DAY-CASE ANAESTHESIA IN ADULT KNEE ARTHROSCOPY

With special reference to recovery and cost-effectiveness after general and spinal anaesthesia

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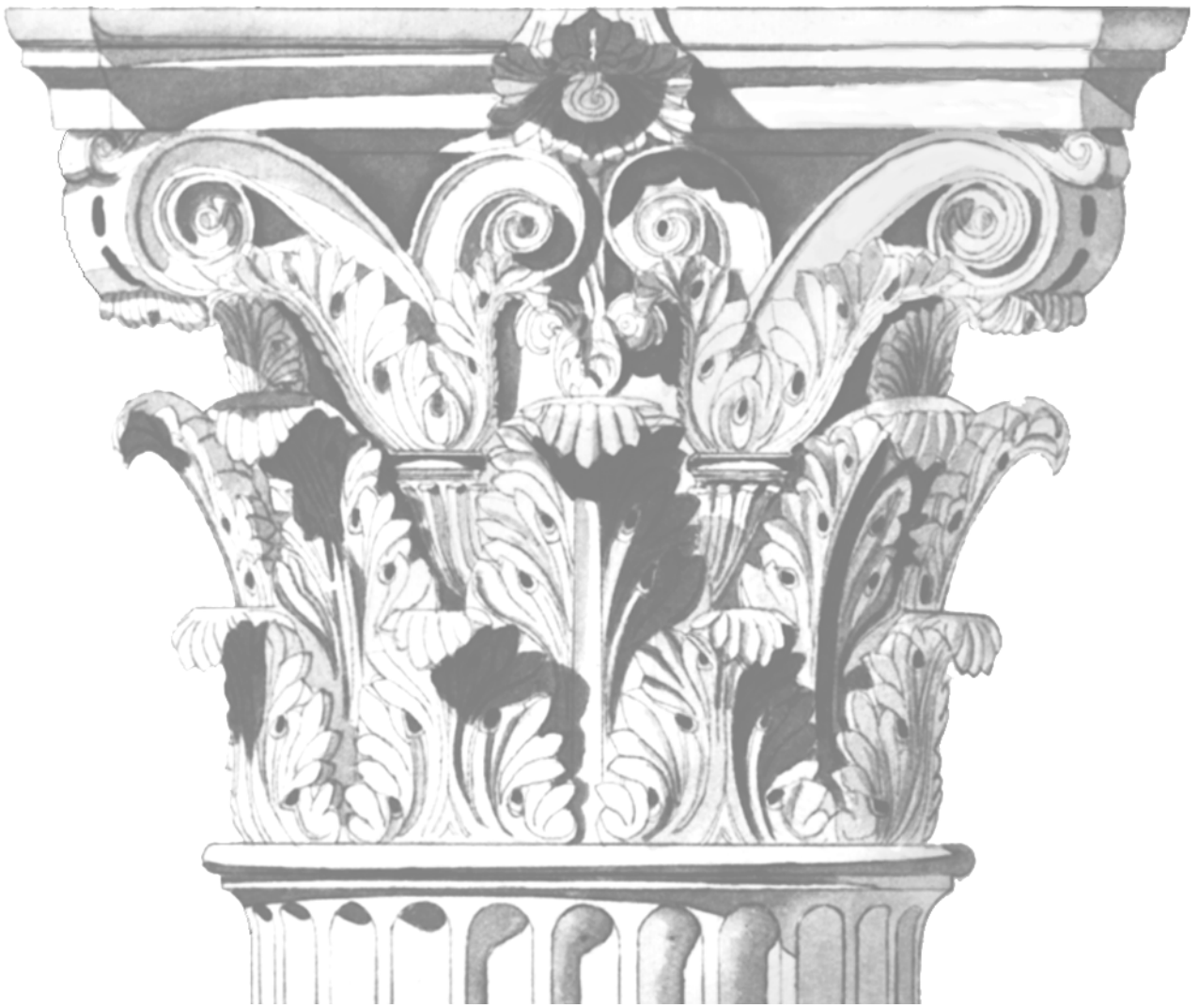
OULU 2002



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Academic Dissertation to be presented with the assent of the Faculty of Medicine, University of Oulu, for public discussion in the Auditorium 1 of the University Hospital of Oulu, on September 13th, 2002, at 12 noon.

OULUN YLIOPISTO, OULU 2002

Supervised by
Docent Tuula Kangas-Saarela

Reviewed by
Docent Päivi Annila
Docent Hannu Kokki

ISBN 951-42-6772-9 (URL: http://herkules.oulu.fi/isbn9514267729/)

ALSO AVAILABLE IN PRINTED FORMAT
Acta Univ. Oul. D 690, 2002
ISBN 951-42-6771-0
ISSN 0355-3221 (URL: http://herkules.oulu.fi/issn03553221/)

OULU UNIVERSITY PRESS
OULU 2002

Martikainen, Matti, Day-case anaesthesia in adult knee arthroscopy With special reference to recovery and cost-effectiveness after general and spinal anaesthesia

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Oulu, Finland
2002

Abstract

The number of ambulatory surgical procedures is increasing throughout the world. This is partly due to the development of a number of new anaesthetic, analgesic and adjuvant drugs, each with more rapid onset and shorter duration of action, over the past two decades. An interest in the issues discussed in this thesis arose out a desire to improve the quality of anaesthesia for patients who undergo day-case surgery. A second aim was to compare the different anaesthetic methods in terms of recovery from anaesthesia and costs.

A total of 233 patients undergoing day-case knee arthroscopy under either 2% or 5% lidocaine spinal anaesthesia or general anaesthesia with desflurane, isoflurane, propofol or sevoflurane were investigated in two prospective, randomised clinical trials. The overall aims were to find the most suitable, satisfactory and economically feasible method for adult ambulatory knee arthroscopy and to assess the factors that affect the immediate postoperative period and the one-week recovery profile at home.

The patients were highly satisfied with all the methods of anaesthesia. There was a slight tendency in favour of general anaesthesia compared to spinal anaesthesia. The general level of pain after ambulatory knee surgery was low after the first few hours postoperatively and continued to be low during the first postoperative week. After short-acting general anaesthesia with desflurane, isoflurane and propofol, home readiness was achieved over two hours earlier than after 5% lidocaine spinal anaesthesia. Home readiness was significantly delayed after 2% lidocaine spinal anaesthesia compared to sevoflurane inhalation anaesthesia. General anaesthesia with isoflurane was cheaper than the other general anaesthetics, i.e. desflurane, sevoflurane, propofol, or 2% and 5% lidocaine spinal anaesthesias. Propofol anaesthesia was the most expensive. The spinal anaesthesia patients had a higher incidence of headache, backache and lower leg pain during the first postoperative week than the patients who had had general anaesthesia.

In busy ambulatory surgery units, remarkable savings may be achieved by using short-acting general anaesthetics, i.e. desflurane and isoflurane, instead of propofol or sevoflurane general anaesthesias or lidocaine spinal anaesthesia. This is due to the lower costs of desflurane and isoflurane compared to sevoflurane and propofol and the shorter time needed for postoperative care compared to spinal anaesthesia.

Keywords: recovery, cost-effectiveness, day-case anaesthesia, home readiness, knee arthroscopy

To Aino, Anna, Kaisa and Kati

Acknowledgements

The work for this thesis was carried out at the Department of Anaesthesiology, Oulu University Hospital, during the years 1995–2001.

I wish to express my warm thanks to Professor Seppo Alahuhta, M.D., Ph.D., Head of the Department of Anaesthesiology, for his encouragement and support during all phases of this study. I would also like to express my sincere gratitude to Professor Lauri Nuutinen, M.D., Ph.D., Medical Director of Oulu University Hospital, former Head of the Department, for his inspiring guidance and persistent interest and trust in my studies as well as in my clinical work.

My sincere thanks are due to Docent Tuula Kangas-Saarela, M.D., Ph.D., my supervisor, and to Esko Poukkula, M.D., Ph.D., for his practical guidance during the very early days of this study. I also thank Esko Poukkula, M.D., Ph.D., and Docent Vilho Vainionpää, M.D., Ph.D., for their friendly and supportive way of guiding my very first steps in the field of anaesthesiology. I am deeply grateful to Docent Kai Kiviluoma, M.D., Ph.D., and Docent Tero Ala-Kokko, M.D., Ph.D., for their expert advice during this study.

I owe my respectful gratitude to the official referees, Docent Päivi Annila, M.D., Ph.D., and Docent Hannu Kokki, M.D., Ph.D., for their detailed review, valuable comments and constructive suggestions during the preparation of this manuscript.

I warmly thank my co-workers Päivi Kaukoranta, M.D., Ph.D., Ari-Pekka Löppönen, M.D., and Timo Salomäki, M.D., Ph.D., for their valuable assistance during this research. I wish to thank Hilkka Tihinen, R.N., and the staff of the Ambulatory Surgery Unit of Oulu University Hospital for their kind and forbearing assistance during the clinical phase of this study. My thanks are also due to all my colleagues and friends at the Department of Anaesthesiology and the Oulu Rescue Helicopter SEPE for their supportive attitude.

My sincere gratitude is due Mr. Risto Leinonen, Programmer Analyst in the Computer Services Centre, University of Oulu, and Pasi Ohtonen, MSc., also my co-writer, for their valuable assistance and advice in statistical analyses. Without their help, I would have been frequently lost in the statistical jungle. My deep thanks also go to Kauko Korpi, R.N., for his pleasant collaboration during this work.

I would like to express my special thanks to Sirkka-Liisa Leinonen, Lic.Phil., who revised the English language of all of the original papers and this summary.

I would also like to thank Lappli Houses for having given me something else to think about during the past months.

My warmest thanks go to my daughters Aino, Anna and Kaisa, who have made the sun shine every time we have been able to be together during the recent years. I would also like to thank my parents, my mother Anni Martikainen and my deceased father Oiva Martikainen, for their everlasting love, understanding and encouragement in all aspects of my life. I also thank and present my highest respect to Ritva and Rauno Poussu family and their close friends Riitta and Erkki Juntunen family, for all the warm and kind feelings they have shown to me.

Finally, I will give my most sincere thanks to my lovely wife Kati. You have changed my life into a better direction in a way that I could not have dreamed of a few years ago. Without you, this thesis would have never been completed. Your true love and positive attitude at all levels of human life has given me the strength to carry on.

The work was financially supported by the Finnish Medical Foundation Duodecim and the Oulu University Scholarship Foundation.

Oulu, June 2002 Matti Martikainen

Abbreviations

ACL	anterior cruciate ligament
ANOVA	analysis of variance
ASA	The American Society of Anesthesiologists' Physical Status Grading
BMI	body mass index
BP	blood pressure
CBA	cost-benefit analysis
CEA	cost-effectiveness analysis
CUA	cost-utility analysis
DSST	digit symbol substitution test
epi	epinephrine
EUR	euro
FIN	Finland
FIM	Finnish mark
FNB	femoral nerve block
GA	general anaesthesia
HR	heart rate
IA	intra-articularly
IV	intravenously
LA	local anaesthesia
LFC	lateral femoral cutaneous nerve
MAC	minimal alveolar concentration
NRS	numerical rating scale
NSAID	non-steroidal anti-inflammatory drug
PACU	postanesthesia care unit
PADSS	postanaesthesia discharge scoring system
PDPH	postdural puncture headache
pKa	acid coefficient
PO	per os
PONV	postoperative nausea and vomiting
QALY	quality-adjusted life years
RA	regional anaesthesia

RU	recovery unit
SA	spinal anaesthesia
SD	standard deviation
T ½	elimination half-life
TCI	target-controlled infusion
TIVA	total intravenous anaesthesia
TNS	transient neurologic syndrome
UK	United Kingdom
USA	United States of America
VAS	visual analogue scale
VDcc	volume of distribution at central compartment
VDss	volume of distribution at steady state

List of original publications

This thesis has been written based on the following original articles after permission by the Elsevier Sciences. The articles are referred to in the text by their corresponding Roman numerals.

I Martikainen M, Kaukoranta P & Kangas-Saarela T (1998) Home readiness after day-case knee arthroscopy: spinal, desflurane, isoflurane or propofol anaesthesia? Ambulatory Surgery 6: 215–9.

II Martikainen M & Kangas-Saarela T (2000) Cost-effective anaesthesia for outpatient arthroscopic knee surgery: spinal, desflurane, isoflurane or propofol anaesthesia? Ambulatory Surgery 8: 63–6.

III Martikainen M, Kangas-Saarela T, Löppönen A & Salomäki T (2000) One-week recovery profiles after spinal, propofol, isoflurane and desflurane anaesthesia in ambulatory knee arthroscopy. Ambulatory Surgery 8: 139–42.

IV Martikainen M, Kangas-Saarela T, Löppönen A, Ohtonen P & Salomäki T (2001) Two percent lidocaine spinal anaesthesia compared with sevoflurane anaesthesia in ambulatory knee surgery – cost-effectiveness, home readiness and recovery profiles. Ambulatory Surgery 9: 77–81.

Contents

1 Introduction

During the last two decades, a number of new anaesthetic, analgesic and adjuvant drugs, each with more rapid onset of action and shorter duration of action, have been developed. As a result, the range of techniques and surgical procedures which can be performed on an ambulatory or day-case basis has increased. Ambulatory surgery patients are usually patients in their prime working age, and their expectations for rapid recovery and high postoperative satisfaction with low morbidity are obvious. A variety of technological developments (e.g. endoscopic procedures) have allowed surgeons to respond to these new expectations by simplifying surgical procedures. Anaesthesiologists are also responding to the new challenges, and a search for ideal anaesthetic agents, which should yield a high standard of quality with reasonable costs, is under a way. Unfortunately, the newer drugs are usually significantly more expensive than the agents they aim to replace. One of the challenges in the current health care environment is to rigorously examine whether these expensive new therapeutic modalities actually produce cost savings by permitting earlier discharge from hospital or by diminishing the need for other therapeutic interventions.

Knee arthroscopy is commonly done on an ambulatory basis because the surgical procedure is short and rapid recovery is to be expected. During the years 1996–2001, almost 4000 adult ambulatory knee arthroscopies were done in the Ambulatory Surgery Unit of Oulu University Hospital (Knee surgery procedures, Ambulatory Surgery Unit of Oulu University Hospital 2001). The most common reason for those procedures was partial extirpation of the knee menisci (30%) and debridement of the knee joint (29%). In Finland, there is a long and established tradition of doing leg surgery under regional anaesthesia. This practice has also been adopted for ambulatory surgery. However, the postoperative recovery period following spinal anaesthesia may be long compared to the short operation time.

An interest in the issues discussed in this thesis arose out of a desire to improve the quality of anaesthesia for patients who undergo day-case surgery. Another aim was to compare spinal anaesthesia to general anaesthesia in terms of late recovery and costs. Most studies have compared anaesthetic techniques in the operating theatre and in the early recovery period (Mulroy *et al*. 2000, Wong *et al*. 2001), but there are only a few reports of the late recovery period when the patients are at home (Nelskylä *et al*.1997,

Twersky *et al*. 1997). The overall aim of this study was to find the most suitable and economically reasonable method for adult ambulatory knee arthroscopy and to assess the factors that affect the immediate postoperative period and the one-week recovery profile at home.

2 Review of the literature

2.1 Development of day-case surgery

The application of outpatient surgery with early ambulation (day-case surgery) is approaching its centenary. Nicoll was one of the first surgeons to challenge the established doctrine that patients required prolonged bed rest following surgery. He demonstrated that a procedure conducted on an outpatient basis cost 10 times less than a similar procedure accomplished using inpatient facilities (Nicoll 1909). There are even earlier reports of the physiological advantages of early ambulation and the disadvantages of prolonged bed rest (Ries 1899). Churchill *et al*. (1927), Asher (1947) and Wright (1951) were also in favour of early ambulation.

The progress was slow in Europe, where the prevailing medical opinion remained firmly against day-case surgery until the early 1950s, when Farquharson described an inguinal herniorrhaphy operation done on an outpatient (Farguharson 1955). In the USA, day surgery began to gain ground in the late 1960s, when Wallace Reed and J L Ford built the first modern free-standing outpatient facility in Phoenix, Arizona, in 1969 (Reed & Ford 1974). The Society for Ambulatory Anesthesia was founded in the USA in 1984, and the British Society of Day Surgery was founded in London in 1989. The first International Congress of Ambulatory Surgery was held in Brussels in 1995. In Finland, outpatient surgery has been performed mainly since the 1970s (Korttila 1975), but day-surgery was performed even earlier by ear, nose and pharynx surgeons in Kuopio during the 1950s (professor Juhani Nuutinen, personal communication).

