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FORUM

Costing anaesthetic practice An economic comparison of regional and general anaesthesia for varicose vein and inguinal hernia surgery

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Summary

A computerised database of operating theatre activity was used to estimate the costs of regional and general anaesthesia for varicose vein and inguinal hernia surgery. Data retrieved for each procedure included the anaesthetic technique and drugs used, and the duration of anaesthesia, surgery and recovery. The costs of anaesthetic drugs and disposables, salary costs of the anaesthetic personnel and maintenance costs for anaesthetic equipment were considered. Drugs and disposables accounted for ≈ 25% of the total cost of an anaesthetic. Anaesthetic times were 5 min longer for regional anaesthesia, but recovery times were 10 min shorter following regional anaesthesia for varicose vein surgery. Staff costs were dependent on the length of time each staff member spent with the patient. Although the number of cases was small, provision of a field block and sedation for inguinal hernia repair was considerably cheaper than other anaesthetic techniques.

Keywords *Anaesthetic costs*: regional; general.

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Cost containment has become a priority in all areas of health care. Clinicians must work within tightly controlled budgets in spite of increasing demand for services, expectations of higher standards, and the introduction of new drugs and techniques. A common view is that anaesthetic costs are insignificant because they are a relatively small component of the total for each surgical episode. This is superficially true; the Audit Commission reported that anaesthetic services comprised only 3% of NHS trust expenditure [1]. However, this adds up to a large sum of money across the service. Anaesthesia for any surgical procedure involves a wide choice of drugs, techniques and monitoring procedures, each with very different cost implications. Selection of any particular method must be determined by the relative costs, as well as the clinical benefits, if the challenge of providing high-quality care within limited resources is to be met.

The cost of each anaesthetic is the sum of a number of components. Information about the price of drugs (the commonest focus for debate) is readily available, but choices based solely on drug acquisition costs ignore many other factors that contribute to the cost of an anaesthetic, including capital and recurrent expenditure on equipment, the prices of disposable equipment, and the salaries of the anaesthetist, anaesthetic assistant and recovery staff. Personnel costs are dependent on the time spent by the patient in the anaesthetic room, operating theatre and recovery area, each of which may be affected by the anaesthetic technique or drugs used. This study used data from a computerised database of operating theatre activity to compare the costs of general and regional anaesthesia for patients undergoing varicose vein and inguinal hernia surgery.

Methods

Data collection

The Ninewells Hospital operating theatre management system was established in 1989 using the Financial Information Project (FIP) Galaxy Theatre System, a software package marketed by Sanderson GA Ltd (1–2 Venture Way, Aston Science Park, Birmingham, UK).

Information on each procedure was recorded by the operating theatre staff on a standard form (Appendix 1) that detailed the surgical procedure, the anaesthetic drugs and equipment used, and the times of the patient entering and leaving the anaesthetic room, operating theatre and recovery area. This information was subsequently entered into the hospital's mainframe computer database by the computer services department.

Anaesthetic coding system

Detailed information about each procedure was recorded on the form as a series of codes. Each code denoted a different component of the anaesthetic, such as the method of airway maintenance and ventilation, the local or regional anaesthetic technique used and details of intravascular access and fluid therapy. Codes were also used to record the agents used for induction and maintenance of general anaesthesia, analgesia and muscle relaxation.

Anaesthetic costing

The data recorded were used to estimate the relative costs of each anaesthetic. Only costs immediately relevant to the anaesthetic department were considered, including the costs of drugs and disposables used, the salary costs of the anaesthetist and nursing staff, and expenditure on anaesthetic equipment. Overhead costs relating to the hospital site, ward services, administration and portering were assumed to be similar for each procedure and were ignored.

Drugs and disposables

The approximate cost of the drugs and disposables used was calculated from a charge sheet (Appendix 2). Rather than quoting the prices of individual items, the charge sheet provided estimated total costs for the administration of a particular drug or the execution of a specific procedure. Thus the assessed cost of using an intravenous drug included not only the price of a single-dose ampoule of the drug, but also the equipment (needles, syringes, etc.) required for its preparation and administration. Likewise, the charge for an epidural included the cost of the local anaesthetic solution, Tuohy needle and catheter, as well as the provision of a sterile tray.

The prices of individual items were obtained from the pharmacy and supplies departments and discounts available for bulk purchase were taken into account. Details of drug dosage were not recorded, therefore it was assumed that one ampoule was opened for each administration of an intravenous drug, with any drug remaining at the end of the procedure being discarded. The exception was the use of neuromuscular blocking agents during long procedures, in which case it was assumed that a further ampoule was opened after every 2 h of operating time. The cost of a propofol infusion was calculated as a fixed cost for induction of anaesthesia and a time-dependent cost for maintenance. Both costs were estimated from average rates of propofol consumption.

