 4% mepivacaine and 0.5% bupivacaine. Br J Anaesth 79:301-5

Hirabayashi Y, Saitoh K, Fukuda H, Shimizu R (1995a) Visceral pain during caesarean section: effect of varying dose of spinal amethocaine. Br J Anaesth 75:266-8

Hirabayashi Y, Shimizu R, Fukuda H, Saitoh K, Furuse M (1995b) Anatomical configuration of the spinal column in the supine position. II. Comparison of pregnant and non-pregnant women. Br J Anaesth 75:6-8

Hirshorn S (2001) The successful use of local knee block for over 7000 knee arthroscopies at the florida center for knee surgery between 1982 and the present. Regional Anesthesia and Pain Medicine 26 Supplement 1

Hogan QH, Prost R, Kulier A, Taylor ML, Liu S, Mark L (1996) Magnetic resonance imaging of cerebrospinal fluid volume and the influence of body habitus and abdominal pressure. Anesthesiology 84:1341-9

Horlocker TT (2000) Complications of spinal and epidural anesthesia. Anesthesiol Clin North America 18:461-85

Imarengiaye CO, Song D, Prabhu AJ, Chung F (2003) Spinal anesthesia: functional balance is impaired after clinical recovery. Anesthesiology 98:511-5

Jacobson E, Forssblad M, Rosenberg J, Westman L, Weidenhielm L (2000) Can local anesthesia be recommended for routine use in elective knee arthroscopy? A comparison between local, spinal, and general anesthesia. Arthroscopy 16:183-90

Jankowski CJ, Hebl JR, Stuart MJ, Rock MG, Pagnano MW, Beighley CM, Schroeder DR, Horlocker TT (2003) A comparison of psoas compartment block and spinal and general anesthesia for outpatient knee arthroscopy. Anesth Analg 97:1003-9

Jokela R, Koivuranta M (1999) Tropisetron or droperidol in the prevention of post-operative nausea and vomiting. A comparative, randomised, double-blind study in women undergoing laparoscopic cholecystectomy. Acta Anaesthesiol Scand 43:645-50

Jokela R, Koivuranta M, Kangas-Saarela T, Purhonen S, Alahuhta S (2002) Oral ondansetron, tropisetron or metoclopramide to prevent postoperative nausea and vomiting: a comparison in high-risk patients undergoing thyroid or parathyroid surgery. Acta Anaesthesiol Scand 46:519-24

Jokela RM, Kangas-Saarela TA, Valanne JV, Koivuranta MK, Ranta PO, Alahuhta SM (2000) Postoperative nausea and vomiting after sevoflurane with or without ondansetron compared with propofol in female patients undergoing breast surgery. Anesth Analg 91:1062-5

Joshi GP (2003) Inhalational techniques in ambulatory anesthesia. Anesthesiol Clin North America 21:263-72

Kahle W, Leonhardt H, Platzer W (1986) Spinal cord and spinal nerves. In: Kahle W (ed) Color Atlas and Textbook of Human Anatomy, vol 3, 3rd edn. Georg Thieme Verlag, Frankfurt, pp 42-63

Kalso E, Smith L, McQuay HJ, Andrew Moore R (2002) No pain, no gain: clinical excellence and scientific rigour – lessons learned from IA morphine. Pain 98:269-75

Kalso E, Tramèr MR, Carroll D, McQuay HJ, Moore RA (1997) Pain relief from intra-articular morphine after knee surgery: a qualitative systematic review. Pain 71:127-34

Kamphuis ET, Ionescu TI, Kuipers PW, de Gier J, van Venrooij GE, Boon TA (1998) Recovery of storage and emptying functions of the urinary bladder after spinal anesthesia with lidocaine and with bupivacaine in men. Anesthesiology 88:310-6

Kaya M, Oguz S, Aslan K, Kadiogullari N (2004) A low-dose bupivacaine: A comparison of hyperbaric and hypobaric solutions for unilateral spinal anesthesia. Reg Anesth Pain Med 29:17-22

Keld DB, Hein L, Dalgaard M, Krogh L, Rodt SA (2000) The incidence of transient neurologic symptoms (TNS) after spinal anaesthesia in patients undergoing surgery in the supine position. Hyperbaric lidocaine 5% versus hyperbaric bupivacaine 0.5%. Acta Anaesthesiol Scand 44:285-90