Day-case surgical procedures represent a large and increasing fraction of all surgery throughout the world. Data from the USA show that the percentage of outpatient surgery grew from 20% in 1981 to 69% in 1996 (SMG Marketing Group 1996). The percentage of outpatient surgery in Finnish hospitals was 24% in 1997 (Punnonen 2001), and it is estimated to rise up to 50% by the year 2003 (Suomen Kuntaliitto 1998).

Table 1. Achievements in day-case surgery.

Authors	Achievements
Ries (1899), USA	Showed that patients improved more with early ambulation and had fewer complications.
Cushing (1900), USA	Described hernia repairs using cocaine as a local anaesthetic.
Nicoll (1909), UK	Reported on a series of 8988 outpatient operations on congenital abnormalities in children, conducted between 1899 and 1909. He stressed the need for good selection of patients.
Hospital for Sick Children (1910–1914), Canada	First reported use of day-case surgery in Canada.
Waters (1919), USA	Established a downtown anaesthetic clinic in Sioux City.
Strittmatter (1925), USA	Carried out three 15-minute dilatation and curettage procedures a day over the preceding 15 years, using ethyl chloride as an anaesthetic.
Churchill & McNeil (1927), UK	Observed reduction in vital capacity with prolonged postoperative stay in bed compared with early ambulation.
Herzfeld (1938), UK	Reported 1000 paediatric herniotomies, many conducted on an outpatient basis.
Israel & Mazer (1938), USA	Confirmed the safety of office curettage in a large series of patients.
Leithauser (1946), USA	Book published to argue for early ambulation. Editorials in the British Medical Journal (1948) and the Lancet (1951) took an opposite view.
Wright (1951), UK	Showed an adverse effect of bed rest on venous blood flow compared with early ambulation.
Palumbo *et al*. (1952), USA	Demonstrated fewer postoperative complications with ambulation from day 1 postoperatively compared with days 7 or 14.
Farquharson (1955), UK	Conducted 485 herniorraphies on outpatients. Recommended appropriate patient selection, cooperation with general practioners and no restriction on age. He argued that a reduction of the conventional 10- to 14-day hospital stay would save 4850 bed days and reduce waiting lists.
Stephens & Dudley (1961), UK	Long waiting lists prompted the establishment of an outpatient surgical service in Aberdeen, Scotland. Good patient selection and high standards in anaesthesia, surgery and assessment were recommended.
Lawrie (1964), UK	First used the term “day surgery” and had used this type of surgery for a number of years because of its obvious benefit to children and their families.
Godber (1967), UK	Chief Medical Officer recommended the concept of day surgery, but gives no specific guidance.
Dornette (1968), USA	Suggested the establishment of independent day-surgery facilities.
Williams (1969) and Ruckley *et al*. (1971), UK	Suggested criteria for effective and successful day surgery.
Reed & Ford (1974), USA	Established the “Surgicenter” in Phoenix, Arizona. The claim to the first free-standing surgical centre came from Providence, Rhode Island, in 1968 (Marks *et al* 1980).
Korttila (1975), FIN	Outpatient anaesthesia in Finland: drugs used and postoperative care of patients
Ogg (1980), UK	Defined the stages of recovery from ambulatory anaesthesia
Royal College of Surgeons of England (1985), UK	Publication of detailed guidelines for day-surgery.
Audit Commission (1990), UK	Further recommendations for increasing the use of day-case surgery.

2.2 Anaesthetic methods for ambulatory knee surgery

Outpatient knee surgery requires substantial modifications of the traditional inpatient anaesthetic practices. Anaesthesia should be specifically tailored for ambulatory surgery, and the anaesthetic drugs must have consistent onset and offset times, permitting rapid changes in the levels of drug effect (Philip 1997). Side effects that are tolerated in an inpatient context, such as nausea, vomiting, and pain, are unacceptable in an outpatient setting, where these complications may delay discharge or even cause unanticipated overnight admissions (Meridy 1982, Gold *et al*. 1989). Vomiting and pain have been documented as the major anaesthetic causes of overnight admissions in all of the large series in both America and Europe (Green & Jonsson 1993). These side effects are considered by both patients and anaesthesiologists alike as the ones most desirable to avoid (Marcario *et al*. 1999). Prevention of postoperative pain, nausea and vomiting is critical to successful implementation of a fast-tracking program in an ambulatory setting (White & Song 1999).

Patients' cooperation is essential at all stages of the ambulatory surgical process, from preparation to recovery at home. Patients' expectations about what will happen during their ambulatory surgical experience must be appropriate, to make them satisfied with their care (Philip 1992). Recent changes in fasting policies (ASA 1999) have allowed patients to continue chronic medications and to avoid the uncomfortable symptoms of dehydration. The use of small doses of sedative-anxiolytic drugs as premedication has been shown to improve the perioperative experience of patients without any adverse effects on the recovery process (Van Vlymen *et al*. 1999).

Anaesthetic techniques that optimize the intraoperative surgical conditions while providing for rapid, early recovery have assumed increased importance. The introduction of more rapid and shorter-acting volatile anaesthetics (desflurane and sevoflurane), intravenous anaesthetics (propofol), opioid analgesics (remifentanil) and muscle relaxants (mivacuronium, rapacuronium) has allowed practitioners to achieve more consistently a recovery profile that facilitates fast-tracking after the administration of general anaesthesia (Savarese *et al*. 1988, Song *et al*. 1998, 1999). The use of nonsteroidal anti-inflammatory drugs (NSAID) (Souter *et al*. 1994) and local anaesthetics has become increasingly important in controlling pain during and after ambulatory surgery (White 2000).

2.2.1 Local anaesthesia

Lower extremity surgery can be performed with peripheral nerve blocade. When a thigh tourniquet is not used, the procedure can be safely done under infiltrative local anaesthesia of the knee cavity and through the ports used to introduce the instruments (Kelly *et al*. 1999). Patel *et al*. (1986) used femoral nerve block for knee arthroscopy, which allowed earlier discharge and improved postoperative analgesia. The choice of anaesthesia in routine knee arthroscopy varies considerably. The concerns about local anaesthesia include the fear that it will take longer to perform surgery and that the anaesthesia will be inadequate, leading to patient discomfort. Forssblad and Weidenhielm

(1999) showed data from patients (n = 6519) who had undergone knee arthroscopy under local anaesthesia (n = 4101) and general anaesthesia (n = 2418). Only 0.9% of the arthroscopies performed under local anaesthesia could not be performed safely due to patient discomfort.

There are many studies to support the conclusion that knee arthroscopy under local anaesthesia can be considered a reliable, well tolerated and safe alternative to conventional procedures (Butterworth *et al*. 1990, Iossifidis 1996, Lorentsen *et al*. 1997, Ramanathan 1998).

Lintner *et al*. studied retrospectively 256 outpatient knee arthroscopies (local and general anaesthesias) and prospectively 100 knee arthroscopies performed using local anaesthesia. They compared the local and general anesthesias in terms of efficacy, cost-effectiveness and safety. The data showed that the use of local anaesthesia for outpatient knee arthroscopy is safe, effective, well accepted and cost-effective compared to general anaesthesia. (Lintner *et al*. 1996). When a combined sciatic-femoral nerve block with 25 ml of 2% mepivacaine was used, a slightly longer preoperative time was needed, but similarly effective anaesthesias with no differences in home discharge times were seen when comparing this block to spinal anaesthesia with 8 mg of hyperbaric bupivacaine (Casati *et al*. 2000).

2.2.2 Spinal anaesthesia

The first operation under spinal anaesthesia was performed in 1898, when the German surgeon August Bier administered cocaine intrathecally for surgical anaesthesia (Bier 1899). At that time, large-diameter spinal needles were commonly used, which frequently resulted in postdural puncture headache (PDPH) (Gielen 1989). In the years to follow, the technique declined in popularity, but resurged with the introduction of small-diameter spinal needles. The relatively low risk of PDPH with these needles (Pittoni *et al*. 1995, Corbey *et al*. 1997, Lambert *et al*. 1997, Despond *et al*. 1998, Spencer 1998, Flaatten *et al*. 2000) has contributed to the increasing popularity of spinal anaesthesia in the ambulatory setting (Halpern & Preston 1994, Kuusniemi 2001).

The advantages of spinal anaesthesia for ambulatory surgery include ease of administration, rapid onset and high reliability (Standl *et al*. 1996, Alon *et al*. 2000). The anaesthetised area can be limited to the surgical site (Kuusniemi *et al*. 2000), the common side effects of general anaesthesia (nausea, vomiting, drowsiness) are reduced, the risks of general anaesthesia (difficult intubation, pulmonary aspiration, malignant hyperthermia) are minimised, and improved analgesia is provided in the postoperative period (Allen *et al*. 1993). The benefits of spinal anaesthesia are most evident in the postoperative phase. The residual block protects the patient from initial pain after the block has worn out (Dahl *et al*. 1997, Raeder 1999). Dahl *et al*. explained that alleviation of the initial, severe postoperative pain results in lesser activation of the pain-enhancing mechanisms in the medullary cord, thus preventing the amplification of pain usually seen when pain is inappropriately treated (Dahl *et al*. 1997). Spinal anaesthesia is associated with a lower incidence of postoperative nausea and vomiting (PONV), drowsiness and postoperative pain compared to general anaesthesia (Dahl *et al*. 1990, Mulroy & Willis

1995, Standl *et al*. 1996). These symptoms are the most frequently reported causes for delays in discharge time among ambulatory patients (Pavlin *et al*. 1998).

Although spinal anaesthesia is considered a simple procedure with a high margin of safety, it is not entirely free from risks. The severe neurological complications associated with spinal anaesthesia and other central blocks may be due to the neurotoxic effects of local anaesthetics, direct neural tissue injury caused by a needle or catheter and spinal cord compression by an epidural haematoma or abscess (Alahuhta 2001). In a retrospective review by Horlocker *et al*. (1997), one disc space infection and one paraspinal abscess were found, but complete neurologic recovery was demonstrated in both patients. In a follow-up of 18,000 consecutive central blocks, 20 neurological complications related to regional anaesthesia were found (Dahlgren & Törnebrandt 1995). In France, 103,730 regional anaesthesias were studied (Auroy *et al*. 1997). The incidence of severe, anaesthesia-related complications was found to be very rare, less than 0.1%. There were 24 neurological deficits among the approximately 40,000 spinal anaesthesias, 12 of which were associated with trauma evidenced by either paresthesia or pain on injection. In Finland, the incidence of serious complications following spinal anaesthesia was 0.45:10,000 (Aromaa *et al*. 1997). Although major complications are rare, they can be devastating to the patient and the anaesthesiologist. For this reason, the patients must be postoperatively followed closely to detect potentially treatable sources of neurologic injury (Horlocker & Wedel 2000).

In recent years, the popularity of spinal anaesthesia has been growing among the outpatient population. There have been attempts to find targeted spinal anaesthesias for outpatients (Kuusniemi 2001, Valanne *et al*. 2001), where the side effects are minimal and the components of ideal spinal anaesthesia maximal. These goals can be approached with a right choice of local anaesthetic and the use of adjuncts to augment spinal anaesthesia (Liu 1997).

2.2.2.1 Lidocaine

Spinal lidocaine has been a popular choice for ambulatory spinal anaesthesia since its introduction in 1945. After that, more than 100 million patients have been operated under lidocaine spinal anaesthesia (Van Zundert 1999). Lidocaine has been popular because of the rapid repression of the sensory and motor blockade (Atanassoff 2001). Though lidocaine has enjoyed a long history of safety and popularity, it has recently come under scrutiny because of transient neurologic symptoms (TNS), which were first described by Schneider *et al*.1993. They reported four patients who, after uneventful spinal anaesthesia with hyperbaric 5% lidocaine, developed a triad of symptoms including low back pain and dysaesthesia with radiation to the buttocks, thighs and lower limbs 1–20 hours after recovery from spinal anaesthesia. The pain was described as dull and aching, and it occasionally decreased when the patient stood up and walked around. It responded well to NSAIDs and resolved spontaneously within two to five days. There were no sensory, motor or reflex disturbances, nor bladder or bowel dysfunctions.

In the recent years, TNS has been shown to occur after all spinal anaesthetisias, but the incidence seems to be significantly higher after lidocaine (Hampl *et al*. 1999). The

incidence of TNS after lidocaine spinal anaesthesia has been reported to range from 0% to 40% (van Zundert 1999). A reduction in lidocaine concentration does not seem to decrease the risk (Pollock *et al*. 1999), a case report of TNS even after spinal anaesthesia with 1% plain lidocaine has been described (Henderson *et al*. 1998). The other factors that have been suggested to increase the risk for TNS include the addition of adrenaline and phenylephrine, the lithotomy position and outpatient status (Hampl *et al*. 1999). On the contrary, Lindh *et al*. did not identify early ambulation after spinal anaesthesia with 2% hyperbaric lidocaine as a risk factor (Lindh *et al*. 2001).

The aetiology of TNS is still speculative. Hampl and co-workers described several cases similar to those reported by Schneider *et al*. in various clinical studies (Hampl *et al*. 1995, 1996), but actual neurologic symptoms were never described. Wong and Slavenas found no cases of TNS among 67 obstetric patients after spinal anaesthesia with 5% lidocaine (Wong & Slavenas 1999). Hiller and Rosenberg reported a 30% incidence of TNS after spinal anaesthesia with 4% mepivacaine (Hiller & Rosenberg 1997), while Liguori *et al*. found no cases of TNS after spinal anaesthesia with 1.5% mepivacaine for knee arthroscopy, but a 22% incidence after 2% lidocaine (Liguori *et al*. 1998). Drasner pointed out that 1.5 and 5% lidocaine produce equally effective spinal anaesthesias, and the risk of neurotoxic injury can be minimised by reducing dose and concentration, although such modifications do not seem to affect the incidence of TNS (Drasner 1998).

The recommendations to reduce the risk of neurologic symptoms after spinal lidocaine include (Alahuhta 2001):

1. Use of the lowest effective concentration and dose. For short-acting spinal lidocaine, the maximum dose is 60 mg at a concentration not higher than 2%.
2. Adrenaline should be avoided as an adjuvant.
3. Avoidance of spinal lidocaine among patients positioned with the knees or hips flexed.

2.2.2.2 Bupivacaine

Bupivacaine has been in clinical use since 1963 (Savarese & Covino 1986). It has been classified as an agent of high anaesthetic potency and long duration of action. Interest in small doses of subarachnoid bupivacaine for spinal anaesthesia in ambulatory patients has arisen due to complaints of radiating backache after spinal lidocaine. Many studies indicate that bupivacaine 0.5% also causes TNS, but less often than lidocaine (Hampl *et al*. 1995, Pollock *et al*. 1996, Freedman *et al*. 1998, Kokki *et al*. 1998a, Kokki *et al*. 2000a, Kuusniemi 2001). Few findings exist about the minimal effective doses of bupivacaine for ambulatory anaesthesia. The majority of studies have used relatively large doses (7.5–20 mg) and have not examined the anaesthetic recovery profiles quantitatively. Recent dose-response data on the clinical anaesthetic characteristics of spinal bupivacaine indicate that small doses can be used for ambulatory anaesthesia (Ben-David *et al*. 1996a, Liu *et al*. 1996, Tarkkila *et al*. 1997, Kuusniemi 2001, Valanne *et al*. 2001). Small doses of bupivacaine (< 10 mg) should be used in ambulatory anaesthesia to avoid prolonged detrusor block, inability to void and excessively prolonged time until discharge (Kamphuis *et al*. 1998). Hyperbaric bupivacaine in doses of 6–8 mg has also

been found to be a suitable alternative to spinal lidocaine for surgical procedures with a mean duration of about one hour (Gentili *et al*. 1997).

2.2.2.3 Mepivacaine

The clinical anaesthetic characteristics of mepivacaine are similar to those of lidocaine (Zayas *et al*. 1999). In an investigation by Liguori *et al*. 1998, 60 patients undergoing knee arthroscopy received either 45 mg of 1.5% mepivacaine or 60 mg of 2% lidocaine through a 27 G Whitacre needle. There was no difference between the two local anaesthetics with respect to recovery from the sensory or motor block or the discharge criteria. There was a difference in the incidence of TNS with no spinal headache in the patients receiving mepivacaine in contrast to 22% of those with lidocaine anaesthesia.

2.2.2.4 Ropivacaine

Ropivacaine is a new amide local anaesthetic, which was approved in Europe about 15 years ago. It is less lipid-soluble than bupivacaine and is reported to be 20% less potent than bupivacaine at equal doses (Polley *et al*. 1998). Ropivacaine produces less motor blockade and is of shorter duration than bupivacaine (Scott *et al*. 1995, Markham & Faulds 1996, Zaric *et al*. 1996). The decreased potency of ropivacaine offers a potential for more rapid recovery and is better suited to be used as an outpatient spinal anaesthetic. However, dose-response data have indicated that equipotent doses of ropivacaine will have similar recovery times as bupivacaine (McDonald *et al*. 1999, Gautier *et al*. 1999) with no signs of TNS (Gautier *et al*. 1999). Ropivacaine in equipotent doses has been shown to be virtually indistinguishable from bupivacaine for clinical anaesthesia without any obvious advantages (Atanassoff 2001).