The cost of fresh gas supplies are dependent on total flow rates through the hospital pipeline system and are difficult to estimate. Therefore, these costs were not considered. The cost of the volatile anaesthetic agents was calculated from their molecular mass and density according to the formula suggested by Dion [2]. The calculations assumed that an average fresh gas flow rate of 6 $l.min^{-1}$ was used with a vaporiser concentration equivalent to 1.0 MAC. This provided an approximate cost-per-minute of anaesthetic time for each inhalational agent.

Precise details of intravenous fluid therapy were not recorded in the database and the cost of an intravenous infusion was considered to be that of a cannula, fluid administration set and 1 l of crystalloid solution.

Staff costs

The salary costs of the anaesthetist and anaesthetic and recovery nurses were considered to be dependent on the time that each spent with the patient. Allocations for the anaesthetist and anaesthetic nurse were determined by the time that the patient spent in the anaesthetic room and operating theatre. Recovery costs were determined by the time spent in recovery, with the assumption that the nurse was responsible for one patient at a time.

The average annual salary of a consultant anaesthetist was obtained from pay-roll information. An hourly rate was estimated by assuming that consultant anaesthetists spend an average of 24.5 h per week in the operating theatre. Division of the annual salary by the total number of hours spent in operating theatres per year gave an approximate rate of £50 per hour. It is clearly possible to calculate similar hourly rates for anaesthetic trainees but the grade of the anaesthetist was not directly relevant to this study and, for simplicity, it was assumed that all anaesthetists were consultants.

The average annual salary of the nursing staff was calculated from the total salary costs of all the anaesthetic and recovery nurses employed in the hospital. Nurses spend a greater proportion of their contracted time in contact with patients and the hourly rate of pay was estimated to be £10.

Anaesthetic equipment

The purchase and maintenance of anaesthetic equipment, such as anaesthetic machines, ventilators and monitors are expensive and account for a substantial proportion of a departmental budget. However, it is not possible to

Table 1 Anaesthetic technique used.

	Inguinal hernia *N* (%)	Varicose veins *N* (%)
General anaesthesia (with or without local block)	581 (59.3)	212 (49.9)
Central nerve block (with or without sedation)	346 (35.3)	213 (50.1)
Combined GA and central nerve block	24 (2.4)	–
Field/local block (with or without sedation)	29 (3.0)	–
Totals	980 (100)	425 (100)

allocate these costs accurately to individual procedures. In this study an equipment cost equal to 30% of that for drugs and disposables was included in the total for each procedure because an historical analysis of departmental expenditure over several years indicated that this was an appropriate weighting.

Study protocol

The costing system was used to analyse the costs of anaesthesia in two surgical groups for which complete sets of data were available; all cases of inguinal hernia surgery in adults between 1 January 1996 and 1 June 1998 and cases of varicose vein surgery between 1 January 1997 and 1 June 1998. The relevant data was downloaded from the computer database into a Microsoft Excel worksheet file.

Within each group, cases were assigned to one of four categories according to the principal anaesthetic technique used: general anaesthesia, central nerve block, combined general anaesthesia and central nerve block, or local anaesthetic field block. The times that each patient spent in the anaesthetic room, operating theatre and recovery area were calculated. Median times and interquartile ranges were calculated for each anaesthetic technique. The total cost of anaesthesia was calculated for each patient, as well as the costs of the drugs and disposables alone. Results are summarised as medians and interquartile ranges.

A two-tailed Mann–Whitney *U*-test for nonparametric, ranked data was used to test the hypotheses that there were no differences in the anaesthetic times, recovery times or costs between patients receiving general anaesthesia and central nerve block. Statistical significance was assumed if $p < 0.05$.

Results

Within the sample periods, there were 1144 elective procedures for inguinal hernia and 484 elective procedures for varicose veins. However, errors or gaps in the anaesthetic data were found in 164 (14.3%) inguinal hernia cases and 59 (12.1%) varicose vein cases. Thus data from 980 inguinal hernia operations and 425 varicose vein operations were analysed. All recorded times were rounded to the nearest minute.

In the inguinal hernia group 581 (59.3%) patients received a general anaesthetic and 346 (35.3%) received a central nerve block. Smaller numbers of patients received a combination of general anaesthesia and central nerve block (24) or an inguinal field block with intravenous sedation (29). In the varicose vein group, half the patients received general anaesthesia (212) and half received a central nerve block (213) (Table 1).