Kiran S, Upma B (2004) Use of small-dose bupivacaine (3 mg vs 4 mg) for unilateral spinal anesthesia in the outpatient setting. Anesth Analg 99:302-3

Kjellberg F, Tramèr MR (2001) Pharmacological control of opioid-induced pruritus: a quantitative systematic review of randomized trials. Eur J Anaesthesiol 18:346-57

Kooger Infante NE, Van Gessel E, Forster A, Gamulin Z (2000) Extent of hyperbaric spinal anesthesia influences the duration of spinal block. Anesthesiology 92:1319-23

Korttila K (1995) Recovery from outpatient anaesthesia. Factors affecting outcome. Anaesthesia 50 Suppl:22-8

Kovac AL (2000) Prevention and treatment of postoperative nausea and vomiting. Drugs 59:213-43

Kuusniemi KS, Pihlajamäki KK, Kirvelä OA, Korkeila JE (2001) Spinal anesthesia with hypobaric bupivacaine for knee arthroscopies: effect of posture on motor block. Reg Anesth Pain Med 26:30-4

Kuusniemi KS, Pihlajamäki KK, Pitkänen MT (2000a) A low dose of plain or hyperbaric bupivacaine for unilateral spinal anesthesia. Reg Anesth Pain Med 25:605-10

Kuusniemi KS, Pihlajamäki KK, Pitkänen MT, Helenius HY, Kirvelä OA (2000b) The use of bupivacaine and fentanyl for spinal anesthesia for urologic surgery. Anesth Analg 91:1452-6

Kuusniemi KS, Pihlajamäki KK, Pitkänen MT, Korkeila JE (1997) A low-dose hypobaric bupivacaine spinal anesthesia for knee arthroscopies. Reg Anesth 22:534-8

Kuusniemi KS, Pihlajamäki KK, Pitkänen MT, Korkeila JE (1999) Low-dose bupivacaine: a comparison of hypobaric and near isobaric solutions for arthroscopic surgery of the knee. Anaesthesia 54:540-5

Langevin S, Lessard MR, Trépanier CA, Baribault JP (1999) Alfentanil causes less postoperative nausea and vomiting than equipotent doses of fentanyl or sufentanil in outpatients. Anesthesiology 91:1666-73

Lennox PH, Chilvers C, Vaghadia H (2002a) Selective spinal anesthesia versus desflurane anesthesia in short duration outpatient gynecological laparoscopy: a pharmacoeconomic comparison. Anesth Analg 94:565-8; table of contents

Lennox PH, Vaghadia H, Henderson C, Martin L, Mitchell GW (2002b) Small-dose selective spinal anesthesia for short-duration outpatient laparoscopy: recovery characteristics compared with desflurane anesthesia. Anesth Analg 94:346-50

Li S, Coloma M, White PF, Watcha MF, Chiu JW, Li H, Huber PJ, Jr. (2000) Comparison of the costs and recovery profiles of three anesthetic techniques for ambulatory anorectal surgery. Anesthesiology 93:1225-30

Lirk P, Messner H, Deibl M, Mitterschiffthaler G, Colvin J, Steger B, Rieder J, Keller C (2004) Accuracy in estimating the correct intervertebral space level during lumbar, thoracic and cervical epidural anaesthesia. Acta Anaesthesiol Scand 48:347-9

Liu SS, Hodgson PS, Moore JM, Trautman WJ, Burkhead DL (1999) Dose-response effects of spinal neostigmine added to bupivacaine spinal anesthesia in volunteers. Anesthesiology 90:710-7

Liu SS, McDonald SB (2001) Current issues in spinal anesthesia. Anesthesiology 94:888-906

Liu SS, Ware PD (1997) Differential sensory block after spinal bupivacaine in volunteers. Anesth Analg 84:115-9

Liu SS, Ware PD, Allen HW, Neal JM, Pollock JE (1996) Dose-response characteristics of spinal bupivacaine in volunteers. Clinical implications for ambulatory anesthesia. Anesthesiology 85:729-36