2.2.3 Epidural anaesthesia

Epidural anaesthesia is not so frequently used for day-case anaesthesia as spinal anaesthesia (Raeder & Korttila 1996). Some patients may fear postspinal headache after a negative previous experience with spinal anaesthesia. Some female patients may have good experiences of epidural anaesthesia as a method of labour pain relief and request the same method again. Sometimes surgical procedures may have an unpredictably long duration and an extra dose of local anaesthetic is needed through an epidural catheter (Knize & Fishell 1997). Drugs of long duration are not appropriate, because ambulatory surgical procedures usually take less than 1–2 hours. Prolonged epidural anaesthesia may result in prolonged postoperative bed occupancy, delayed discharge and an increased risk of urinary retention (Raeder & Korttila 1996). In adults, lidocaine seems to be the drug of choice for epidural anaesthesia in day cases (Kopacz & Mulroy 1990, Seeberger *et al*.

1994). Due to the need of prolonged postoperative surveillance, the use of opioids in the epidural mixture is usually not recommended in day-surgery, but some authors have recently advocated the use of opioids other than morphine for this indication (eg. alfentanil, fentanyl, sufentanil) in order to speed up onset, to improve the quality of the block and to improve postoperative analgesia (Kwa *et al*. 1995). There are recommendations to use epidural anaesthesia for day-case surgery in the lower half of the body if the surgery is expected to be last for more than 2 hours, if the extent of surgery is very unpredictable or if there is a special request from the patient (Raeder 1999).

2.2.4 General anaesthesia

Since the first application of diethyl ether in 1846 (Kennedy & Longnecker 1990), numerous agents have been investigated as potential clinical inhalable general anaesthetics and abandoned for diverse reasons, including adverse effects and high flammability (Robbins 1946, Vitcha 1971, Wallin *et al*. 1972, Calverly 1986). The availability and clinical introduction in 1956 of the first nonflammable agent, halothane (Bryce-Smith & O'Brien 1956, Johnstone 1956), revolutionised inhalation anaesthesia. Further work, modelled on halothane, led to the development of a new generation of inhalation anaesthetic agents (enflurane, isoflurane, desflurane and sevoflurane) in the quest for an ideal agent conferring the following key properties (Jones 1990, Marshall & Longnecker 1990):

- Rapid and tolerable induction
- Rapid recovery
- Rapid adjustment of the depth of anaesthesia
- Adequate skeletal muscle relaxation
- Wide margin between the concentrations producing the desired pharmacological effect and those producing toxicity
- Absence of toxic effects or other adverse events at normal doses

The use of drugs intravenously to facilitate the production of general anaesthesia started during the late nineteenth century, when morphine was sometimes used to supplement inhaled anaesthetics (Way & Trevor 1986). In the early years of the twentieth century, barbiturates were discovered (Weese 1933). Thiopental was first used in anaesthesia almost 70 years ago by Waters and colleagues (Pratt *et al*. 1936) and soon after that by Lundy (Lundy 1935). Since that time, thiopental has been established as an intravenous anaesthetic drug against which all the more recently introduced drugs (e.g. propofol) are compared.

Concerns regarding the side effects of succinylcholine (Smith *et al*. 1993) and the neuromuscular reversal drugs (Ding *et al*. 1994, Watcha *et al*. 1995) have increased interest in the use of more rapid and shorter-acting nondepolarizing neuromuscular blocking drugs in the ambulatory setting. The availability of mivacurium and rocuronium provide anaesthesiologists with alternatives to succinylcholine for outpatient anaesthesia (Tang *et al*. 1996).

Although various forms of anaesthesia are used for ambulatory knee surgery, general anaesthesia has remained as a popular method for many of these operations. Both surgeons and patients prefer general anaesthesia (Fairclough *et al*. 1990), and the recent advances in inhalational and intravenous methods of anaesthesia induction have made general anaesthesia safer and more predictable. Duncan and colleagues (Duncan *et al*. 1992) evaluated 6914 adult ambulatory surgery patients and reported that only 8% of all outpatients experienced a postanaesthesia care unit (PACU) complication. Of the complications that were reported, respiratory and circulatory complications accounted for only 0.4% and 0.3%, respectively. In this outcome study, the presence of preexisting underlying disease was the most important factor in determining which outpatients were at risk of developing a postoperative complication.

2.2.4.1 Isoflurane

Isoflurane was the most widely used potent inhaled anaesthetic before the introduction of desflurane and sevoflurane (Eger 1993). It is still widely used for the maintenance of anaesthesia in outpatients (Herregods *et al*. 1988, Ghouri *et al*. 1991a, Eriksson *et al*. 1995, O'Hara *et al*. 1996, Philip *et al*. 1996), especially combined with propofol induction of anaesthesia (Gupta *et al*. 1992). Isoflurane has a slightly pungent odour and irritates the airways, and it is thus less readily accepted by patients for mask induction of the anaesthesia than sevoflurane (Sloan *et al*. 1996).

2.2.4.2 Desflurane

Desflurane was registered in Finland in 1994. It differs from its predecessors in having lower solubility in blood and tissues (Eger 1993). The lower solubility imparts greater control over the maintenance of anesthesia and more rapid elimination and recovery from anaesthesia. In other respects, the pharmacological properties of desflurane resemble those of isoflurane (Eger 1993). Transient airway irritant effects are the most common adverse effects during the induction of anaesthesia with desflurane, and this agent is hence not recommended for induction (Patel & Goa 1995). A rapid concentration increase has also been shown to provoke autonomic nervous system hyperactivity and haemodynamic instability (Ebert & Muzi 1993).

2.2.4.3 Sevoflurane

Sevoflurane is one of the new generation of inhalational general anaesthetic agents, and it was synthesised in 1971 (Wallin *et al*. 1972, Frink & Brown 1993). It has been in clinical practice in Japan since 1990 and in Finland since 1995. Sevoflurane is a colourless, nonflammable liquid of mild ethereal odour with lower solubility in lipids (Malviya &

Lerman 1972) and blood (Yasuda *et al*. 1991) than halothane or isoflurane but not desflurane (Patel & Goa 1996). The solubility of sevoflurane in blood does not change significantly with age (Malviya & Lerman 1972), unlike that of isoflurane or other inhalable agents (Eger *et al*. 1971, Lerman *et al*. 1984). The anaesthetic potency of sevoflurane, quantified as the minimum alveolar concentration (MAC) that, at a steady state, produces immobility in 50% of individuals exposed to a noxious stimulus (Eger *et al*. 1965), is almost 50% lower than that of isoflurane, but almost 30% more higher than that of desflurane (Patel & Goa 1996). The plastic/gas and rubber/gas partition coefficients (i.e. solubility in the rubber and plastic components of an anaesthesia breathing circuit) consistently result in the following order: halothane > isoflurane > sevoflurane > desflurane (Targ *et al*. 1989). Sevoflurane is the volatile anaesthetic agent least irritant to the airways (Van Hemelrijck *et al*. 1991, Doi & Ikeda 1993). These properties allow both rapid induction and recovery and fast changes in the administration (Eger 1994). The partial pressure of the gas in the brain increases more rapidly than it does with the older inhaled anaesthetics (Yurino & Kimura 1993), and when the administration of sevoflurane is discontinued, the fall in the partial pressure of the gas in the brain is rapid, resulting in rapid recovery.

The structural formulae of halogenated inhaled general anaesthetic agents are shown in Fig. 1, and the most common physical characteristics of these anaesthetics are shown in Table 2.

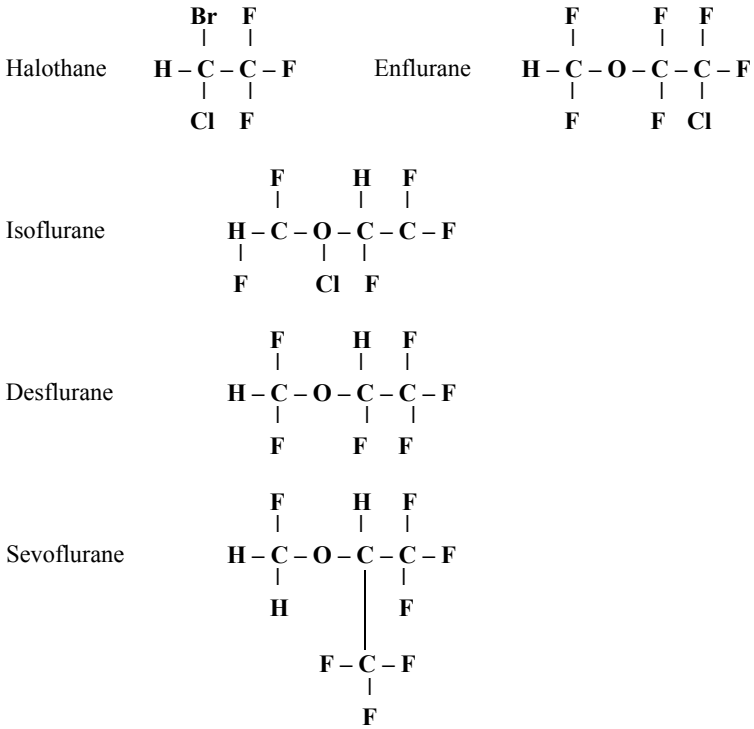

Fig. 1. Structural formulae of halogenated inhalable general anaesthetic agents (Patel & Goa 1996).

Table 2. Physical characteristics of inhalable anaesthetic agents (Rosenberg 1999).

Parameter	Halothane	Enflurane	Isoflurane	Desflurane	Sevoflurane
Molecular weight	197.4	184.5	184.5	168	200
Specific gravity (20°C)	1.86	1.52	1.50	1.48	1.52
Boiling point (°C)	50.2	56.5	48.5	22.8	58.6
Vapour pressure at 20°C (mmHg)	244	172	240	669	157
MAC with 100% O_2 (%)	0.75	1.68	1.15	6–7	2.0
MAC with 70% N_2O (%)	0.29	0.57	0.50	~3	0.66
blood/gas partition coefficient (37° C)	2.3	1.9	1.4	0.42	0.65
preservative	thymol	–	–	–	–
stability in soda-lime	unstable	stable	stable	stable	unstable
metabolism (%)	20	2.4	0.17	0.02	2.5

2.2.4.4 Propofol

In adult ambulatory practice, anaesthesia is usually induced with a short-acting intravenous anaesthetic. Propofol was introduced into clinical practice in 1984, and its advantages as an induction agent and also as an agent for maintaining anaesthesia were soon noted: rapid, smooth induction of anaesthesia, fast recovery and a low incidence of postoperative nausea and vomiting (Langley & Heel 1988, Boysen *et al*. 1989, Korttila *et al*. 1992). When used in combination with fentanyl or alfentanil, propofol is suitable for the provision of total intravenous anaesthesia (TIVA) (Langley & Heel 1988). With target-controlled infusion (TCI) of propofol, where a computer-controlled pump delivers a specific targeted plasma concentration, the use of TIVA may increase (Coetzee *et al*. 1995). Infusions of subanaesthetic doses of propofol have been used to sedate patients for surgery under regional anaesthesia (Korttila 1999). The most common physical and clinical characteristics of propofol compared to the other intravenous anaesthetics are shown in Table 3.

Table 3. Physical and clinical characteristics of intravenous anaesthetics (Scheinin 1999).

Anaesthetic	Clearance (ml/min/kg)	VDss (l/kg)	T ½ (elimination) (h)	Induction dose (mg/kg)
thiopentone	3–4	1.5–3.0	7–15	3–5
metohaxital	10	2.2	2–6	1–1.5
propofol	22–30	1.5–3.0	4–24	2–2.5
diazepam	0.3–0.5	1.0–1.5	30–50	0.3–0.5
midazolam	6–11	1.0–1.5	1.7–2.6	0.1–0.3
ketamine	11–20	3.0	2–3	1.5–2
etomidate	18–25	1.5–3.5	3–5	0.2–0.3

2.2.4.5 Mivacurium

Mivacurium is a benzylisoquinolinium muscle relaxant, which is rapidly hydrolysed by plasma cholinesterases (Bevan 1995). Although the onset time of an intubating dose of mivacurium (0.15–0.2 mg/kg) is quite long (2.5–3 min), recovery begins within 15 min and is virtually complete after 30 min (Smith 1994). In patients carrying atypical forms of plasma cholinesterase or having renal or hepatic dysfunction, the action of mivacurium is prolonged (Ostergaard *et al*. 1993, Savarese *et al*.1995), but the residual mivacurium-induced neuromuscular block can be antagonised with neostigmine (Lessard *et al*. 1997). Mivacurium has a potential for histamine release, and although this is seldom a problem in normal practice, some difficulty may arise if large doses are administered rapidly (Smith 1994). Mivacurium is a non-cumulative agent, and it is suitable for short-term ambulatory anaesthesia, but may be also used for longer operations as continuous infusion (Diefenbach *et al*. 1995).

2.2.4.6 Rocuronium

Rocuronium is a steroid muscle relaxant structurally related to vecuronium (Smith 1994). Because of its low potency, it has a very rapid onset of action (Kopman 1993). A dose of 0.6 mg/kg produces complete twitch depression within 75–150 seconds and acceptable intubation conditions after 60 seconds (Kopman 1993). The clinical duration of action of an intubating dose of rocuronium is very similar to that of vecuronium. Rocuronium was used widely during the late 1990's, but since that, there have been many reports of anaphylactic reactions during the induction of anaesthesia using rocuronium for muscle relaxation (Matthey *et al*. 2000, Heier & Guttormsen 2000).

The pharmacodynamics of the most common muscle relaxants are shown in Table 4.

Table 4. Pharmacodynamics of muscle relaxants (Erkola 1999).

Relaxant	ED95 dose (mg/kg)	Intubation dose (mg/kg)	Time to maximal effect (min)	Time to intubation (min)	Clinical duration (min)	Recovery index (min)	Maintaining dose (mg/kg)
mivacurium	0.08	0.25	2.3	1.5–2.0	18–22	6.5	0.05–0.2
rapacurium	1.30	1.0–2.5	1.5–2.5	1–1.5	15–45	7–12	0.5
atracurium	0.25	0.5	3.0	2–2.5	35–45	11–16	0.1–0.2
cisatracurium	0.05	0.15	3.5	2–3	55	10	0.03
rocuronium	0.3	0.6–1.0	1.5–2.5	1	30–60	7–5	0.1
vecuronium	0.045	0.1	3.0	2–2.5	30–45	10–20	0.015–0.03
pancuronium	0.06	0.1	3.5–4	3–4	75–115	30–50	0.015

2.2.4.7 Short-acting opioids

Opioids are frequently administered in the immediate preinduction period to suppress autonomic responses to endotracheal intubation and during the maintenance of general anaesthesia to prevent autonomic responses to painful stimuli. Although morphine and pethidine can be used in outpatient anaesthesia, they are not so popular as the more potent, rapid and shorter-acting opioid analgesics fentanyl, sufentanil, alfentanil and remifentanil (Van Vlymen *et al*. 2000). The basic pharmacokinetic data for opioids are shown in Table 5.

A study comparing morphine and fentanyl in ambulatory surgical patients reported higher pain scores and more analgesic use in the fentanyl group. Morphine produced better-quality analgesia, but was associated with increased nausea and vomiting, especially after discharge. There were no differences in recovery times or discharge times despite the shorter duration of fentanyl action (Claxton *et al*. 1997). Compared with a standard inhaled anaesthetic, most investigators have demonstrated improved intraoperative conditions and more rapid emergence from anaesthesia when fentanyl or one of its newer analogues was administered as a part of a balanced anaesthetic technique (White *et al*. 1986, Ghouri & White 1991). When sufentanil infusion was compared with fentanyl for the maintenance of general anaesthesia with nitrous oxide, its use was associated with less nausea and postoperative pain (Phitayakorn *et al*. 1987).

Alfentanil has a rapid onset and a short duration of action (Van Vlymen & White 2000). These characteristics make it particularly useful in the outpatient setting. Most investigators have reported faster emergence and recovery of psychomotor function after alfentanil-based anaesthesia compared with fentanyl (Van Vlymen & White 2000). During the last decade, alfentanil has been the most widely used opioid in ambulatory TIVA regimens (Philip *et al*. 1997b).