There was considerable variation in the times spent by each subgroup within each location (Table 2). However, the median anaesthetic time for central nerve block

Table 2 Duration (min) of anaesthesia, surgery and recovery times. Results are given as median (interquartile range)

Technique	Anaesthesia	Surgery	Recovery
Inguinal hernia			
General anaesthesia (with or without local block)	10 (5–12)*	60 (45–80)	55 (25–80)
Central nerve block (with or without sedation)	15 (10–16)*	60 (50–64)	55 (30–53)
Combined GA and central nerve block	23 (12–30)	73 (59–114)	55 (45–89)
Intravenous sedation and local block	10 (5–15)	50 (45–65)	20 (10–45)
Varicose veins			
General anaesthesia (with or without local block)	10 (5–10)*	63 (50–85)	60 (40–75)**
Central nerve block (with or without sedation)	15 (10–20)*	60 (50–80)	50 (35–65)**

*$p = 0.0001$, **$p = 0.0002$.

Table 3 Costs (£). Data are given as median (interquartile range)

Technique	Total	Drugs and disposables
Inguinal hernia		
General anaesthesia (with or without local block)	102 (82–127)*	23 (19–26)
Central nerve block (with or without sedation)	109 (94–125)*	22 (22–22)
Combined GA and central nerve block	127 (106–199)	29 (22–39)
Intravenous sedation and local block	67 (59–101)	3 (3–4)
Varicose veins		
General anaesthesia (with or without local block)	106 (86–133)	24 (20–27)**
Central nerve block (with or without sedation)	111 (95–135)	22 (22–22)**

*p = 0.0005, **p = 0.0001.

(15 min) was 5 min longer than for general anaesthesia (10 min) in both surgical groups ($p < 0.001$). The median duration of surgery was, at ≈1 h, much the same irrespective of type of surgery or anaesthetic. The median time in recovery was 10 min shorter after central nerve block than general anaesthesia in the varicose vein patients ($p = 0.002$). However, no difference was found in recovery times in the inguinal hernia patients.

Materials costs were ≈20–25% of the total, and the differences between general anaesthesia and central nerve block were small (Table 3). However, the higher cost of materials used for general anaesthesia in the varicose vein group was statistically significant. Differences in the overall costs of anaesthesia were also small, although central nerve block was significantly more expensive than general anaesthesia for inguinal hernia repair.

The median cost in the 29 patients (3% of total) who received a field block and intravenous sedation for hernia repair was much lower (£67) than the cost of either general anaesthesia (£102) or central nerve block (£109). The cost was greatest in patients who received both general anaesthesia and central nerve block (£127).

Discussion

Identifying the true cost of an anaesthetic is difficult. In an absolute analysis virtually every aspect of hospital expenditure would have to be considered, but when comparing the costs of two anaesthetic techniques it is probably reasonable to ignore many of the overhead costs, as they apply equally to both. This study concentrated on three main aspects of anaesthetic expenditure: staff time, consumables and capital costs. However, a number of other assumptions had to be made and it is important that these are recognised and justified.

The data relating to the times that each patient spent in the anaesthetic room, operating theatre and recovery room are of central importance to this study, because staff costs were based on the time each staff member spent with the patient. However, this may be an over-simplification. From the perspective of the institution, the salaries of anaesthetists and their assistants are fixed rather than time-dependent. These costs are only truly time dependent if a reduction in anaesthetic time allows additional patients to be added to an operating list. It has been shown that anaesthetic time would have to be reduced by more than half to allow one extra 30-min operation to be added to an 8-h operating theatre session [3].

Recovery costs are semifixed [4]. It was assumed that one nurse was responsible for one patient. However, recovery nurses are often responsible for more than one patient at a time and some patients may require more than one nurse for part of their recovery stay. Staff also have to spend time on essential duties not involving direct patient contact. Thus staffing levels are determined by the average workload and a reduction in recovery times would only produce economies if it resulted in fewer staff being employed. The shorter recovery stay noted here for varicose vein patients who received central nerve block is unlikely to result in any significant cost savings, even if it were generally applicable. However, in North America, it has been suggested that the use of short-acting general anaesthetic agents, or regional techniques, for more minor surgery might allow some patients to bypass the recovery unit altogether and be cared for in an area that is less labour-intensive and costly [4, 5].

Estimating the costs of drugs and disposables is even more complex. Precise cumulative costs, particularly for general anaesthesia, require the collection of detailed information about fresh gas flow rates, vaporiser settings and type of breathing circuit. However, the number of incomplete records (13.6%) found in the database emphasise how difficult such data collection is in the routine clinical setting. Requests for more detail might increase the quantity, but not the quality of the data collected. Therefore, a standard flow-rate and drug concentration were assumed, and volatile anaesthetic agent costs were calculated from these. For reasons outlined previously, no charge was made for gas flow. This underestimates the cost of general anaesthesia, but because it is routine practice to administer oxygen to patients who receive central nerve block, the comparison may be balanced to some degree.