Lynch J, Kasper SM, Strick K, Topalidis K, Schaaf H, Zech D, Krings-Ernst I (1994) The use of Quincke and Whitacre 27-gauge needles in orthopedic patients: incidence of failed spinal anesthesia and postdural puncture headache. Anesth Analg 79:124-8

Maroof M, Khan RM, Siddique M, Tariq M (1995) Hypobaric spinal anaesthesia with bupivacaine (0.1%) gives selective sensory block for ano-rectal surgery. Ca J Anaesth 42:691-4

Marshall SI, Chung F (1999) Discharge criteria and complications after ambulatory surgery. Anesth Analg 88:508-17

McDonald SB, Liu SS, Kopacz DJ, Stephenson CA (1999) Hyperbaric spinal ropivacaine: a comparison to bupivacaine in volunteers. Anesthesiology 90:971-7

McGrath B, Chung F (2003) Postoperative recovery and discharge. Anesthesiol Clin North America 21:367-86

Meyer J, Enk D, Penner M (1996) Unilateral spinal anesthesia using low-flow injection through a 29-gauge Quincke needle. Anesth Analg 82:1188-91

Moiniche S, Mikkelsen S, Wetterslev J, Dahl JB (1999) A systematic review of intra-articular local anesthesia for postoperative pain relief after arthroscopic knee surgery. Reg Anesth Pain Med 24:430-7

Moore JM, Liu SS, Pollock JE, Neal JM, Knab JH (1998) The effect of epinephrine on small-dose hyperbaric bupivacaine spinal anesthesia: clinical implications for ambulatory surgery. Anesth Analg 86:973-7

Mulroy MF (2002a) Epidural Anesthesia. In: Mulroy MF (ed) Regional Anesthesia: an illustrated procedural guide, 3rd edn. Lippincott Williams Wilkins, Philadelphia

Mulroy MF (2002b) Spinal Anesthesia. In: Mulroy MF (ed) Regional Anesthesia: an illustrated procedural guide, 3rd edn. Lippincott Williams Wilkins, Philadelphia

Mulroy MF, Larkin KL, Hodgson PS, Helman JD, Pollock JE, Liu SS (2000) A comparison of spinal, epidural, and general anesthesia for outpatient knee arthroscopy. Anesth Analg 91:860-4

Mulroy MF, McDonald SB (2003) Regional anesthesia for outpatient surgery. Anesthesiol Clin North America 21:289-303

Mulroy MF, Salinas FV, Larkin KL, Polissar NL (2002) Ambulatory surgery patients may be discharged before voiding after short-acting spinal and epidural anesthesia. Anesthesiology 97:315-9

Mulroy MF, Wills RP (1995) Spinal anesthesia for outpatients: appropriate agents and techniques. J Clin Anesth 7:622-7

Niemi L, Tuominen M, Pitkänen M, Rosenberg PH (1993) Effect of late posture change on the level of spinal anaesthesia with plain bupivacaine. Br J Anaesth 71:807-9

Olsen KH, Nielsen TH, Kristoffersen E, Husegaard HC, Wernberg M, Dorup J (1990) Spinal analgesia with plain 0.5% bupivacaine administered at spinal interspace L2-3 or L4-5. Br J Anaesth 64:170-2

Pan PH, Fragneto R, Moore C, Ross V, Justis G (2002) The incidence of failed spinal anesthesia, postdural puncture headache and backache is similar with Atraucan and Whitacre spinal needles. Can J Anaesth 49:636-7

Patterson L, Avery N, Chan P, Parlow JL (2001) The addition of fentanyl does not alter the extent of spread of intrathecal isobaric bupivacaine in clinical practice. Can J Anaesth 48:768-72

Pavlin DJ, Pavlin EG, Fitzgibbon DR, Koerschgen ME, Plitt TM (1999) Management of bladder function after outpatient surgery. Anesthesiology 91:42-50

Pavlin DJ, Rapp SE, Polissar NL, Malmgren JA, Koerschgen M, Keyes H (1998) Factors affecting discharge time in adult outpatients. Anesth Analg 87:816-26