Remifentanil is an ultra-short-acting opioid analgesic with an analgesic potency similar to that of fentanyl (Van Vlymen & White 2000). It is metabolised by nonspecific esterases via a process that allows rapid systemic elimination (Glass 1995, Michelsen & Hug 1996). In consequence of that, remifentanil has short-lived opioid side effects, but also results in short-lived analgesia (Smith 1999). When remifentanil was compared with alfentanil as part of a total intravenous anaesthesia technique, remifentanil provided more effective suppression of intraoperative responses, but prolonged awakening and recovery room stay (Philip *et al*. 1997b). There was an earlier need for analgesics postoperatively with remifentanil, and both groups had similar discharge times. The later studies have shown that the adjunctive use of remifentanil infusion during desflurane-N_2O anaesthesia facilitated early recovery without increasing PONV, pain or need for rescue medication after ambulatory laparoscopic surgery (Song & White 1999). Studies involving the use of remifentanil in combination with less soluble anesthetics suggest that low-dose infusion (0.05–0.2 μg/kg/min) may produce a significant anaesthetic-sparing effect (Song *et al*. 1998b).

Table 5. Pharmacokinetic data for opioids (Laitinen & Salomäki 1999).

Parameter	Morphine	Oxycodone	Pethidine	Fentanyl	Alfentanil	Sufentanil	Remifentanil
pKa	8	8.9	8.5	8.4	6.5	8	7.1
% un-ionized at pH 7.4	23	–	< 10	< 10	90	20	67
Octanil-water partition coefficient	1.4	1.6	39	813	145	1778	18
Percentage bound to plasma proteins	20–40	–	70	84	92	93	70
T ½ (h)	2.9	2–4	3–5	3.7	1–2	2–3	0.1–0.2
VDcc (l/kg)	0.1–0.4	–	1–2	0.5–1	0.1–0.3	0.2	0.2
VDss (l/kg)	3–5	3–6	3–5	3–5	0.4–1	2.5–3	0.3–0.4
Clearance (ml/kg/min)	15–30	6–19	8–18	10–20	4–9	10–15	42

2.2.4.8 Laryngeal mask airway

The laryngeal mask (LMA) airway was designed by Brain in 1981 as a new concept in airway management (Brain 1991). The beauty of the LMA is that it forms an airtight seal by enclosing the larynx rather than plugging the pharynx and hence avoids airway obstruction in the oropharynx. The LMA appears to be a safe and acceptable technique for day-case anaesthesia (Coyne 1990, Smith & White 1992, Goodwin *et al*. 1992). The placement of the LMA is easy to learn (Davies *et al*. 1990). Muscle relaxants and laryngoscopy are not necessary, and the emergence and recovery times are shorter when LMA is used and similar to those in patients on whom a face mask is used (Smith & White 1992). Compared with endotracheal intubation, the insertion of a LMA causes a minimal cardiovascular response and is better tolerated at lighter levels of anaesthesia (Pennant & White 1993). Postoperative side effects, such as the incidence of sore throat, are markedly reduced when a LMA is used. In a large survey, 47% of intubated patients complained of sore throat postoperatively versus only 7% of the patients with a LMA (Alexander & Leach 1989, Joshi *et al*. 1997). When compared with anaesthesia with a face mask and an oral airway, patients with a LMA had fewer desaturation episodes, fewer intraoperative airway manipulations and fewer difficulties in maintaining an airway (Smith 1992).

2.3 Postoperative pain management

Postoperative pain is one of the main barriers to increasing the range of ambulatory procedures. Persistent pain has been shown to lead to postoperative nausea and vomiting (Anderson *et al*. 1996), delayed discharge (Chung 1995c), contact with medical facility after discharge (Fortier *et al*. 1996) and unanticipated admissions (Gold *et al*. 1989, Fortier *et al* 1996). Undertreatment of pain is common in outpatients (Beauregard *et al*. 1998). Beauregard *et al*. reported that 40% of discharged outpatients suffered from moderate to severe pain during the first 24 hours. Chung and colleagues (1997) found that

orthopedic procedures and the duration of anaesthesia were predictors of postoperative pain.

Opioids are the mainstay of postoperative pain therapy in ambulatory surgery (Tong & Chung 1999); however, opioid analgesia has to be balanced against the potential side effects, mainly nausea and vomiting (Anderson *et al*. 1996). Therefore, outpatient studies on opioids have focused on finding the particular opioid and the timing of administration that would lead to a lower incidence of postoperative nausea and vomiting (Claxton *et al*. 1997). To avoid postoperative nausea and vomiting, the use of postoperative opioids should be minimized (Tong & Chung 1999). In painful outpatient procedures, opioids may be needed to treat patients with severe pain. In this case, the use of lower doses (0.1 mg/kg) of intravenous morphine in the PACU did not cause more nausea and vomiting during the patients' hospital stay compared with fentanyl (Claxton *et al*. 1997).

Niemi *et al*. (1994) showed that postoperative analgesia in patients undergoing knee arthroscopy under local anaesthesia with 1% lidocaine plus adrenaline, but not under hyperbaric 0.5% bupivacaine spinal anaesthesia, could be improved with a single intra-articular injection of 1 mg of morphine. Allen *et al*. (1993) showed that morphine, at 1 mg intra-articularly, in 30 ml of 0.25% bupivacaine, with 1:200,000 epinephrine may provide superior postoperative analgesia compared to bupivacaine or morphine alone after ambulatory knee surgery under general anaesthesia. Van Ness *et al*. (1995) concluded that intra-articular morphine after general anaesthesia reduces postoperative pain and analgesic requirements more effectively and at a lower average patient cost than bupivacaine.

There are also opposite findings showing no benefit from intra-articular administration of morphine or bupivacaine compared to isotonic saline after elective knee arthroscopy (McSwiney *et al*. 1993, Björnsson *et al*. 1994, Laurent *et al*. 1994, Ruwe *et al*. 1995, Aasbo *et al*. 1996). Morphine is a poorly lipid-soluble opioid and it can be absorbed from any anatomical tissue, which is why the results can be attributed to either local or systemic effects (Debruyne *et al*. 1985). An intra-articular alpha(2) agonist clonidine has been shown to enhance patient analgesia after arthroscopic knee surgery, and the combination of clonidine with morphine resulted in decreased postoperative pain and analgesic use as well as increased analgesic duration compared with either drug alone (Joshi *et al*. 2000). Intra-articular sufentanil (5–10 μg) administration has been shown to improve, in a double-blinded fashion, postoperative management after day-case diagnostic arthroscopic knee procedures (Vranken *et al*. 2001).

The efficacy of preoperative NSAID administration for postoperative pain has been extensively investigated in randomized, controlled trials. Most comparisons of NSAIDs with placebo demonstrated a decrease in postoperative pain scores or analgesic requirements (Dueholm *et al*. 1989, Comfort *et al*. 1992, Ben-David *et al*. 1996b, Jakobsson *et al*. 1996, Murrell *et al*. 1996). NSAIDs also gave rise to a lower side effect profile during recovery (Rosenblum *et al*. 1991, Wong *et al*. 1993, Forse *et al*. 1996, Sukhani *et al*. 1996). Most outpatient studies comparing NSAIDs with opioids in perioperative use have demonstrated that opioids provide comparable or better pain relief in the early recovery period (McLoughlin *et al*. 1990, Wong *et al*. 1993, Twersky *et al*. 1995), whereas NSAIDs provide better pain relief in the late recovery period (McLoughlin *et al*.1990, Rosenblum *et al*. 1991, Twersky *et al*. 1995). Combination of opioids with NSAIDs involves a rapid effect of opioids followed by a longer analgesic

duration of NSAIDs (McLoughlin *et al*. 1990, Rosenblum *et al*. 1991, Twersky *et al*. 1995, Sukhani *et al*. 1996).

The efficacy of NSAIDs for postoperative pain relief depends on the timing and route of administration (Tong & Chung 1999). Because of their peripheral mechanisms of action, NSAIDs have longer onsets than opioids, and parenteral NSAIDs are therefore usually administered at induction or intraoperatively, allowing adequate time for them to exert their peak effect (Tong & Chung 1999). Norris *et al*. (2001) found no difference in pain relief regardless of whether the NSAID (diclofenac) was given preoperatively or postoperatively in patients undergoing unilateral day-case knee arthroscopy. There is no scientific documentation of the superiority of any individual NSAID for perioperative use (Morrow *et al*. 1993). The choice of preparation, therefore, depends on availability, the desired route of administration, the duration of effect and cost (Kehlet & Mater 1992).

Several studies have investigated the use of low-concentration, low-dose spinal anaesthetics and the addition of an intrathecal opioid to take advantage of prolonged postoperative analgesia, while avoiding postoperative motor block, urinary retention, and prolonged recovery time (Orr *et al*. 1987, Urmey *et al*. 1995, Chilvers *et al*. 1997).

Table 6. Pain studies on outpatient knee arthroscopy.

Study	Sample size	Treatment versus control	Result
Patel *et al*. (1986)	90	General anaesthesia vs. FNB + LFC vs. FNB	VAS: not assessed; analgesics: both FNB groups had fewer patients who required postoperative analgesics
Milligan *et al*. (1988)	40	0.25% bupivacaine, 25 ml IA, vs. 0.5% bupivacaine, 25 ml IA, vs. placebo	VAS, analgesics: ↔
Chirwa *et al*. (1989)	79	0.25% bupivacaine, 20 ml IA, vs. placebo	VAS, analgesics: ↓ up to 5 h, longer time to first analgesic
Henderson *et al*. (1990)	100	0.25% bupivacaine, 30 ml IA, vs. placebo	VAS, analgesics: ↔
White *et al*. (1990)	27	0.5% prilocaine, 20 ml IA with epi, vs. placebo	VAS, analgesics: ↔; time to first analgesics longer in LA
Smith *et al*. (1991)	97	0.5% bupivacaine, 30 ml IA, vs. placebo	VAS: ↔; analgesics; ↓; quicker ambulation and discharge
Sorensen *et al*. (1991)	40	0.5% bupivacaine, 10 ml IA with epi, vs. placebo	VAS, analgesics:↔; procedure under LA with 1% lidocaine with epi
Stein *et al*. (1991)	52	Morphine, 1 mg IA, vs. morphine, 1 mg IV, vs. morphine, 0.5 mg IA, vs. morphine, 1 mg IA + naloxone, 0.1 mg IA, 40 ml-total volume for all treatment arms	VAS, analgesics: 1 mg morphine IA better than IV at 3–6 h. 1 mg morphine better than 0.5 mg morphine after 6 h. VAS: 1 mg morphine better than morphine + naloxone.
Joshi *et al*.(1992)	20	Morphine, 5 mg IA, vs. placebo	VAS, analgesics: ↓
Khoury *et al*. (1992)	33	Morphine, 1 mg IA, vs. 0.25% bupivacaine, 25 ml IA, vs. morphine, 1 mg IA, + 0.25% 25 ml IA bupivacaine	VAS: at 1 h, 1 mg morphine > bupivacaine, 1 mg morphine + bupivacaine: 2–3 h, ↔; 4 h–2 d, bupivacaine > 1 mg morphine, 1 mg morphine + bupivacaine. Analgesics: at 1 h, ↑ in 1 mg morphine; > 1 h, ↑ in bupivacaine
Heard *et al*. (1992)	112	0.25% bupivacaine, 20 ml IA with epi, vs. morphine, 6 mg IA, vs. placebo	VAS: bupivacaine better, longer time to first analgesic; analgesics: 24–h total requirement: ↔
De Anderes *et al*. (1993)	60	0.25% bupivacaine, 20 ml IA, vs. 3-in-1 continuous FNB vs. morphine, 1 mg IA	VAS: lowest in FNB; analgesics: ↔, little required by all groups

Table 6. Continued

Study	Sample size	Treatment versus control	Result
Allen *et al*. (1993)	120	0.25% bupivacaine IA, vs. morphine, 1 mg IA, vs. morphine, 2 mg IA, vs. morphine, 1 mg IA + 0.25% bupivacaine – all treatment arms given in 30 cc solution with epi	VAS, analgesics: bupivacaine + 1 mg morphine best in early postoperative period; 1 mg morphine, 2 mg morphine, bupivacaine + 1 mg morphine best at 24 h after surgery
Joshi *et al*. (1993a)	40	Morphine, 5 mg IA, vs. 0.25% bupivacaine, 25 ml IA, vs. morphine, 5 mg IA, + 0.25% bupivacaine, 25 ml IA vs. placebo	VAS: ↓ versus placebo up to 4 h; analgesics: ↓ versus placebo up to 4 h (after 4 h, 5 mg morphine and 5 mg morphine + bupivacaine and placebo ↔)
Joshi *et al*. (1993b)	20	Morphine, 5 mg IA, vs. placebo	VAS, analgesics: ↓
Laurent *et al*. (1994)	58	0.25% bupivacaine, 40 ml IA, + morphine, 5 mg, vs. 0.25% bupivacaine, 40 ml IA + morphine, 2 mg IA, vs. 0.25% bupivacaine, 40 ml IA	VAS, analgesics: ↔
Gupta *et al*. (1994)	40	Fentanyl 0.1 mg + 0.05 mg fentanyl every 30 min, vs. alfentanil 0.5 mg + 0.25 mg every 15 min	VAS: ↔ Clinical recovery and home readiness significantly longer with fentanyl
Heine *et al*.(1994)	31	0.5% bupivacaine, 20 ml IA, vs. morphine, 1 mg IA, +0.5% bupivacaine, 20 ml IA, vs. morphine, 3 mg IA, + 0.5% bupivacaine, 20 ml IA	VAS: 3 mg morphine + bupivacaine better up to day 2; analgesics: 1 mg morphine + bupivacaine, 3 mg morphine + bupivacaine better up to day 3
Jaureguito *et al*. (1995)	59	Morphine, 4 mg IA, vs. 0.25% bupivacaine, 20 ml IA, vs. placebo	VAS: lowest in morphine at 24 h, morphine, bupivacaine ↓ 2–6 h; analgesics: lowest in morphine 12–24 h, morphine, bupivacaine ↓ 2–6 h; procedure done under LA
Urmey *et al*. (1995)	90	Combined 2% lidocaine spinal anaesthesia + epi, lidocaine 40 mg, vs., 60 mg, vs. 80 mg	Sensory and motor blocks shortest with 40 mg lidocaine
Juhlin-Dannfelt at al. (1995)	82	Sublingual buprenorphine, 0.4 mg 90 min preoperatively, vs. placebo	VAS: ↔ Analgesics: ↓
Wrench *et al*. (1996)	60	Morphine, 1 mg IA, vs. buprenorphine, 30 μg IA, vs. saline	VAS, analgesics ↔
Cook *et al*. (1997)	63	0.25% bupivacaine, 40 ml IA, vs. tenoxicam, 20 mg IA, vs. placebo	VAS: ↔ among all groups; analgesics: tenoxicam better up to 2 h
Goranson *et al*. (1997)	60	2% lidocaine 20 ml with epi, portal + IA vs. FNB 2% chloroprocaine 20 ml with epi vs. FNB + IA lidocaine	VAS, analgesics: ↔ among all groups
Dahl *et al*. (1997)	91	5% lidocaine spinal anaesthesia, vs. 2% mepivacaine + 5 μg epi, epidural vs. GA with propofol	VAS: spinal and epidural significantly ↓ postoperatively
Reuben *et al*. (1998)	100	0.25% bupivacaine, 30 ml IA, vs. morphine, 5 mg IA, vs. bupivacaine 0.25% 30 ml IA + morphine, 5 mg IV, vs. bupivacaine 0.25% 30 ml IA + morphine, 5 mg IA	VAS, analgesics: bupivacaine was better up to 6 h; no benefit in combining with morphine up to 24 h

FNB = femoral nerve block; LFC = lateral femoral cutaneous nerve; VAS = visual analogue scale; IA = intra-articularly; LA = local anaesthesia; GA = general anaesthesia; IV = intravenously; epi = epinephrine; ACL = anterior cruciate ligament; ↔ = no difference; ↑ = higher; ↓ = lower

2.4 Home readiness

The success of ambulatory surgery depends on appropriate and timely discharge of the patients who have had anaesthesia (Korttila 1988). Premature release of patients, who later experience postoperative complications requiring unanticipated admission into hospital, should not occur. Excessive fatigue, nausea, vomiting or pain delay the patient's discharge (White & Song 1999). Patients with psychomotor impairment may be prone to accidents while travelling or at home (Korttila 1990a). Short stays are an acceptable practice only if the patient can return home safely and comfortably with minimal side effects from anaesthesia and surgery.

2.4.1 Stages of recovery

Recovery from outpatient anaesthesia includes dissipation of anaesthetic agents, normalization of physiological functioning, observation for medical or surgical complications, treatment of immediate side effects of anaesthesia and surgery and, ultimately, discharge and return at home (Rapp 1996). Recovery from anaesthesia may be divided into three main stages (Ogg 1980, Korttila 1995):

2.4.1.1 Early recovery

Early or phase I recovery (Rapp 1996) means the time from the end of anaesthesia until the patient wakes up. During that time, protective reflexes recover, vital signs stabilize and the patient becomes able to obey commands. Assessment of early recovery usually involves recording of the time when certain events occur (e.g. eye opening) or the measurement of physiological parameters, such as blood pressure and respiratory rate, and crude measurements of alertness (Aldrete & Kroulik 1970, Steward 1975, Chung 1995a).