The costs of drugs and disposables were higher for general anaesthesia than central nerve block, especially in

the varicose vein group. The greater variation in charges for general anaesthesia in both surgical groups is more striking. This may reflect the range of drugs available for general anaesthesia, and that consumption of general anaesthetics is time dependent. For regional anaesthesia, in which initial costs (sterile pack, special needle, drugs, etc.) are greater, subsequent drug and consumable requirements are small. Thus the economic argument in favour of one anaesthetic method or the other will depend on the duration of surgery.

This study did not identify all expenditure on drugs and disposables, for example the use of sympathomimetic agents to support blood pressure during central nerve block. Of greater relevance to comparative costing is the lack of information about the use of anti-emetics and analgesics in recovery. The requirement for these is less after regional than general anaesthesia, at least in the early postoperative phase, and the reduced recovery time after central nerve block in varicose vein patients might reflect this. The duration of the recovery period is an important determinant of overall costs, especially in day-surgery units where postoperative complications may result in expensive, unplanned admissions.

The final assumption was that expenditure on capital equipment could be estimated as 30% of the drugs and consumables subtotal; this figure was based on a historical review of overall departmental spending. It could be argued that there was no need to include capital charges in a comparison of two methods within the same department because they would apply equally. However, it was important to identify differences between regional and general anaesthesia and the higher costs incurred for general anaesthesia reflect the increased use of anaesthetic equipment. Comparison of the estimated costs for drugs and disposables showed that there is little difference between general anaesthesia and central nerve blockade. The costs of drugs and disposables accounted for only 20–25% of the total for each anaesthetic method, which is supported by the observation that consumables currently comprise 23.6% of overall departmental expenditure. This illustrates the relative importance of staff time in determining the costs of anaesthesia. Attention to the detail of consumable use would achieve significant savings over time, but greater savings might be made with a small reduction in staff costs. Differences in recovery times between the two anaesthetic techniques may be important in this context.

Although the numbers reviewed were small, it is interesting to note that consumable costs and recovery times were much lower when field block and sedation were used for hernia repair. Had an anaesthetist not been in attendance because of inclusion of these patients on a standard operating list, the 'anaesthetic' cost would have been even lower.

Analysis of anaesthetic costs is complex and no model can be perfect. It has been suggested that the best evaluations of costs are those that measure and compare actual costs in large populations of patients [6]. Computerised operating theatre management systems are used widely and are a valuable source of information about the use of operating theatre time and personnel. Modification of the software allowed additional information to be recorded about the anaesthetic drugs and equipment used for each case. Sufficient data for detailed consideration of the costs of anaesthesia in large numbers of patients can be accumulated. Such databases may provide the most effective means of evaluating the costs of anaesthetic practice.

Acknowledgment

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Appendix 1

PATIENT LABEL

CHI ☐☐☐☐☐☐☐☐☐☐

SURNAME .....

FORENAME .....

SEX : MALE ☐ FEMALE ☐

WARD .....

CONSULTANT .....

OPERATION DATE ...../...../..... **ACTUAL THEATRE** .....

ICU / HDU BED REQUIRED POST-OP? **ICU** ☐ **HDU** ☐

RECEPTION

TIME PATIENT SENT FOR .....:.....

TIME PATIENT ARRIVED .....:.....

TIME INTO ANAES. RM .....:.....

REASON FOR PATIENT DELAY

No Porter Available ☐
No Nurse Available ☐
Patient Not Ready ☐
Delay With Lift ☐

OPERATION TYPE

Elective (Routine) ☐
Urgent ☐
Emergency ☐
Immediate ☐

SURGERY

TIME SURGERY STARTED .....:.....

TOURNIQUET YES ☐ NO ☐

TIME TOURNIQUET ON .....:.....

TIME TOURNIQUET OFF .....:.....

TIME SURGERY FINISHED .....:.....

TIME INTO EXIT ROOM .....:.....

SURGICAL STAFF

MAIN SURGEON .....
2ND SURGEON .....
3RD SURGEON .....
4TH SURGEON .....

NURSING STAFF

SCRUB NURSE 1 .....
SCRUB NURSE 2 .....
FIRST CHECK .....
FINAL CHECK BY: .....

MAIN OPERATION (PLEASE PRINT) .....

.....

OTHER OPERATION(S) .....

.....

.....

OPERATION CODES

THEATRE : VISIT COMMENTS **CODE 1** **CODE 2** **CODE 3** **CODE 4**

IMPLANTS / CONSUMABLES				CSSD TRAYS		DRAINS		SPECIMENS	
CODE	QTY	LOT NO.	SIZE	CODE	QTY	CODE	QTY	CODE	QTY

RECOVERY

TIME INTO RECOVERY .....:.....