Pitkänen M, Haapaniemi L, Tuominen M, Rosenberg PH (1984) Influence of age on spinal anaesthesia with isobaric 0.5% bupivacaine. Br J Anaesth 56:279-84

Pitkänen MT (1987) Body mass and spread of spinal anesthesia with bupivacaine. Anesth Analg 66:127-31
Pittoni G, Toffoletto F, Calcarella G, Zanette G, Giron GP (1995) Spinal anesthesia in outpatient knee surgery: 22-gauge versus 25-gauge Sprotte needle. Anesth Analg 81:73-9
Pollock JE (2003) Neurotoxicity of intrathecal local anaesthetics and transient neurological symptoms. Best Pract Res Clin Anaesthesiol 17:471-84
Pollock JE, Liu SS, Neal JM, Stephenson CA (1999) Dilution of spinal lidocaine does not alter the incidence of transient neurologic symptoms. Anesthesiology 90:445-50
Pollock JE, Mulroy MF, Bent E, Polissar NL (2003) A comparison of two regional anesthetic techniques for outpatient knee arthroscopy. Anesth Analg 97:397-401
Povey HM, Jacobsen J, Westergaard-Nielsen J (1989) Subarachnoid analgesia with hyperbaric 0.5% bupivacaine: effect of a 60-min period of sitting. Acta Anaesthesiol Scand 33:295-7
Puolakka R, Haasio J, Pitkänen MT, Kallio M, Rosenberg PH (2000) Technical aspects and postoperative sequelae of spinal and epidural anesthesia: a prospective study of 3,230 orthopedic patients. Reg Anesth Pain Med 25:488-97
Reynolds F (2001) Damage to the conus medullaris following spinal anaesthesia. Anaesthesia 56:238-47
Rigler ML, Drasner K, Krejcie TC, Yelich SJ, Scholnick FT, DeFontes J, Bohner D (1991) Cauda equina syndrome after continuous spinal anesthesia. Anesth Analg 72:275-81
Rocco AG, Raymond SA, Murray E, Dhingra U, Freiberger D (1985) Differential spread of blockade of touch, cold, and pinprick during spinal anesthesia. Anesth Analg 64:917-23
Rosow C, Manberg PJ (2001) Bispectral index monitoring. Anesthesiol Clin North America 19:947-66
Rowlingson JC (2000) To avoid "transient neurologic symptoms" – the search continues. Reg Anesth Pain Med 25:215-7
Russell IF (2004) A comparison of cold, pinprick and touch for assessing the level of spinal block at caesarean section. Int J Obstet Anesth 13:146-52
Salinas FV, Sueda LA, Liu SS (2003) Physiology of spinal anaesthesia and practical suggestions for successful spinal anaesthesia. Best Pract Res Clin Anaesthesiol 17:289-303
Salmela L, Aromaa U (1998) Transient radicular irritation after spinal anesthesia induced with hyperbaric solutions of cerebrospinal fluid-diluted lidocaine 50 mg/ml or mepivacaine 40 mg/ml or bupivacaine 5 mg/ml. Acta Anaesthesiol Scand 42:765-9
Santanen U, Rautoma P, Luurila H, Erkola O, Pere P (2004) Comparison of 27-gauge (0.41-mm) Whitacre and Quincke spinal needles with respect to post-dural puncture headache and non-dural puncture headache. Acta Anaesthesiol Scand 48:474-9
Schell RM, Brauer FS, Cole DJ, Applegate RL, 2nd (1991) Persistent sacral nerve root deficits after continuous spinal anaesthesia. Can J Anaesth 38:908-11