2.4.1.2 Intermediate recovery

Intermediate or phase II recovery (Rapp 1996) means the time from discharge from the recovery room or the postanaesthesia care unit (PACU) until the patient has recovered sufficiently to be safely discharged from hospital. During that time, psychomotor functions recover. Full return to the preoperative levels is not essential, and the patient may be escorted home by a competent adult who remains with the patient until the stage of late recovery is achieved.

2.4.1.3 Late recovery

During this time, which takes some hours or days after the cessation of anaesthesia, the patient returns to the preoperative fitness level. This means complete and physiological recovery, such as going to work and driving.

2.4.2 Recovery tests

Scoring systems developed to guide the transfer from the hospital recovery room to the ward may be used to assess the early recovery of ambulatory surgical patients (Chung 1995b). The most commonly used method, described by Aldrete and Kroulik (Aldrete & Kroulik 1970), assigns a score analogous to the Apgar method (Apgar 1953) to provide objective information on the physical condition of patients arriving in the recovery room after anaesthesia. This test assigns a score of 0, 1 or 2 to activity, respiration, circulation, consciousness and skin colour, with a score of 10 indicating the best possible condition for discharge from the PACU. A score of 8 to 10 indicates adequacy of early recovery (Table 7.).

Table 7. Postanaesthesia Recovery Score (Aldrete & Kroulik 1970).

Variable	Score
Consciousness	
Fully awake and oriented (name, place, date)	2
Arousable on calling	1
Not responding	0
Activity	
Moves all four extremities voluntarily on command	2
Moves two extremities	1
Unable to move extremities	0
Respiration	
Breathes deeply and coughs freely	2
Dyspnea, limited breathing, or tachypnea	1
Apneic	0
Circulation	
BP ± 20% of preanaesthetic level	2
BP ± 20%–50% of preanaesthetic level	1
BP ± 50% of preanaesthetic level	0
Color	
Pink	2
Pale, dusky, blotchy, jaundiced, other	1
Cyanotic	0
Maximum score	10

Digit Symbol Substitution Test (DSST) is also used as a baseline recovery test (Korttila 1990b). In this test, the person is asked to replace random digits of 0–9 by symbols given in the test paper. The score is calculated as the number of correctly substituted digits in 120 s. The P-deletion test, in which the patient is asked to identify Ps in lines of random letters, is commonly used to test early recovery (Dixon & Thornton

1973). Quinn *et al*. 1993 evaluated recovery scores using the observers' determination of home readiness as the "gold standard". They found that a clinical recovery score based on respiration, circulation, consciousness, ambulation, colour and PONV appeared to be more in agreement with the observers' determination of recovery than pencil and paper tests (e.g. DSST). The results of these studies (MacKenzie & Grant 1985, Quinn *et al*. 1993) suggest that anaesthesiologists prefer to rely on their own clinical judgement in assessing recovery.

Intermediate recovery to home readiness cannot be determined solely with early recovery tests (Chung 1995b). Inpatients who satisfy the Aldrete criteria are transferred into a hospital room where they are monitored continuously by nursing personnel, whereas ambulatory surgical patients must be capable of returning home. Many ingenious tests have been devised to measure psychomotor recovery and are described in a review by Hindmarch (Hindmarch 1980). The six tests with the highest efficiency ratings were: critical flicker fusion threshold (CFFT, efficiency rating 90%), choice reaction time (CRT, 83%), simple reaction time (78%), simulated driving test (78%), letter deletion (77%) and picture and object recall and recognition (77%) (Hindmarch & Bhatti 1987). The validity of such testing is questioned by the results of studies of MacKenzie and Grant (1985), and the emphasis on psychomotor recovery tests has been largely replaced by more practical discharge criteria (Korttila 1995).

Chung suggested a postanaesthetic discharge scoring system (PADSS), which may provide a reliable measure of anaesthetic recovery (Chung 1995c). Using this, she found that periodic, objective evaluation of home readiness resulted in 82% of patients being discharged two hours after surgery and 95.6% three hours after surgery, and the time to discharge was prolonged by non-medical factors, such as delay in the arrival of escorts. PADSS is based on five major criteria: (1) vital signs, including blood pressure, heart rate, respiratory rate and temperature; (2) ambulation and mental status; (3) pain, nausea/vomiting; (4) surgical bleeding; and (5) fluid intake/output (Table 8.). The qualifications for discharge include a postoperative discharge score of 9 or more and the presence of a competent adult to accompany the patient home.

Table 8. Postanaesthesia Discharge Scoring System (PADSS) (Chung 1995c).

Variable	Score
Vital signs	
Within 20% of preoperative value	2
20–40% of preoperative value	1
40% of preoperative value	0
Ambulation and mental status	
Oriented x 3 and has a steady gait	2
Oriented x 3 or has a steady gait	1
Neither	0
Pain or nausea/vomiting	
Minimal	2
Moderate	1
Severe	0
Surgical bleeding	
Minimal	2
Moderate	1
Severe	0
Intake and output	
Has had PO fluids and voided	2
Has had PO fluids or voided	1
Neither	0

Assessment of late recovery (e.g. when the patient is ready to drive a car or resume normal daily activities) requires sophisticated laboratory tests that cannot be used in normal clinical practice (Korttila 1995). A practical way to improve late recovery is the use of feedback information achieved from patient questionnaires for day-surgery (Audit commission 1990). Computer-assisted testing of recovery from anaesthesia has also been attempted (Korttila *et al*. 1992).

2.4.3 Discharge criteria

Practical discharge criteria have become important for patient comfort and safety and for medicolegal reasons. The availability of a written discharge policy has been a requirement of the major accreditation bodies in the United Kingdom (Royal College of Anaesthetists 1994) and North America (Joint Commission on Accreditation of Healthcare Organizations 1994). Korttila has compiled a basic set of day-surgery discharge criteria (Table 9., Korttila 1995).

Table 9. Discharge criteria after ambulatory surgery (Korttila 1995).

Discharge criteria
Vital signs stable for at least 1 hour
The patient must be: oriented to person, place, time able to tolerate orally administered fluids (drinking recommended before discharge but not mandatory) able to void (recommended before discharge but not mandatory, apart from after spinal/epidural blocks and pelvic surgery) able to dress able to walk without assistance
The patient must not have: more than minimal nausea or vomiting excessive pain bleeding
The patient must be discharged by both the person who administered anaesthesia and the person who performed surgery or their designee.
Written instructions for the postoperative period at home, including a contact place and a person who may be telephoned, need to be reinforced
The patients must have a responsible adult to escort them home and to stay with them at home

2.4.4 Recovery after different anaesthetic techniques

2.4.4.1 Studies comparing regional anaesthesia with general anaesthesia

A common feature of many studies that find regional anaesthesia (RA) recovery better than general anaesthesia (GA) recovery is that they were done before the introduction of new-generation GA agents (Meridy 1982, Patel *et al*. 1986, Gold *et al*. 1989). These studies have shown an earlier ability to ambulate, earlier oral intake and increased alertness with RA compared with GA (Katz 1973, Selzer 1991, Tetzlaff 1993). Patients who received epidural anaesthesia were discharged from the PACU one hour earlier than those given GA for laparoscopic tubal ligation (Bridenbaugh & Soderstrom 1979).

Wong *et al*. compared the recovery profiles of 50 mg of 1% lidocaine and standardized GA in ambulatory knee arthroscopy. They found early recovery better with lidocaine, but the durations of PACU stay and the discharge times were similar (Wong *et al*. 2001). Mulroy with colleagues studied general anaesthesia with propofol and spinal and epidural anaesthesia for outpatient knee arthroscopy (Mulroy *et al*. 2000). The PACU discharge times for the GA and epidural groups were similar, whereas the spinal group had a significantly longer recovery time with increased side effects. Patel *et al*. showed that regional anaesthesia and i.v. sedation were associated with faster operation room exit times compared with general anaesthesia with desflurane (Patel *et al*. 1996). A comparison of spinal, epidural and propofol anaesthesias for outpatient knee arthroscopy (Dahl *et al*. 1997) revealed no differences in the frequency of nausea, while pain was clearly more common in the propofol group. The propofol group had the shortest stay in the operation theatre but the highest cost of drugs and disposables. In a recent study by Ben-David and colleagues, after minidose lidocaine-fentanyl spinal anaesthesia (i.e. 20 mg lidocaine + 20 μg fentanyl) and after local anaesthesia with lidocaine (supplemented

with propofol), outpatients with knee arthroscopy reached home readiness in less than 50 minutes (Ben-David *et al*. 2001).

2.4.4.2 Studies comparing desflurane, isoflurane, sevoflurane and propofol

Valanne compared propofol infusion to isoflurane anaesthesia in dental patients and found that patients who had received propofol were discharged earlier than patients given isoflurane (80 ± 14 min and 102 ± 32 min, $p < 0.01$), even after long anaesthesias (Valanne 1992).

In studies comparing desflurane with propofol in terms of early recovery, emergence from anaesthesia has been shown to be faster with desflurane (Van Hemelrijck *et al*. 1991, Rapp *et al*. 1992, Graham & Aitkenhead 1993, Lebenbom-Mansour *et al*. 1993). The early recovery in these studies has been 2 to 6 minutes faster (e.g. eye opening) after desflurane anaesthesia. Data from a meta-analysis demonstrate that the differences between desflurane and propofol in early recovery may be of minor clinical importance (Dexter & Tinker 1995a).

Intermediate recovery and readiness for discharge from recovery rooms did not appear to be significantly different between desflurane and propofol. A meta-analysis of these data with respect to the time to discharge showed that patients receiving propofol tended to be discharged an average of 17 minutes earlier than those receiving desflurane, although this was suggested to be of minor clinical importance (Dexter & Tinker 1995a). Some studies (Wrigley *et al*. 1991, Lebenbom-Mansour *et al*. 1993) have showed that patients anesthetized with propofol were significantly less capable than patients anesthetized with desflurane of performing the P-deletion test 30 minutes postoperatively, while other studies did not reveal any such difference (Van Hemelrijck *et al*. 1991, Rapp *et al*. 1992, Graham & Aitkenhead 1993).

In one study comparing desflurane with isoflurane anaesthesia (Ghouri *et al*. 1991), emergence from desflurane anaesthesia was reported to be significantly earlier, by 5 minutes, than emergence from isoflurane anaesthesia. However, the later course of recovery was not significantly different between the groups. These data are generally supported by data from other comparative studies with isoflurane anaesthesia in ambulatory patients (Fletcher *et al*. 1991, Rane *et al*. 1995).

A study comparing desflurane with sevoflurane showed that, despite the shorter exposure time to sevoflurane (79 vs 98 minutes), emergence from desflurane anaesthesia was significantly more rapid (5.2 vs 8.8 minutes to eye opening) (Nathanson *et al*. 1994). However, there were no differences between the two anaesthetic groups with respect to the recovery of cognitive function, orientation and readiness for discharge (Nathanson *et al*. 1994). Similar result were achieved in a study where the rates of early and intermediate recovery were quicker in the desflurane compared to the sevoflurane group, but there were no differences in discharge times (Naidu-Sjösvärd *et al*. 1998). A study by Castaneda and Philip (Castaneda & Philip 1997) suggested that desflurane is associated with more nausea and vomiting than sevoflurane, which may lead to prolonged recovery

times. Tarazi and colleagues showed that psychomotor functions are marginally, but not significantly better with sevoflurane than desflurane (Tarazi *et al*. 1998).

There are many studies which have proved that early recovery from sevoflurane anaesthesia is significantly faster than recovery from isoflurane anasthesia, although discharge times are not different. (Eriksson *et al*. 1995, Philip *et al*. 1996, O'Hara *et al*. 1996)

In a study where desflurane and sevoflurane were compared to propofol anaesthesia, desflurane and sevoflurane resulted in a higher percentage of outpatients being judged eligible for fast-tracking (Song *et al*. 1998a). Raeder with colleagues compared the recovery characteristics of sevoflurane- or propofol-based anaesthesia for day-surgery. They reported that maintenance of anaesthesia with sevoflurane results in more rapid emergence but a higher incidence of nausea and vomiting compared to propofol. There were no statistical differences in home readiness between the groups (Raeder *et al*. 1997).

As a conclusion of these studies, it can be said that, although there are differences between the anaesthesia agents in terms of early recovery, the late recovery profile is less different between the agents.

2.4.5 Economics of ambulatory surgery practice

Cost containment and reduction have become major goals in ambulatory surgery. The use of newer anaesthetic drugs, e.g. propofol, sevoflurane and desflurane, permits greater ease of titration, earlier awakening and a shorter time to achieve the PACU discharge criteria (Smith *et al*. 1994, Patel & Goa 1995, Smith *et al*. 1995, Patel & Goa 1996). These newer anaesthetics are also more costly than the older drugs they were designed to replace, and it is unclear whether the earlier awakening and the decreased times to a home-ready condition are associated with a true decrease of costs (Watcha & White 1997). To decrease costs, hospital managers and physicians need to know the principal determinants of costs. These determinants are not always obvious, despite widespread beliefs. Poor understanding of the individual factors comprising the total cost of providing care to surgical patients may hamper the efforts to decrease costs (Dexter & Tinker 1995a).

There are four commonly used methods for economic analysis in health care (Detsky & Naglie 1990, Jolicoeur *et al*. 1992, Robinson 1993), which are also suitable for the evaluation of costs in ambulatory surgery. These are Cost minimisation, Cost-benefit analysis (CBA), Cost-effectiveness analysis (CEA) and Cost-utility analysis (CUA). Table 10 shows the methods for calculating these measures.

Table 10. The three main measures used in economic evaluation: CBA, CEA and CUA (Drummond & Ward 1986).

Formula
CBA = B1 + B2 – C1 – C2
CEA = (C1 + C2 – B1 – B2) / E
CUA = (C1 + C2 – B1 – B2) / U

C_1 = direct costs, C_2 = indirect costs, B_1 = direct economic benefits, B_2 = indirect economic benefits, E = health effects, (natural units), U = quality of adjusted life years (QALY), (utility units)

2.4.6 Cost minimisation

This involves a comparison of the acquisition costs of various alternative drug regimens without regard to the outcome or associated side effects (e.g. emesis, delayed awakening and discharge). Unless there is equality of outcomes, other methods should be used (Eisenberg 1989, White & Watcha 1993).

2.4.7 Cost-benefit analysis

This is a comparison of pertinent costs and the consequences or outcome (benefit) in monetary terms (Bulpitt & Fletcher 1990, Robinson 1993b).

2.4.8 Cost-effectiveness analysis

This expresses the costs of an intervention in units of success or effect (e.g. cost per mmHg reduction in blood pressure, costs per patient free from a postoperative complication). This analysis, rather than a cost-benefit analysis, is often performed because of the difficulty of converting outcomes to monetary values (Detsky & Naglie 1990, Robinson 1993c).

2.4.9 Cost-utility analysis

This analysis is similar to the cost-effectiveness analysis, wherein the measure of effectiveness includes the patients' preferences and satisfaction with their quality of life by expressing outcome in terms of QALYs (Robinson 1993d).

2.4.10 Definitions and types of costs

Definitions of the cost-accounting terms: average, marginal, fixed, semi-fixed, and variable costs, are listed in Table 11. The total costs associated with a medical intervention consist of direct and indirect costs (Watcha & White 1997). The direct costs of drug treatment are not limited to the cost of acquisition of the amount of drug administered, but they include the costs of drug wasted, the equipment needed to administer the medication (e.g. intravenous sets, syringes), the pharmacy dispensing costs and the costs of managing possible drug-induced side effects (Robinson 1993a, Elixhauser 1995).

The term 'indirect costs' is used differently by physicians, accountants and health care economists (Watcha & White 1997). Although some anaesthesiologists include the costs of managing side effects and delayed recovery in indirect costs (Wetchler 1992), most health care economists would describe these as associated direct costs (Parker 1992, Sanchez & Hirsch 1992, Robinson 1993e). Accountants include all fixed costs (e.g. administration, engineering, housekeeping, utilities, maintenance) in their calculation of indirect costs, whereas economists usually refer to indirect costs as the costs related to lost productivity (Davidson *et al*. 1987, Robinson 1993e).

Table 11. Definitions of commonly used types of costs (Davidson et al. 1987).