TIME OUT OF RECOVERY .....:.....

OUTCOME OF OPERATION

OPERATION CARRIED OUT ☐
OPERATION CANCELLED ☐ *If Yes,* REASON CODE ☐
OPERATION ABANDONED ☐ *If Yes,* REASON CODE ☐
PATIENT DIED ☐

DESTINATION

STANDARD WARD ☐
ICU ☐
HDU ☐
TRANSFER OUT OF HOSPITAL ☐
MORTUARY ☐
HOME ☐

ANAESTHETIC

OPERATION CARRIED OUT IN ANAESTHETIC ROOM? YES ☐ NO ☐

TIME ANAESTHETIC STARTED .....:.....

TIME INTO THEATRE .....:.....

ANAESTHETIC ADMINISTRATION COMMENCED AFTER INTO THEATRE ☐

ANAESTHETIC STAFF

MAIN ANAESTHETIST .....

2ND ANAESTHETIST .....

3RD ANAESTHETIST .....

4TH ANAESTHETIST .....

ANAESTHETIST ASSISTANT .....

ASA GRADE

Normally healthy individual ☐
Mild systemic disease ☐
Severe systemic disease not incapacitating ☐
Incapacitating systemic disease/threat to life ☐
Moribund patient ☐

ASA Emergency ☐

ANAESTHETIC DRUG INFORMATION

AIRWAY ADJUNCT

Nasal cannula ☐
Nasal prongs ☐
Endotracheal catheter ☐

Mask - Hudson ☐
Mask - Ventimask ☐
Mask - Face mask ☐
Mask - Nasal mask ☐

LMA - standard ☐
LMA - reinforced ☐

ETT - disposable ☐
ETT - silicone armoured ☐
ETT - metal laser ☐
ETT - double Lumen ☐
ETT - tracheostomy tube ☐
ETT - laryngectomy tube ☐

Other .....

O_2 / CARRIER GAS (AT CGO)

oxygen-nitrous oxide ☐
oxygen-air ☐
air ☐
100% oxygen ☐

VENTILATION

spontaneous ☐
IPPV ☐
IPPV + PEEP ☐
jet ventilation ☐
high frequency ventilation ☐
Hayek ☐

Other .....

LINES

peripheral IV ☐
central venous ☐
intra-arterial ☐
pulmonary artery ☐

SEDATION / GA TECHNIQUE

SEDATION ☐ **GA** ☐

SEDATION / GA	**I**	**M**
propofol	☐	☐
propofol target-controlled infusion	☐	☐
propofol patient-controlled infusion	☐	☐
etomidate	☐	■
thiopentone	☐	■
fentanyl	☐	■
midazolam	☐	☐
halothane	☐	☐
enflurane	■	☐
isoflurane	■	☐
desflurane	■	☐
sevoflurane	☐	☐

Other .....

ANALGESIA	**I**	**M**
alfentanil	☐	☐
fentanyl	☐	☐
remifentanil	☐	☐
morphine	☐	☐
diamorphine	☐	☐
pethidine	☐	☐
tramadol	☐	☐
ketorolac	☐	☐
diclofenac	☐	☐

Other .....

RELAXANT	**I**	**M**
suxamethonium	☐	☐
rocuronium	☐	☐
vecuronium	☐	☐
atracurium	☐	☐
cis-atracurium	☐	☐
mivacurium	☐	☐
pancuronium	☐	☐

Other .....

Note: I = Induction M = Maintenance

SITE

NEURAL AXIS	**1**	**2**	**3**
saddle block	☐	☐	☐
spinal	☐	☐	☐
lumbar epidural	☐	☐	☐
thoracic epidural	☐	☐	☐
combined spinal-epidural	☐	☐	☐
caudal	☐	☐	☐
PLEXUS			
axillary brachial	☐	☐	☐
supraclavicular brachial	☐	☐	☐
interscalene brachial	☐	☐	☐
lumbar	☐	☐	☐
cervical	☐	☐	☐
PERIPHERAL NERVE			
retro/peri bulbar	☐	☐	☐
trigeminal branch(es)	☐	☐	☐
paravertebral	☐	☐	☐
intercostal	☐	☐	☐
median	☐	☐	☐
radial	☐	☐	☐
ulnar	☐	☐	☐
Bier's	☐	☐	☐
sciatic	☐	☐	☐
femoral	☐	☐	☐
ankle/distal foot	☐	☐	☐
ilioinguinal	☐	☐	☐
penile	☐	☐	☐
digital	☐	☐	☐
INFILTRATION / TOPICAL/OTHER TECHNIQUE			
infiltration	☐	☐	☐
topical	☐	☐	☐
intra urethral	☐	☐	☐

Other .....