Schiffer E, Van Gessel E, Fournier R, Weber A, Gamulin Z (2002) Cerebrospinal fluid density influences extent of plain bupivacaine spinal anesthesia. Anesthesiology 96:1325-30
Schlaich N, Mertzlufft F, Soltész S, Fuchs-Buder T (2000) Remifentanil and propofol without muscle relaxants or with different doses of rocuronium for tracheal intubation in outpatient anaesthesia. Acta Anaesthesiol Scand 44:720-6
Schneider M, Ettlin T, Kaufmann M, Schumacher P, Urwyler A, Hampl K, von Hochstetter A (1993) Transient neurologic toxicity after hyperbaric subarachnoid anesthesia with 5% lidocaine. Anesth Analg 76:1154-7
Schwabe K, Hopf HB (2001) Persistent back pain after spinal anaesthesia in the non-obstetric setting: incidence and predisposing factors. Br J Anaesth 86:535-9
Seeberger MD, Kaufmann M, Staender S, Schneider M, Scheidegger D (1996) Repeated dural punctures increase the incidence of postdural puncture headache. Anesth Analg 82:302-5
Sigl JC, Chamoun NG (1994) An introduction to bispectral analysis for the electroencephalogram. J Clin Monit 10:392-404
Sneyd JR, Carr A, Byrom WD, Bilski AJ (1998) A meta-analysis of nausea and vomiting following maintenance of anaesthesia with propofol or inhalational agents. Eur J Anaesthesiol 15:433-45
Song D, Joshi GP, White PF (1997) Titration of volatile anesthetics using bispectral index facilitates recovery after ambulatory anesthesia. Anesthesiology 87:842-8
Song D, Joshi GP, White PF (1998) Fast-track eligibility after ambulatory anesthesia: a comparison of desflurane, sevoflurane, and propofol. Anesth Analg 86:267-73
Spencer HC (1998) Postdural puncture headache: what matters in technique. Reg Anesth Pain Med 23:374-9; discussion 384-7
Stewart AV, Vaghadi H, Collins L, Mitchell GW (2001) Small-dose selective spinal anaesthesia for short-duration outpatient gynaecological laparoscopy: recovery characteristics compared with propofol anaesthesia. Br J Anaesth 86:570-2
Stienstra R, Greene NM (1991) Factors affecting the subarachnoid spread of local anesthetic solutions. Reg Anesth 16:1-6
Taivainen T, Tuominen M, Rosenberg PH (1990) Influence of obesity on the spread of spinal analgesia after injection of plain 0.5% bupivacaine at the L3-4 or L4-5 interspace. Br J Anaesth 64:542-6
Tanasichuk MA, Schultz EA, Matthews JH, Van Bergen FH (1961) Spinal hemianalgesia: an evaluation of a method, its applicability, and influence on the incidence of hypotension. Anesthesiology 22:74-85
Tang J, Joshi GP, White PF (1996) Comparison of rocuronium and mivacurium to succinylcholine during outpatient laparoscopic surgery. Anesth Analg 82:994-8
Tang J, White PF, Wender RH, Naruse R, Kariger R, Sloninsky A, Karlan MS, Uyeda RY, Karlan SR, Reichman C, Whetstone B (2001) Fast-track office-based anesthesia: a comparison of propofol versus desflurane with antiemetic prophylaxis in spontaneously breathing patients. Anesth Analg 92:95-9
Tarkkila P, Isola J (1992) A regression model for identifying patients at high risk of hypotension, bradycardia and nausea during spinal anesthesia. Acta Anaesthesiol Scand 36:554-8
Tarkkila PJ (1991) Incidence and causes of failed spinal anesthetics in a university hospital: a prospective study. Reg Anesth 16:48-51