Term	Definition
Costs	Sacrifice measured as the price paid for the irreversible use of resources
Direct costs	Cost of the material and labor used for production
Indirect costs	Costs related to the consequences of an event on society or an individual
Intangible costs	Expenses involving items that lack physical substance (e.g. goodwill, patent rights granted by a government)
Average costs	Total costs divided by the number of units produced
Fixed costs	Costs that remain the same regardless of the number of goods or services produced (e.g. rent, salaries, building, equipment)
Marginal costs	Change in costs for producing one additional unit of output
Semi-fixed costs	Expenses that remain unchanged only over a certain range of output (Personnel costs in the operating room are semi-fixed costs, as they remain the same regardless of the number of cases done in a given shift, but change with the number of emergency cases performed outside regular working hours)
Variable costs	Costs that change with the number of services provided (e.g. number of doses of neuromuscular blocking agent used, regional anaesthesia trays)

In measuring the margin between extra costs and extra benefits, the analyst usually derives a ratio of the extra costs required to achieve one extra unit of clinical outcome (Detsky & Naglie 1990). The units of clinical outcome can be measured in direct clinical terms, such as life-years extended or premature deaths avoided, in which case the analysis will estimate "cost-effectiveness ratios". If the unit of clinical outcomes is measured in units that also consider the utility or quality of life, then the analysis estimates "cost-utility ratios". If the clinical outcomes are translated into monetary terms via approaches such as "willingness to pay" (that is, asking persons how much they would be willing to pay to receive a given health benefit, such as avoiding pain or disability), then the ratio is known as a "cost-benefit ratio". (Detsky & Naglie 1990)

When both the resource requirements and the clinical outcomes are measured in monetary terms (i.e., cost-benefit analysis), one can either examine the ratio of costs to benefits or determine the net costs of a program or a drug by subtracting the treatment costs from the treatment benefits (net costs = treatment benefits – treatment costs) (Detsky & Naglie 1990).

2.4.11 Cost comparisons of anaesthesia methods used in ambulatory surgery

The cost of certain anaesthesia method is the sum of a number of different components. Information about the price of drugs is readily available, but choices based solely on drug acquisition costs ignore many other factors that contribute to the cost of an anaesthetic, including the capital and recurrent expenditure on equipment, the prices of disposable equipment and the salaries of the anaesthesiologist, nurses and recovery room staff (Kendell *et al*. 2000). The anaesthetic medications are estimated to account for less than 10% of the overall costs (Drummond 1994, Macario *et al*. 1995). While the costs of drugs used for ambulatory anaesthesia constitute only a small fraction of overall health care cost, they are highly visible costs, which are easy for administrators to scrutinize (Vitez 1994). Although costs savings in an individual case are small, the total savings are impressive because of the large volume of cases managed (White & White 1994). Dexter and Tinker found that anaesthesiologists have little control over PACU economics via the choice of anaesthetic drugs (Dexter & Tinker 1995b). According to them, greater savings could be achieved by timing the arrival of patients into the PACU to reduce the peak requirement of nursing personnel. Hospital and operating room managements are better served by improving efficiency than by forcing anaesthesiologists to base drug usage on acquisition costs (Broadway & Jones 1995, Dexter & Tinker 1995a). Salaries make up the largest part of the cost (Drummond 1994), and personnel costs are dependent on the times spent by the patient in the operating room and recovery area, both of which may be affected by the anaesthetic technique or the drugs used (Kendell *et al*. 2000).

Table 12 shows summarised cost comparisons of different ambulatory anaesthesia methods found from the literature. Most of these studies have compared different general anaesthesia methods to each other, and only a few of them have compared general anaesthesias to local (spinal) anaesthesia. As a conclusion, these studies suggest that there is a tendency for propofol anaesthesia to be more expensive than inhalation or local anaesthesias.

Table 12. Cost comparisons of different ambulatory anaesthesia methods.

Study	Sample size	Anaesthesia agents/methods	Costs	Recovery in PACU
Rosenberg *et al*. (1994) orthopedy	50	propofol infusion + N_2O/O_2, vs. desflurane + O_2	des maintenance cheaper	des ↔ pro
Alhashemi *et al*. (1997) knee arthroscopy	93	isoflurane/fentanyl/N_2O, vs. alfentanil/N_2O, vs. propofol/alfentanil	iso/fentanyl/N2O cheapest	all groups ↔
Jakobsson *et al*. (1997) knee arthroscopy	80	propofol + N_2O/O_2, vs. desflurane + N_2O/O_2	des cheaper	des ↔ pro
Nathan *et al*. (1998) gynaecology	52	sevo ind + sevo maint, vs. propofol ind + propofol maint	sevo cheaper	sevo ↔ propofol
Raeder *et al*. (1998) laparoscopic cholecystectomy	60	propofol + O_2/air, vs. desflurane + O_2/air	des cheaper	more rapid with des
Ries *et al*. (1999) knee arthroscopy	40	sevoflurane + N_2O/O_2, vs. isoflurane + N_2O/O_2	iso cheaper	iso ↔ sevo
Tang *et al*. (1999) office-based surgery	104	propofol ind + pro maint, vs. pro ind + sevo maint, vs. sevo ind + sevo maint	pro ind + pro maint cheapest	prolonged with sevo ind + sevo maint
Fleischmann *et al*. (1999) gynaecology	80	sevo ind + rebreath sevo/N_2O/O_2, vs. sevo ind + sevo nonrebreath/N_2O/O_2, vs. pro ind + pro bolus, vs. thiopental ind + thiopental bolus	total cost cheapest with thiopental, intermediate with sevo rebreath, most expensive with sevo nonrebreathing	recovery shortest with sevo, intermediate with pro and longest with thiopental induction
Stuttner *et al*. (1999) laparoscopic cholecystectomy	60	propofol (TIVA) /remifentanil, vs. isoflurane/fentanyl, vs. propofol(standard delivery)/ fentanyl	highest cost: propofol(TIVA)/ remifentanil	most rapid recovery: propofol(TIVA)/ remifentanil
Smith *et al*. (1999) multicentre European study	211	propofol ind + maint, vs. propofol ind + sevo maint, vs. sevo ind + sevo maint	propofol ind + propofol maint total cost highest	all groups ↔
Sun *et al*. (1999) ambulatory surgery	120	methohexital ind + desflurane maint, vs. methohexital ind + sevo maint, vs. propofol ind + desflurane maint, vs. propofol ind + sevo maint	methohexital ind + desflurane maint cheapest	all groups ↔
Heidvall *et al*. (2000) knee arthroscopy	75	ind: all propofol/fentanyl maint: sevo + O_2/air, vs. propofol/ alfentanil + O_2/air, vs. propofol/ remifentanil + O_2/air	sevo: lowest cost propofol/alfentanil: intermediate cost propofol/remifentanil: highest cost	all groups ↔
Li *et al*. (2000) ambulatory anorectal surgery	93	LA, 15 ml 2% lidocaine + 15 ml 0.5% bupivacaine with epi + propofol sedation, vs. SA, 30 mg lidocaine + 20 µg fentanyl + 1–2 mg midazolam iv, vs. GA, propofol ind + sevo N2O/O2 maint	LA with propofol sedation most cheapest	time to home readiness shortest in LA group

ind = induction of anaesthesia, maint = maintenance of anaesthesia, des = desflurane, epi = epinephrine, iso = isoflurane, sevo = sevoflurane, LA = local anaesthesia, GA = general anaesthesia, SA = spinal anaesthesia, rebreath = rebreathing system, nonrebreath = nonrebreathing system, ↔ = no difference

3 Purpose of the present study

The overall aim of this study was to find out the most appropriate and economical method for adult ambulatory knee arthroscopy and to assess the factors that affect the immediate postoperative period and the one-week recovery profile at home. Two groups of patients were collected, and the results of those groups were reported in four original articles. The articles I–III were reports of study 1 and article IV of study 2.

The purposes of the different original articles were:

1. to compare 5% lidocaine spinal anaesthesia and desflurane, isoflurane and propofol anaesthesias in terms of the early postoperative recovery profile (pain, sedation, nausea and home readiness) (I).
2. to compare the costs of 5% lidocaine spinal anaesthesia and three modes of general anaesthesia with desflurane, isoflurane or propofol (II).
3. to compare the one week-recovery periods after 5% lidocaine spinal anaesthesia and the three modes of general anaesthesias with desflurane, isoflurane or propofol (III).
4. to compare low-concentration (2%) lidocaine spinal anaesthesia and general anaesthesia with sevoflurane in terms of the total costs of anaesthesia in elective ambulatory knee arthroscopy. A further purpose was to evaluate the recovery characteristics of both anaesthesias (early recovery, recovery at 24 hours and recovery during the first postoperative week) (IV).

4 Patients and methods

This study was conducted in the Department of Anaesthesiology, University of Oulu. The study was approved by the Ethics Committee of the University of Oulu. A written consent was obtained from all patients.

4.1 Patients

Two hundred and thirty-three patients participated in the studies. There were 173 patients in study 1 and 60 patients in study 2. The inclusion criteria were ASA I or II, age 18–65 years and day-case knee arthroscopy. The exclusion criteria were asthma, drug allergy for non-steroidal anti-inflammatory drugs, obesity (women over 80 kg, men over 95 kg or BMI over 32), known epilepsy, pregnancy, active gastric ulcer or previous PDPH.

4.2 Study designs

All the studies were prospective. In study 1, the patients were randomly assigned to receive 5% lidocaine spinal anaesthesia (n = 55) or desflurane (n = 48), isoflurane (n = 38) or propofol (n = 32) general anaesthesia (I, II, III). In study 2 (IV), the patients were randomised to receive either 2% lidocaine spinal (n = 30) or sevoflurane anaesthesia (n = 30). Randomisation was done by closed envelopes. After interviewing and eliciting a written consent from the patient, the envelope that showed the anaesthesia method was opened. All the anaesthesias were managed by the author. The postoperative follow-up in the recovery unit was done by the author and by the Ambulatory Surgery Unit nurses. The patients were interviewed on the next day over telephone by two anaesthesiologists. After one week, all the patients were asked to complete a questionnaire about their recovery at home.

4.3 Anaesthetic techniques

All patients had fasted for over four hours before the anaesthesia. The nurse from the Ambulatory Surgery Unit of the Oulu University Hospital checked the exclusion criteria before the patient was recruited into the study. All the patients were given 100 mg of ketoprofen diluted in 20 ml 0.9% NaCl intravenously over 30 min after i.v. cannulation, and 1000 ml of 0.9% NaCl was given i.v. during their stay in hospital. The patients received alfentanyl 0.5 mg i.v. as premedication just before the spinal puncture or the induction of anaesthesia. The anaesthetic methods of study 1 have been described in detail on page 140 in the original paper III. The anaesthetic method used in study 2 was similar to that in study 1, except that spinal anaesthesia was administered with 60 mg of lidocaine (1.2 ml of lidocaine 50 mg/ml in 7.5% glucose) diluted with 1.8 ml of 0.9% NaCl to get 3 ml of 2% lidocaine solution. A sharp-pointed 27 G spinal needle was used in all spinal anaesthesias given in the studies 1 and 2. In study 2, the patients were anesthetised with sevoflurane after similar induction as in study 1. The anaesthesia was maintained with 8% sevoflurane inhalation with a fresh gas flow of 5 l/min for three minutes. After this, the sevoflurane inhalation was cut down and the fresh gas flow was reduced to 1 l/min for all patients. The goal was to reach 1 MAC before the skin incision and to continue at that level during the operation. All the anaesthetics were turned off at the moment when the operation was over. Postoperative pain was treated with 100 mg of ketoprofen three times per day during the first days after discharge.

4.4 Postoperative follow-up

All patients were followed up in the same way:

Early recovery: The time of extubation, the patient's eye opening when asked, the ability to obey orders, orientation and the ability to sit, drink, stand and walk were recorded for the patients with general anaesthesia. The times when the spinal anaesthesia patients could move their toes and ankle, flex their knee, lift their foot, sit, stand, walk and void were recorded. In the recovery unit, vital signs were monitored regularly (HR, BP, SaO2, alertness) at intervals of 30 min after arrival until discharge from the recovery unit. The following parameters were recorded: degree of pain as estimated on VAS (0–10), degree of alertness (on a scale of 1 = fully awake, 2 = sleepy, mostly awake, 3 = sleeps, wakable, 4 = in coma), postoperative nausea and vomiting (PONV) (on a scale 0 = no PONV, 1 = mild PONV, no medical treatment, 2 = PONV with medical treatment, 3 = serious PONV, medical treatment ineffective). If the patient vomited or the nausea lasted for over 15 min, the patient was given metoclopramide 10 mg i.v. If the patient felt nausea after the metoclopramide dose, 4 mg of ondancetrone was given i.v. DSST was administered preoperatively and 60 min after the end of anaesthesia to evaluate home readiness. For spinal anaesthesia patients, the time from the end of the spinal injection until the recovery of full strength in the lower extremities and the ability to walk and void were noted. Discharge readiness was defined as fulfilment of the following criteria in all groups: alert, stable vital signs, able to ambulate, able to take oral fluids, no nausea and

pain controllable without intravenous opioids. The times to achieve home readiness and times for total stay in the recovery unit were measured.

Recovery profile after 24 hours: On the first postoperative day, the patiens were contacted by phone at home to ascertain their nausea after leaving the Ambulatory Surgery Unit on an 11-point rating scale (0, no nausea; 10, worst possible nausea). The intensity of pain was evaluated as an average during the 24-h period on an 11-point rating scale (0, no pain; 10, worst pain imaginable). The patients were also asked whether they had headache (in a supine or upright position), backache or pain in the legs or thighs. Abnormal postoperative sleepiness at home was also inquired. The patients' overall satisfaction with their general condition during the first 24 h after surgery, the timing of discharge, the anaesthesia method, the treatment of postoperative pain as well as their satisfaction with the staff (surgeon, anaesthesiologist and nurses) were all evaluated on an 11-point rating scale. The patients were also asked whether they would have a similar procedure done in an ambulatory setting in the future and if they would have the same type of anaesthesia.

Recovery profile during the first week: After one week, the patients were asked to complete a questionnaire. They were asked about the pain during the first week (severe, moderate, mild, none), the number of days for which they needed pain medication, or whether the instructions for pain treatment were adequate or inadequate. The patients were also asked about discomfort during the first week (nausea, headache, backache and leg pain) and about their overall satisfaction during the first week on an 11-point rating scale (0 dissatisfied, 10 totally satisfied). The number of readmissions was recorded.

4.5 Costs

The direct costs of the materials needed for certain types of anaesthesia and the work in the operation theatre and the recovery unit were calculated. The drug prices were calculated by using the catalogue prices (Pharmaca Fennica 1999), and possible special sales for hospitals were ignored. The fixed costs that remain unchanged regardless of the number of operations were ignored. The times spent in the operation theatre and in postoperative care in the recovery unit before discharge were measured. The average operation theatre and recovery unit salary costs per minute were calculated by dividing the total salaries with the operation theatre and recovery unit working hours. The surgical team in the operation theatre consisted of two doctors and three nurses. During the postoperative period, one nurse was able to take care of three patients.

The price for liquid drugs was calculated as per quantity of each drug used in ml. The costs for wasted drugs were also calculated. The costs of inhalation anaesthetics were calculated from the formula (Dion 1992):

Cost in Finnish marks (FIM) = $PFTMC/2412d$

where, P is the vaporiser concentration (Fi%); F is fresh gas flow (l/min); T is the duration of anaesthesia (min); M is the molecular weight of anaesthetic (g); C is the cost of anaesthetic (FIM/ml), and d is density of anaesthetic (g/l).

This calculation assumes that the gases are delivered from the machine at an atmospheric density corresponding to 21°C, which explains the factor 2412 in the formula. Fi% was analyzed automatically after each minute with a printer connected to the anaesthesia respirator (AS3, Datex-Ohmeda, Instrumentarium corp., Helsinki, Finland).

Table 13. Physiological characteristics of isoflurane, desflurane and sevoflurane.

Parameter	Isoflurane	Desflurane	Sevoflurane
M (g)	184	168	200
C (FIM/ml)	3.3	1.4	3.4
d (g/l)	1.496	1.450	1.530

M = molecular weight, C = concentration, d = density

4.6 Statistical methods

The summary statistics for continuous variables were expressed as mean and range or standard deviation (SD). The inter-group comparison was done by Student's t-test or, in a non-normal situation, by the Mann-Whitney U-test. The Chi-square or Fisher's exact test was utilized for categorical variables. The longitudinal data were analyzed by analysis of variance for repeated measurements, where the preoperative value was used as a baseline value. Significance levels are reported for comparisons with two-tailed $p < 0.05$. The analyses were performed using a standard statistical software (SPSS 10.0, SPSS Inc., Chigaco, III). The analysis between the four groups was done with ANOVA and Kruskall-Wallis tests.