AGENT

LA			
bupivacaine	☐	☐	☐
lignocaine	☐	☐	☐
prilocaine	☐	☐	☐
ropivacaine	☐	☐	☐
EMLA	☐	☐	☐
Ametop	☐	☐	☐

Other .....

OPIOID			
fentanyl	☐	☐	☐
morphine	☐	☐	☐
diamorphine	☐	☐	☐

Other .....

VASOPRESSOR			
adrenaline	☐	☐	☐
felypressin	☐	☐	☐

ANAESTHETIC COMPLICATIONS

	EVENT 1	**EVENT 2**	**EVENT 3**	**EVENT 4**
COMPLICATION CODE (10-99)				
SEVERITY (1-5)				
LARYNGOSCOPY GRADE (1-4)				

Enter numerical codes from the "Anaesthetic Complications" reference sheet.
(Laryngoscopy Grade required only for Difficult / Failed Intubation)

Appendix 2

Anaesthetic costs

Intravenous agents
Thiopental £1. 54
Propofol £4. 50
Propofol infusion £12. 00 h^{-1}
Etomidate £1. 70
Midazolam £1. 00
Ketamine £3. 52

Inhalational agents
Halothane £0.75 h^{-1}
Isoflurane £5.00 h^{-1}
Enflurane £2.00 h^{-1}
Desflurane £8.00 h^{-1}
Sevoflurane £15.00 h^{-1}

Opioids
Morphine £0.60
Diamorphine £0.50
Omnopon £0.10
Fentanyl £0.15
Alfentanil £0.75

Muscle relaxants
Suxamethonium £0.70
Atracurium £3.30
Vecuronium £4 60
Rocuronium £3.30

Local anaesthetics
Lidocaine £1.50
Bupivacaine £1.50
Heavy bupivacaine £1.50
Prilocaine £1.50
Ropivacaine £1.50

Airway maintenance
Laryngeal mask airway £8.50
Endotracheal tube £1.25

Local and regional anaesthesia
Local infiltration £1.50
Field block £1.50
Intravenous block £1.50
Nerve block £8.50
Plexus block £8.50
Caudal £8.50
Epidural £10.00
Spinal £18.50

Intravascular access and fluid therapy
Cannula £0.60
Infusion £2.50
Infusion & CVP line £15.50
Infusion & CVP & arterial line £28.50
Infusion & arterial line £13.50
Infusion & CVP & arterial line & PA catheter £90.00

FORUM
Epidural catheter fixation: subcutaneous tunnelling with a loop to prevent displacement

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Summary
A method of fixing the epidural catheter by subcutaneous tunnelling and looping was devised. A prospective, randomised, double-blind, clinical trial was conducted in 68 adult patients, where postoperative pain relief was planned by thoracic epidural analgesia. In the tunnelled group ($n = 34$), the epidural catheter was fixed with a subcutaneous tunnel and loop, whereas in controls ($n = 34$), a simple loop of epidural catheter was left over the skin without tunnelling. An adhesive dressing was used to secure the epidural catheter. We observed that catheter dislodgement occurred in only one patient in the tunnelled group compared to seven control patients (21%). Despite local inflammation of

the skin around the tunnel in nine patients (27%), no catheter infection (positive culture tip) was found in patients with subcutaneous tunnelling for the extended period of 4–5 days. The method described allows the catheter to lie flat on the skin and outward traction of the catheter during movement of patients is dampened by the interposed loop which protects it against dislodgement. At the time of removal, both ends of the catheter can be removed under direct vision. In conclusion, we recommend this fixation method in cases where epidural analgesia is to be used for postoperative pain relief.

Keywords *Epidural catheter*: fixation; subcutaneous tunnelling.

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Displacement of long-term epidural catheters is a significant cause for concern in patients in whom catheters are frequently used and left in place long-term. Frequent changes of posture for physiotherapy, diagnostic scanning and early mobility increase the chances of epidural catheter dislodgement in the immediate postoperative period. Epidural catheter dislodgement not only leads to embarrassment, but also jeopardises the very purpose of the technique, i.e. good postoperative pain relief. Subcutaneous tunnelling of the epidural catheter [1] has been reported to reduce the incidence of inward but not outward migration of epidural catheters [2]. We wish to share the experience of our epidural catheter fixation technique to overcome this problem.