Tarkkila PJ, Kaukinen S (1991) Complications during spinal anesthesia: a prospective study. Reg Anesth 16:101-6
Tesniere A, Servin F (2003) Intravenous techniques in ambulatory anesthesia. Anesthesiol Clin North America 21:273-88
Tuominen M, Taivainen T, Rosenberg PH (1989) Spread of spinal anaesthesia with plain 0.5% bupivacaine: influence of the vertebral interspace used for injection. Br J Anaesth 62:358-61
Turnbull DK, Shepherd DB (2003) Post-dural puncture headache: pathogenesis, prevention and treatment. Br J Anaesth 91:718-29
Urmey WF, Stanton J, Bassin P, Sharrock NE (1997) The direction of the Whitacre needle aperture affects the extent and duration of isobaric spinal anesthesia. Anesth Analg 84:337-41
Vaghadia H (1998) Spinal anaesthesia for outpatients: controversies and new techniques. Can J Anaesth 45:R64-75
Vaghadia H, McLeod DH, Mitchell GW, Merrick PM, Chilvers CR (1997) Small-dose hypobaric lidocaine-fentanyl spinal anesthesia for short duration outpatient laparoscopy. I. A randomized comparison with conventional dose hyperbaric lidocaine. Anesth Analg 84:59-64
Vaghadia H, Viskari D, Mitchell GW, Berrill A (2001) Selective spinal anesthesia for outpatient laparoscopy. I: characteristics of three hypobaric solutions. Can J Anaesth 48:256-60
Valanne J (1992) Recovery and discharge of patients after long propofol infusion vs isoflurane anaesthesia for ambulatory surgery. Acta Anaesthesiol Scand 36:530-3
Valanne J, Korttila K (1985) Effect of a small dose of droperidol on nausea, vomiting and recovery after outpatient enflurane anaesthesia. Acta Anaesthesiol Scand 29:359-62
Van Gessel EF, Forster A, Gamulin Z (1993) Continuous spinal anesthesia: where do spinal catheters go? Anesth Analg 76:1004-7
Vandam LD (2004) Concerning neurologic sequelae of spinal anesthesia. Anesthesiology 100:176-7
Warwick JP, Kearns CF, Scott WE (1997) The effect of subhypnotic doses of propofol on the incidence of pruritus after intrathecal morphine for caesarean section. Anaesthesia 52:270-5
Watcha MF, Smith I (1994) Cost-effectiveness analysis of antiemetic therapy for ambulatory surgery. J Clin Anesth 6:370-7
Waxler B, Mondragon SA, Patel SN, Nedumgottil K (2004) Prophylactic ondansetron does not reduce the incidence of itching induced by intrathecal sufentanil: [L'administration prophylactique d'ondansetron ne reduit pas l'incidence de prurit induit par le sufentanil intrathecal]. Can J Anaesth 51:685-9
White JL, Stevens RA, Kao TC (1998) Differential sensory block: spinal vs epidural with lidocaine. Can J Anaesth 45:1049-53
White PF (2002) The role of non-opioid analgesic techniques in the management of pain after ambulatory surgery. Anesth Analg 94:577-85
White PF, Song D (1999) New criteria for fast-tracking after outpatient anesthesia: a comparison with the modified Aldrete's scoring system. Anesth Analg 88:1069-72

Whiteside JB, Burke D, Wildsmith JA (2001) Spinal anaesthesia with ropivacaine 5 mg ml(-1) in glucose 10 mg ml(-1) or 50 mg ml(-1). Br J Anaesth 86:241-4

Whiteside JB, Wildsmith JA (2001) Developments in local anaesthetic drugs. Br J Anaesth 87:27-35

Williams BA (2004) For outpatients, does regional anesthesia truly shorten the hospital stay, and how should we define postanesthesia care unit bypass eligibility? Anesthesiology 101:3-6

Williams BA, Kentor ML, Williams JP, Figallo CM, Sigl JC, Anders JW, Bear TC, Tullock WC, Bennett CH, Harner CD, Fu FH (2000) Process analysis in outpatient knee surgery: effects of regional and general anesthesia on anesthesia-controlled time. Anesthesiology 93:529-38

Williams BA, Kentor ML, Williams JP, Vogt MT, DaPos SV, Harner CD, Fu FH (2002) PACU bypass after outpatient knee surgery is associated with fewer unplanned hospital admissions but more phase II nursing interventions. Anesthesiology 97:981-8

Williams BA, Kentor ML, Vogt MT, Vogt WB, Coley KC, Williams JP, Roberts MS, Chelly JE, Harner CD, Fu FH (2004) Economics of nerve block pain management after anterior cruciate ligament reconstruction: potential hospital cost savings via associated postanesthesia care unit bypass and same-day discharge. Anesthesiology 100:697-706

Wong J, Marshall S, Chung F, Sinclair D, Song D, Tong D (2001) Spinal anesthesia improves the early recovery profile of patients undergoing ambulatory knee arthroscopy. Can J Anaesth 48:369-74

Yeh HM, Chen LK, Lin CJ, Chan WH, Chen YP, Lin CS, Sun WZ, Wang MJ, Tsai SK (2000) Prophylactic intravenous ondansetron reduces the incidence of intrathecal morphine-induced pruritus in patients undergoing cesarean delivery. Anesth Analg 91:172-5