5 Results

5.1 Patients

Two hundred patients were invited to participate in study 1. Altogether 27 patients refused or were excluded from the analyses because of missing data or because the registration had not been done according to the protocol. A total of 60 patients were scheduled to participate in study 2, and none were excluded. Of the 173 patients in study 1, 168 (97%) were reached by phone on the next day, and 163 (94%) returned the questionnaire. In study 2, all of the 60 patients were reached by phone on the next day, and 56 (93%) returned the questionnaire.

The patients were haemodynamically stable in the early recovery period until discharge, and no statistical differences were noted compared to the preoperative values in any of the groups.

The demographic characteristics, the duration of operation and the time to reach home readiness in study 1 are shown in Table 14. The same parameters for study 2 are shown in Table 15.

Table 14. Demographic characteristics, duration of operation and time to reach home readiness in study 1. The values are presented as means and standard deviation.

Parameter	spinal	propofol	isoflurane	desflurane
N	55	32	38	48
Men/women (n)	25/30	12/20	24/14	30/18
Age (years)	40 (11.0)	39 (12.6)	39 (11.0)	38 (14.0)
BMI	25.6 (3.2)	24.9 (3.4)	25.3 (3.3)	25.7 (2.7)
Operation time (min)	24 (12.9)	21 (15.6)	22 (12.1)	19 (11.4)
Home readiness (min in RU)	168** (41.6)	55 (20.2)	56 (29.1)	46 (30.7)

** $p < 0.001$, compared to all the other values. RU = recovery unit

Table 15. Demographic characteristics and time to reach home readiness in study 2 (IV). The values are presented as means and standard deviation.

Parameter	spinal	sevoflurane
N	30	30
Men/women (n)	15/15	18/12
Age (years)	44.9 (11.5)	35.7 (11.8)
BMI	26.9 (3.4)	25.6 (4.4)
Operation time (min)	23 (10.9)	25 (17.9)
Home readiness (min in RU)	140.8 *(52)	96.4 (62)

* $p = 0.02$

5.2 Recovery characteristics

The recovery characteristics for 5% lidocaine spinal, deslurane, isoflurane and propofol anaesthesias are shown in the tables 16 and 17.

Table 16. Recovery characteristics in study 1 (I). Values are presented as mean and standard deviation.

Parameter	propofol	isoflurane	desflurane
opens eyes (min)	11 (7.4)	12 (5.4)	8 (3.1)
extubation (min)	9 (6.4)	11 (5.0)	8 (3.4)
obeys orders (min)	12 (7.5)	12 (5.4)	8 (3.2)
orientation (min)	13 (7.0)	13 (5.5)	9 (3.5)
sits (min)	35 (13.7)	32 (4.8)	28 (9.0)
drinks (min)	38 (19.4)	37 (19.3)	31 (17.5)
stands (min)	51 (23.0)	46 (23.0)	38 (20.9)
walks (min)	50 (18.8)	50 (25.8)	38 (20.8)
home readiness (min)	55 (20.2)	56 (29.1)	46 (30.7)
total stay in RU (min)	184 (44.3)	204 (49.7)	197 (57.0)

Table 17. Recovery characteristics in study 1 (I). Values are presented as mean and standard deviation.

Parameter	spinal
moves toes (min after spinal injection)	100 (28.6)
moves ankle	100 (26.7)
flexes knee	90 (26.9)
lifts foot	98 (29.9)
sits	108 (29.0)
stands	169 (36.9)
walks	173 (36.7)
voids	210 (42.5)
home readiness (min in RU)	168 (41.6)
total stay in RU (min)	208 (43.1)

In study 2, the mean time to reach home readiness was 141 min (SD 52) in the 2% lidocaine spinal anaesthesia group and 96 min (SD 62) in the sevoflurane anaesthesia (p = 0.02). There were no differences in the total RU time: 224 min (SD 67) for spinal anaesthesia and 218 min (SD 59) for sevoflurane anaesthesia.

5.3 Postoperative pain

The level of postoperative pain in the recovery unit was low in all groups in study 1. (median VAS for pain < 4)

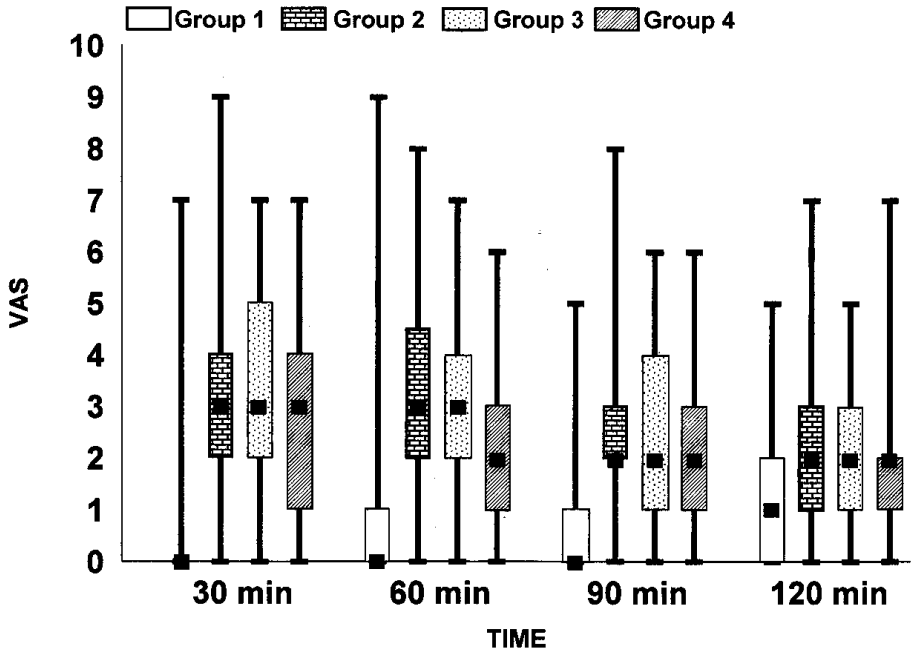

Fig. 2. Postoperative pain. Median, 25 and 75 % percentiles and range. Group 1 = 5% lidocaine spinal. Group 2 = propofol. Group 3 = isoflurane. Group 4 = desflurane.

The median VAS was 1 for 2% lidocaine spinal and 2.5 for sevoflurane anaesthesia patients during the first 90 min postoperatively. At 120 min, the median VAS for both groups was 1. The overall need for postoperative opioids was 12.8% in study 1 and 28.3% in study 2. The more detailed results of the postoperative opioid need are shown in Table 18.

Table 18. Need for postoperative opioids.

Parameter	5% lidocaine*	propofol	isoflurane	desflurane	2% lidocaine*	sevoflurane
N	55	32	38	48	30	30
Patients who needed postoperative opioids	3	7	4	5	5	11

*spinal anaesthesia

5.4 Postoperative sedation

At 30 min postoperatively, the isoflurane anaesthesia and propofol anaesthesia groups were more sedated than the desflurane anaesthesia and 5% lidocaine spinal anaesthesia groups ($p < 0.001$). At 60 min postoperatively and afterwards during the early recovery period, all groups were alert and no statistical differences were noted. The DSST value 60 min after the end of the surgical procedure in all groups was slighty below the preoperative DSST value, but no statistical differences were noted between the groups.

The sevoflurane anaesthesia patients were more sedated than the 2% lidocaine spinal anaesthesia patients at 30 min ($p = 0.01$) and 60 min ($p = 0.012$) postoperatively. After that, all patients were alert and there were no differences between the groups in the early recovery period. The DSST values were equal in both groups preoperatively and 60 min postoperatively. The more detailed values of postoperative sedation are shown in the tables 19 and 20.

Table 19. Postoperative sedation (VAS) in study 1. Values are presented as means and standard deviation.

Anaesthesia	30 min	60 min	90 min	120 min
5% lidocaine spinal anaesthesia	1.15 (0.49)	1.13 (0.55)	1.04 (0.27)	1.0
propofol	1.69** (0.78)	1.22 (0.49)	1.06 (0.35)	1.06 (0.25)
isoflurane	1.42** (0.60)	1.21 (0.47)	1.16 (0.49)	1.08 (0.36)
desflurane	1.19 (0.45)	1.06 (0.24)	1.0	1.0

**$p < 0.001$, compared to 5% lidocaine spinal anaesthesia and desflurane anaesthesia

Table 20. Postoperative sedation (VAS) in study 2. Values are presented as means and standard deviation.

Anaesthesia	30 min	60 min	90 min	120 min
2% lidocaine spinal anaesthesia	1.13 (0.35)	1.13 (0.51)	1.20 (0.61)	1.13 (0.51)
sevoflurane	1.47** (0.51)	1.20** (0.41)	1.13 (0.43)	1.20 (0.48)

**$p = 0.01$ (at 30 min) and 0.012 (at 60 min)

5.5 Postoperative nausea

The incidence of postoperative nausea in the early recovery period in 5% lidocaine spinal anaesthesia and desflurane, isoflurane and propofol anaesthesias was 3.4% with no statistical difference between the groups. No patients in the 2% lidocaine spinal group had nausea in the early recovery period. Six sevoflurane patients (20%) had nausea which required treatment in the recovery unit ($p = 0.024$).

The incidence of nausea during the first postoperative week was 4.2% and that of vomiting 1.8% in all groups (5% lidocaine spinal anaesthesia, desflurane, isoflurane and propofol anaesthesia) with no statistical difference between the groups (I). Four patients in the sevoflurane group and one patient in the 2% lidocaine spinal group had nausea during the first 24 hours (IV). After that, no nausea and vomiting were noted in these groups during the first postoperative week.

5.6 Postoperative satisfaction

In the early recovery period and during the first 24 hours postoperatively, all the patients were generally satisfied with their respective anaesthesia methods. Two percent (1/55) of the 5% lidocaine spinal anaesthesia patients would have chosen general anaesthesia and 4.3% (5/118) of the general anaesthesia patients would have chosen spinal anaesthesia for the next operation. There was slight, but not statistically significant dissatisfaction with the surgeon compared with the anaesthesiologists and nurses in all groups.

Based on the questionnaires returned after one week, 8.3% of the 5% lidocaine spinal anaesthesia patients wanted to have general anaesthesia and 4.7% of the general anaesthesia patients wanted to have spinal anaesthesia for a similar procedure next time. 98% of the 5% lidocaine spinal anaesthesia patients and 96% of the general anaesthesia patients (desflurane, isoflurane and propofol anaesthesias) said they would have ambulatory surgery in the future. In the 2% lidocaine spinal anaesthesia and sevoflurane anaesthesia groups, everybody would have liked to have a similar operation done on an ambulatory basis, and 93% would have liked to choose the same kind of anaesthesia. Of the all 2% lidocaine spinal anaesthesia and sevoflurane anaesthesia patients, 92% were satisfied with the first postoperative week.

5.7 Late recovery profile

In all groups, most of the patients found their condition moderate or good on the way home. Headache within the first 24 postoperative hours was experienced by 15.7% of the 5% lidocaine spinal anaesthesia group and 20.0% of the 2% lidocaine spinal anaesthesia group. The incidence of headache was 10.3% in the general anaesthesia groups (propofol, desflurane and isoflurane). In the sevoflurane group, no headache was reported at all during the first 24 hours. After one week, the 5% lidocaine spinal anaesthesia group patients had experienced headache when standing in 13.5% of cases and the 2% lidocaine

spinal group patients in 13.3% of cases. Nobody needeed a blood patch. During the first week, the incidence of backache and leg pain in the 5% lidocaine spinal and 2% lidocaine spinal anaesthesia groups was 36.5% and 59.6% versus 3.3% and 10.0%, respectively. Among the general anaesthesia patients (propofol, desflurane and isoflurane), headache was reported by 4.5%, backache by 9.9% and lower leg pain by 39.6% ($p < 0.05$, compared to the 5% lidocaine spinal anaesthesia patients). The corresponding figures of the sevoflurane anaesthesia patients during the first week were: no headache, backache 10.0% and leg pain 3.3%.

The mean period with a need for postoperative analgesics was 3 days with no difference between the groups. The patients considered the pain treatment instructions good enough in 96% of the cases. Only one readmission was noted, and that was because of pain and swelling of the operated knee. A medical consultation by phone or a visit to general practitioner was needed by 17.6% (9/51) of the 5% lidocaine spinal patients and 14.8% (16/108) of the general anaesthesia patients (desflurane, isoflurane, propofol).

5.8 Costs

The total personnel costs incurred in ambulatory knee surgery and the anaesthetic material costs in the operation theatre and in the recovery unit until home readiness are shown in table 21.

Table 21. A cost comparison of the different anaesthetic methods in ambulatory knee surgery.

Anaesthesia	Material and operation theatre costs	RU costs	Total cost
Propofol	164 FIM	40 FIM	204 FIM 34.3 EUR
5% lidocaine spinal	104 FIM	68 FIM	172 FIM 29.0 EUR
Sevoflurane	115 FIM	56 FIM	171 FIM 28.8 EUR
2% lidocaine	83 FIM	78 FIM	161 FIM 27.0 EUR
Desflurane	123 FIM	35 FIM	158 FIM* 26.6 EUR*
Isoflurane	111 FIM	41 FIM	152 FIM* 25.6 EUR*

*$p < 0.05$, compared to propofol and 5% lidocaine spinal
FIM = Finnish mark, EUR = euro, RU = recovery unit

6 Discussion

6.1 Methodological considerations

A total of 233 patients participated in the studies 1 and 2. Two hundred patients were invited to participate in study 1. Only 11 (5.5%) refused, because they had made up their mind to choose a certain type of anaesthesia. The groups in study 1 were unequal in size because 11 patients refused to participate after randomisation and 16 patients were excluded because an incorrect study protocol. There were 60 patients in study 2, and none refused. The small number of refusals shows the high motivation of the patients to participate in studies which aim to improve the methods of anaesthesia in ambulatory surgery. The patients also retained their good motivation in the later stages of the studies. The patients were reached well through the next-day phone calls (97% in study 1 and 100% in study 2). The questionnaires after one week from the operation were returned by 94% in study 1 and by 93% in study 2.

The author interviewed and anethetized all the patients who participated in the studies. The reason for doing so was the aim to minimise the random errors possibly caused by the different working methods of a larger group of anaesthesiologists. The PACU phase of study 1 was analysed by one person. In study 2, the nurses in the PACU filled in the postoperative questionnaires. All of the phone interviews were done by a person blinded to anaesthesia method.

The sizes of the groups were based on the previous studies reported in the literature (Broadway *et al*. 1994, Drummond 1994, White *et al*. 1994, Vitez 1994, Dexter *et al*. 1995, Macario *et al*. 1995) in a way that allowed economic considerations. The number of patients was too small to allow evaluation of the postoperative incidence of rare side effects of the anaesthetics. Such evalutions would have required thousands of patients (Hopwood 1993). One of the weaknesses of this thesis is the lack of sample size calculations, which should have been done before starting to collect patient data. The reason for this was the previously mentioned studies concerning the study group sizes. Nevertheless, the groups were big enough to show significant differences in home readiness and total costs, which were the main study points in this thesis.

6.2 Characteristics of anaesthesia

At the time when the studies for this thesis were started, ambulatory knee surgery was mostly done under 5% lidocaine spinal anaesthesia in Oulu University Hospital. The popularity of spinal anaesthesia in ambulatory surgery has arisen from its ease of administration, rapid onset and high reliability (Standl *et al*. 1996, Alon *et al*. 2000). The knowledge of the connection between TNS and lidocaine spinal anaesthesia increased during the time when the anaesthesia studies were done (Hampl *et al*. 1999, Pollock *et al*. 1999). The incidence of leg pain and back pain was far higher in the 5% lidocaine spinal anaesthesia group than in the groups with the general anaesthetics used (III), or in the 2% lidocaine spinal anaesthesia group (IV). No connection between TNS and 2% lidocaine spinal anaesthesia could be shown, although some of the 2% lidocaine spinal patients had symptoms that resembled TNS (IV). The number of patients was far too low to show statistical significance. There is still some debate in the literature concerning the origin of TNS. Schneider (1993), Henderson (1998) and Pollock (1999) with their colleagues have found a clear connection between lidocaine spinal anaesthesia and TNS. There are some new studies that have failed to demonstrate such a connection (Wong & Slavenas 1999). The clinical importance of TNS warrants discussion, because neurological deficiences have not been described in any of the studies (Scneider *et al*. 1993, Hiller & Rosenberg 1997). The pain in TNS reacts well to NSAIDs and opioids, which is against the hypothesis of a neurotoxic origin of TNS (Scneider *et al*. 1993, Hiller & Rosenberg 1997). Selander renamed TNS as transient lumbar pain, because the symptoms resemble the symptoms of myofascial pain (Hartrick 1997, Selander 1999). The pain mechanism in transient lumbar pain might be the straightening of the lumbar lordosis, which is potentiated by the elevation of the legs after lidocaine spinal anaesthesia (Holmdahl 1998). Lidocaine and mepivacaine cause a larger motor block than bupivacaine, and that might be the reason for the lower incidence of TNS after bupivacaine spinal anaesthesia (Pitkänen *et al*. 1984, Salmela *et al*. 1998). In this study, leg and back pain was also described in the general anaesthesia groups (III). This may suggest that TNS does not alone explain the leg pain. One cause for the leg pain may be the effect of the patient's position (Selander 1999) and the consequences of the usage of a tourniquet. Many ambulatory surgery centres use routinely tourniquets in knee arthroscopies, although there are reports suggesting that the tourniquet increases the risk of complications. Among the 184 consecutive patients scheduled for knee arthroscopy, deep vein thrombosis was detected in 33 (18%) (Demers *et al*. 1998). The risk of deep vein thrombosis was significantly higher among the patients who had a tourniquet applied for more than 60 minutes (Demers *et al*. 1998). There are also opposite findings from a group of 120 patients randomized to tourniquet inflation (300 mmHg) or no tourniquet inflation, where the use of a pneumatic tourniquet did not affect the patients' overall quality of life or functional outcome following routine knee arthroscopy (Kirkley *et al*. 2000). There are also studies where the skeletal muscle ischaemic metabolic changes were more pronounced with a long tourniquet time in knee ligament reconstruction (Kokki *et al*. 1998b), and the safe use of a tourniquet should be limited to less than two hours (Kokki *et al*. 2000b).