Methods

Catheter fixation technique

The Tuohy needle is placed with full aseptic precautions into the epidural space at the appropriate level. After placing the epidural catheter, the Tuohy needle is removed and is then passed subcutaneous 3–5 cm back along the paraspinous groove to exit from the skin 1.5 cm away from the catheter puncture site. The distal end of the catheter is fed into the bevel of the Tuohy needle and pulled through the subcutaneous tunnel; the needle is then removed. A small loop of catheter is left between the catheter puncture site and the tunnel. A sterile piece of paper or small piece of sterile gauze sponge is fed through the loop to maintain it (Fig. 1). A sterile adhesive transparent dressing is directly applied to cover up the loop and the epidural catheter. The rest of the catheter is taped to the back of the patient and the port with filter is secured to the shoulder.

In a double-blind, prospective study, we compared this fixation technique with the control group technique in which an epidural catheter was fixed with a simple loop on the skin. Approval was obtained from the Institute's Ethics Committee and written informed consent was obtained from all patients after explaining about the nature of the study. Sixty-eight adult patients of both sexes, scheduled to have postoperative pain relief by continuous thoracic epidural analgesia, were randomly allocated to one of two groups. In the tunnelled group ($n = 34$), epidural catheter fixation was achieved by the method of subcutaneous tunnelling as described above. In the control group ($n = 34$), a simple loop of epidural catheter was left over the skin and secured by the adhesive dressing. All catheters were placed at a mid to low thoracic intervertebral level (T_{7-8} to T_{10-11}). The management team in the postoperative ward remained unaware of the fixation method. In order to judge catheter migration, we fixed the 15-cm mark of the catheter at the insertion site and the 20 cm mark at the proximal end of the subcutaneous tunnel. The epidural catheter was maintained from 4 to 5 postoperative days in the Intensive Care Unit or on the ward. Bupivacaine 0.1% with fentanyl 10 $\mu g.ml^{-1}$ was infused at 4–6 $ml.h^{-1}$ according to level of block and pain. Patients were subject to physiotherapy, mobilisation and radiological investigations either at the bedside or in the Radiology Department.

We recorded the duration of successful maintenance of the epidural catheter *in situ* in the postoperative period, incidence of inward migration of the catheter (15-cm mark completely disappearing below the skin), incidence of outward migration (20-cm mark pulled inside the subcutaneous tunnel) and local inflammation. The catheter tip was cultured after removal to check for any infection. Student's *t*-test and Chi-squared test were used as appropriate to assess the statistical analysis of the data. A calculated value of $p < 0.05$ was taken as statistically significant.

Results

The baseline data in both groups were similar. The mean (SD) duration of the epidural catheter remaining *in situ*

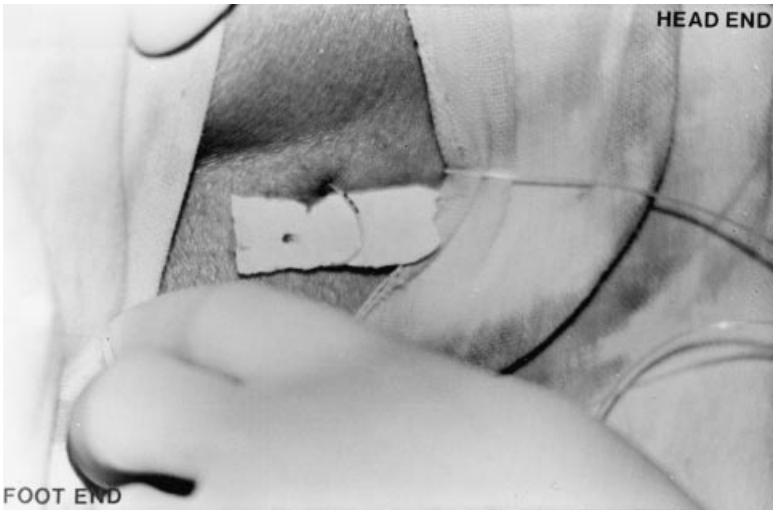

Figure 1 The epidural catheter loop formed in between the epidural end of the catheter and the beginning of the subcutaneous tunnel. The tunnel was formed by passing the Tuohy needle subcutaneously 3–4 cm in a caudad direction, then threading the distal end of the catheter back through the needle from bevel to hub. The piece of sterile paper or gauze is fed through the loop just before placing the sterile dressing.

for postoperative pain relief in patients with subcutaneous tunnelling was significantly longer than in controls (4.6 (2.1) vs. 2.4 (3.0) days; $p < 0.05$). In seven control patients (21%), epidural analgesia was terminated owing to dislodgement due to complete displacement of the catheter compared to one patient in the tunnelled group ($p < 0.05$; Table 1). The incidence of inward migration of the epidural catheter was higher in control patients (27% vs. 12%), but this was not statistically significant. The epidural catheter tip did not grow pathogenic bacteria in any patient. Inflammation of the skin over the subcutaneous tunnel occurred in nine patients (27%), generally after 3 days.