The transient neurologic syndrome has restricted the use of lidocaine in spinal anaesthesia (Hampl *et al*. 1995), and compensatory methods have been searched for.

Promising results have been obtained when small doses of hypo- or hyperbaric bupivacaine have been used to achieve unilateral spinal anaesthesia (Kuuusniemi *et al*. 2000, Fanelli *et al*. 2000, Valanne *et al*. 2001). The anaesthesia is reliable and the duration allows the most common day-case procedures to be performed. The anaesthetic effect of bupivacaine is longer than the effect of lidocaine. Although lower bupivacaine concentrations have been used (Valanne *et al*. 2001), home readiness is attained much later compared to the anaesthetics used in the studies 1 and 2. Home readiness has varied from 181 minutes with 4 mg of bupivacaine (Valanne *et al*. 2001) and 190–200 minutes with 6 mg of bupivacaine (Kuusniemi 2001) to 264 minutes with 8 mg of bupivacaine (Fanelli *et al*. 2000). Home readiness after 2% lidocaine spinal anaesthesia was shown to be 141 minutes (IV). It seems that the optimal local anaesthetic to substitute lidocaine in terms of short recovery time has not yet been developed. Bupivacaine has been used because of the lower incidence of TNS, but the cost-effectiveness of bupivacaine is not so good as that of general anaesthetics (IV) or the 2% lidocaine spinal anaesthesia (IV) used in the present study. Ben-David and colleagues used mini-dose lidocaine-fentanyl spinal anaesthesia in knee arthroscopies, and they found that home readiness could be achieved within 50 minutes (Ben-David *et al*. 2001). The short PACU phase is equal to the short PACU phase of the general anaesthetics used in study 1.

There is still a high risk among young patients to develop PDPH after lumbar puncture, although thin special needles are used in ambulatory spinal anaesthesias (Despond *et al*. 1998). In this thesis, the most common side effect of spinal anaesthesia was PDPH (III). Although the study groups were small, postdural puncture headache was reported. One reason for this might have been the 27 G sharp-pointed needle that was used. It might have been better to use a 27 G pencil-point needle, because there are at least two meta-analyses to show a lower risk of headache when thin pencil-point needles are used for spinal anaesthesia (Halpern & Preston 1994, Flaaten *et al*. 2000). Flaaten *et al*. (2000) found the relative risk of developing PDPH to be 0.38 in a pencil-point group compared to sharp-pointed needles. Sharp-pointed needles were routinely used in the unit where the clinical studies for this thesis were done.

Although there are comprehensive reports in the literature concerning the benefits of local anaesthesia in ambulatory knee surgery (Butterworth *et al*. 1990, Iossifidis 1996, Lorentsen *et al*. 1997, Ramanathan 1998), the use of local anaesthesia is uncommon. This may be due the impracticability of local anaesthesia when tourniquets are used and the fear of inadequate anaesthesia and patient discomfort (Forssblad & Weidenhielm 1999). One purpose of this thesis was to find an anaesthesia method considered highly satisfactory by patients operated on an ambulatory basis. The finding that patient discomfort was reported in only 0.9% of local anaesthesia arthroscopies in a large patient series (Forssblad & Weidenhielm 1999) favours the the use of local anaesthesia. Recently, the fastest recovery and lowest perioperative costs have been obtained with a combination of local anaesthesia and sedation in ambulatory surgery (Song *et al*. 2000, Li *et al*. 2000). However, the value of local anaesthesia is underestimated in ambulatory surgery. The finding that general anaesthesia patients need postoperative opioids in the early recovery phase more often than spinal anaesthesia patients (IV) favours the use of intra-articular local anaesthesia (Allen *et al*. 1993, Van Ness & Gittins 1995) combined with short-acting general anaesthetics in ambulatory surgery. There are some new findings in the literature which suggest that lower doses of lidocaine should be used in

spinal anaesthesia (Wong *et al*. 2001) and that opiates could be combined with local anaesthetics (Stewart *et al*. 2001). These studies have reported equal or shorter PACU times with spinal anaesthesia than with novel general anaesthetics.

The laryngeal mask airway was not routinely used in the ambulatory surgery unit of Oulu University Hospital at the time when the clinical studies for this thesis were started. That was the reason for choosing a general anaesthesia method with muscle relaxation and tracheal intubation. Mivacuronium substituted suxamethonium as a short-acting muscle relaxant (Bevan 1995). The use of suxamethonium is not common because of the reported side effects, e.g. muscle pain and stiffness (Smith *et al*. 1993). The patients were not premedicated, because one aim in ambulatory surgery is a short recovery time and home readiness with minimal possible sedation. Premedication is often substituted by interviewing the patient and by giving adequate information. The patients who wanted to be premedicated were excluded from the study. Alfentanil was given to all patients who participated in the study because of its analgesic and euphorizing effect and short action (Ali-Melkkilä 1999).

6.3 Characteristics of recovery

6.3.1 Home readiness

One of the most important results of this thesis was the finding that the patients with 5% lidocaine spinal anaesthesia needed an over threefold recovery time before home readiness than the patients who had general anaesthesia with propofol, desflurane or isoflurane. The 5% lidocaine spinal anaesthesia patients had to stay in the PACU for over two hours longer than the patients who had general anaesthesia (I). When lidocaine was diluted to a 2% concentration, no remarkable shortening of the PACU time was achieved (IV). This result plays an important role in busy ambulatory surgery units, where a crowded PACU may limit the effective use of the operation theatre. In those units, it is worthwhile to use general anaesthesias.

It turned out that the patients spent a longer time in the PACU than was necessary (I, IV). The main reason for this was the abscence of an escort at the time when the patient reached home readiness. Some patients may be kept in the PACU for that reason, although they would be ready to go home. Nurses may also be too busy in big units to be able to determine the optimal time for home readiness in every case, and some patients may have to wait for their attention.

6.3.2 Postoperative pain

In all knee arthroscopies studied here, the pain scores were low. In the early recovery phase, the lidocaine spinal anaesthesia patients had lower pain descriptions than the patients anaesthetized with general anaesthetics (I, IV). This can be explained by the

relatively long duration of lidocaine spinal anaesthesia in the PACU. Pain can be assessed with a verbal or numerical rating or with visual pain scales. The most frequently used visual pain scale is a straight line with the extremepain intensities at each end (Visual Analogue Scale, VAS). In this study, the 11-point Numerical Rating Scale (NRS) was used because it provides sufficient levels of discrimination to describe pain intensity (Jensen *et al*. 1994) and is used widely in everyday practice (Salomäki 1995). In this thesis, pain measurements were based on simple numerical and verbal descriptions of pain and therefore lack exact quantification.

The general level of pain was lower in this thesis than in other studies on knee arthroscopy (Juhlin-Dannfelt *et al*. 1995). This may be ascribed to the fact that all the patients received analgesia with an anti-inflammatory drug and alfentanil before the operation, which supports the assumption of a pre-emptive analgesic effect (Wall 1988). Also, knee arthroscopy is a surgical procedure with a low level of tissue damage, and the low incidence of pain may be related to that. The median need for postoperative analgesics was 3 days (IV). The patients anesthetized with sevoflurane were most painful and the need for opioids in the PACU was most obvious (IV). At any rate, the level of pain among sevoflurane patients was low because their VAS scale median for pain was less than 4. Special attention should be paid to adequate pain treatment during the first few postoperative days in the patients who have had general anaesthesia with short-acting anaesthetics and opioids. Good postoperative pain instructions are important. This study showed that these instructions are sufficiently good, because 96% of the patients were satisfied with their postoperative pain instructions and treatments (IV).

6.3.3 Postoperative sedation

The patients anesthetized with propofol, isoflurane and sevoflurane were more sedated during the first postoperative hour than the patients anesthetized with lidocaine spinal anaesthesia (I, IV). During the second postoperative hour, there were no differences between the spinal anaesthesia and general anaesthesia groups. During the home readiness phase, the patients were alert and no differences in sedation could be noticed. This result resembles those reported about the comparison of new general anaesthetics (desflurane, sevoflurane, propofol) to each other and to older general anaesthetics (isoflurane) (Alhashemi *et al*. 1997, Jakobsson *et al*. 1997, Ries *et al*. 1999, Heidvall *et al*. 2000). These studies have revealed no differences between the agents used in terms of late recovery. The difference in recovery time between the anaesthetics, which is commonly some minutes in the early recovery phase, may not seem to be clinically important. However, a 6-minute difference in the length of recovery with five patients makes 30 minutes extra time. That time equals to the time spent on one arthroscopy. Song and colleagues showed that 26% of patients anaesthetized with propofol, 75% of patients anaesthetized with sevoflurane and 90% of patients anaesthetized with desflurane recovered so fast that the phase I recovery period (patient do not need to stay in RU) could have passed (Song *et al*. 1998). To evaluate the recovery of cognitive and motor functions, the DSST was done to all patients preoperatively and at one hour after arrival in the PACU. The results showed that although the highest cognitive and motor functions

were not fully recovered at one hour postoperatively, the patient could be safely escorted home (I).

6.3.4 Postoperative nausea

The incidence of nausea and vomiting was low in all groups and resembled the results of other studies done on ambulatory knee surgery (Dahl *et al*. 1997). Earlier studies have shown that nausea and vomiting often delay discharge in outpatient surgery (Raeder *et al*. 1988, Juhlin-Danfelt *et al*. 1995). The incidence of nausea was high in the sevoflurane group (IV). The other groups studied had a lower incidence of nausea, and this may be the reason why home readiness was achieved later by the patients anaesthetized with sevoflurane (I, IV). One reason for the higher incidence of nausea in the sevoflurane group might be the higher need of opioids in the PACU (IV), because of the rapid termination of sevoflurane anaesthesia (Eger 1994).

6.3.5 Stability of vital functions

The time within which the vital functions (haemodynamics and spontaneous breathing) recover and stay stable in the PACU and the lack of side effects (pain, nausea and vomiting) are the key points in view of the differences between the anaesthetics. If the Phase I PACU can be avoided, i.e. if fast tracking is possible, significant time saving is possible in the busy PACU.

All patients did well haemodynamically and none of them had breathing problems at any stage of anaesthesia or the recovery phase (I, IV). The number of patients was too small to allow assessment of the rare side effects, but the stability of vital functions in all the patients supports the safety of all of the anaesthetics studied here. This was also shown by the very low rate of readmissions during the first postoperative week: only one patient (0.04%) had an unanticipated admission (IV). Unexpected hospital admission after ambulatory surgery has been used as an index of ambulatory patients' morbidity and complications. The reported incidence of unanticipated hospital admission rates varies between 0.1% and 5% (Meridy 1982, Levy 1987).

6.4 Evaluation of cost-effectiveness

The material costs of spinal anaesthesia are lower than the material costs of the new general anaesthetics (II, IV). The studies I and IV showed the PACU phase to be significantly longer when spinal anaesthesia was used. More working resources were needed then, which caused a rise in the costs that was bigger than the cost rise in the materials used in general anaesthesia.

Sevoflurane was the most expensive inhalation anaesthetic, although the fresh gas flow was only 1 l/min (IV). The cost difference would have been greater if the fresh gas flow had been the same as the gas flow (2 l/min) used with isoflurane and desflurane anaesthesias (I, II). The costs of general anaesthetics might have been lower if N_2O had been used as an anaesthetic adjuvant (Jakobsson *et al*. 1997). The high material costs of propofol made this anaesthesia the most expensive method of all (II, IV).

One reason to start the studies for this thesis was the overall marked increase of ambulatory surgery procedures in Finland (Suomen kuntaliitto 1998). Most Finnish hospitals were built at the time when ambulatory surgery procedures were not yet in use. This means that the hospitals do not have enough room for preoperative patient examinations and the PACUs have a limited capacity to take over the large number of ambulatory patients. When the studies for this thesis started, almost all ambulatory knee arthroscopy patients were anaesthetized with 5% lidocaine. The surgical procedure for knee arthroscopy takes about 20 minutes (II). The PACU phase after that is excessively long compared to the time spent on the surgical procedure (I, IV). That led to crowded PACUs, which in turn caused delays in the operating theatre. Excessive financial losses were incurred when the operating theatre had to wait to start a new procedure. The loss in cost effectiveness is due to the underuse of the operating theatre personnel and the excessive work load of the nurses in the PACU. Personnel expenditure is the main factor that determines cost-effectiveness in the hospital budget (Drummond 1994).

Postdural puncture headache may raise the total costs by increasing postoperative hospital admissions. The need for an epidural blood patch following spinal anaesthesia among adolescents is 0.8% (Aldrete 1994). In this study, nobody needed a blood patch. There were some postspinal headache patients, and it can be assumed that if the number of patients had been higher, some patient might have needed a blood patch. That might have caused a loss of working time among the patients' relatives who had to stay at home. Correspondingly, the same phenomenon might occur if the patients had excessive pain, nausea and vomiting.

6.5 Clinical implications

The fast early recovery that was seen among general anaesthesia patients has increased the use of inhalational anaesthesia. At the same time, the connection between TNS and lidocaine has modified the ambulatory anaesthesia practice into the same direction. An optimal short-acting local anaesthetic to replace lidocaine spinal anaesthesia is still needed. Inhalational anaesthesia with a laryngeal mask has been the popular practical choice in ambulatory knee arthroscopy during the last few years. Isoflurane inhalation anaesthesia is still competitive compared to the new general anaesthetics in terms of cost-effectiveness and patient satisfaction, because the results of the present study equal the findings in the literature, where late recovery has been shown to depend very little on the general anaesthetic used (Alhashemi *et al*. 1997, Jakobsson *et al*. 1997, Ries *et al*. 1999, Heidvall *et al*. 2000).

7 Conclusions

1. The immediate recovery profile of general anaesthesia with propofol infusion and isoflurane or desflurane inhalation was smooth with low levels of pain and nausea, and home readiness was achieved over two hours earlier than after 5% lidocaine spinal anaesthesia. Patients anaesthetised with isoflurane or propofol were more sedated in the early recovery period than patients anaesthetised with desflurane. Patients anaesthetised with spinal 5% lidocaine had the lowest sedation score.
2. General anaesthesia with isoflurane or desflurane was more cost-effective than spinal anaesthesia with 5% lidocaine in ambulatory knee surgery if a short recovery unit time was needed. Propofol anaesthesia was the most expensive anaesthesia method compared to isoflurane, desflurane or 5% spinal anaesthesia.
3. The general level of pain after ambulatory knee surgery was low after the first few hours postoperatively, and it continued to be low in propofol, 5% spinal, desflurane and isoflurane anaesthesias during the first postoperative week. The patients were highly satisfied with knee surgery done on an ambulatory basis. There was a slight tendency to favour general anaesthesia compared to spinal anaesthesia in the questionnaires returned after one week postoperatively.
4. Home readiness after 2% lidocaine spinal anaesthesia was significantly longer (almost 45 min) than home readiness after sevoflurane inhalation anaesthesia. Sevoflurane was more cost-effective than spinal anaesthesia with 2% lidocaine if a short PACU time was needed. The spinal anaesthesia patients had a higher incidence of headache, backache and lower leg pain during the first postoperative week than the patients who had had general anaesthesia.

Isoflurane inhalation anaesthesia was the cheapest anaesthetic method compared to general anaesthesias with desflurane, sevoflurane, propofol and 2% and 5% lidocaine spinal anaesthesias in adult ambulatory knee surgery.

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