So far, we have used this fixation method in 118 adult patients (age range 21–79 years; male : female ratio = 58 : 49) requiring pain relief during surgery and intensive care. We have been able to effectively maintain the epidural catheter in place for extended periods of time (range 3–9 days). The only problem, namely kinking at the loop site, occurred in three patients (2.8%). This could be easily detected because complete obstruction developed to injection of a repeat dose. In these patients, the catheter was pulled back, thus restoring the loop and reducing the kink, before a fresh dressing was applied.

Discussion

Inward migration of the epidural catheter has been reported with intravascular [3], subdural [4] or subarachnoid injection of repeat doses. Outward migration might lead to loss of analgesia and unsuccessful attempts to re-establish it. Many factors have been correlated with migration [5] but an appropriate fixation technique for the catheter should form the most practical way to prevent it. In our method of epidural catheter fixation, the interposed loop dampens any drag on the catheter, thus protecting the part of the catheter entering the epidural space. Furthermore, being flat on the back of the patient, this fixation method was more acceptable to patients when lying flat. An adhesive dressing over the epidural catheter seals both the catheter entry points and decreased chances of catheter contamination or infection. Local inflammatory reaction of the skin may restrict its prolonged use, e.g. in cancer pain patients.

The incidence of inward migration of the epidural catheter (27%) was marginally higher in our study as compared to an earlier report of 21% [2] for thoracic epidural catheters without tunnelling. We also found a higher incidence of inward migration of epidural catheters in patients with subcutaneous tunnelling (12%) as compared to 2.4% [2]. We left a small loop between the puncture site and tunnel entry of the catheter, and this may have allowed easy inward catheter movement than if a loop had not been used.

Table 1 Baseline and study data. Results are given as mean (SD) or percentage.

	Tunnelled	Control
Total number of patients	34	34
Age; years	34 (16)	36 (18)
Male : female	18 : 16	23 : 11
Duration of intact epidural catheter; days	4.6 (2.1)	2.4 (3.0)*
Incidence of dislodgement; %	1 (3%)	7(21%)*
Incidence of inward migration of epidural end; %	4 (12%)	9 (27%)
Local inflammation of skin	9 (27%)	2 (6%)*

* $p < 0.05$.

In conclusion, we recommend this method of fixation of the epidural catheter for short-term postoperative pain relief. Its long-term feasibility in terms of infection in patients for chronic pain relief still remains to be seen. The technique does not require extra equipment, and there is no risk of shearing the epidural catheter. Access to the loop facilitates removal of the catheter under direct vision.

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FORUM
Intrathecal alfentanil with and without bupivacaine for analgesia in labour

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Summary
Combined spinal–epidural (CSE) for analgesia in labour is widely used as a method of providing pain relief while minimising motor blockade. Aiming to further reduce the associated motor weakness, we investigated the use of alfentanil alone as the initial intrathecal injection in a double-blind study. Thirty women were randomly allocated to receive either alfentanil 0.25 mg with bupivacaine 2.5 mg intrathecally, or alfentanil 0.25 mg in the same volume. Onset of analgesia did not differ significantly between groups but duration was significantly longer in those receiving alfentanil–bupivacaine (mean 55 min vs. 40 min; $p < 0.05$). Quality of analgesia was satisfactory for all women, although the cumulative analgesia scores were significantly lower in the women receiving the alfentanil–bupivacaine mixture ($p = 0.003$). More women in the alfentanil–bupivacaine group developed both a sensory level (15/15 vs. 6/15; $p < 0.01$) and sympathetic block (12/15 vs. 4/15; $p < 0.01$). Sixty per cent of women receiving the alfentanil–bupivacaine mixture demonstrated an impaired ability to straight leg raise compared with none of the women in the alfentanil–saline group ($p < 0.01$). The incidence of adverse effects in mother and fetus was similar in both groups. We conclude that intrathecal alfentanil 0.25 mg alone as part of a CSE technique provides rapid analgesia of satisfactory quality without detectable motor blockade.

Keywords *Analgesia*: obstetric; combined spinal-epidural. *Anaesthetics*, *local*: bupivacaine. *Opioid*: alfentanil.

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Current obstetric epidural analgesic practice can be improved by reducing dense motor blockade which is reported as occurring in up to 84% of cases even when dilute concentrations of bupivacaine are used [1]. Mothers frequently find this paralysis frightening, and dislike feeling helpless and not being in control of themselves. Motor blockade has been shown to reduce maternal satisfaction with epidural analgesia [2].

Efforts to improve epidural analgesia led to Morgan and colleagues from Queen Charlotte's Hospital popularising the combined spinal–epidural technique (CSE) for analgesia in labour. This technique involved an initial intrathecal injection of low-dose opioid and bupivacaine to establish analgesia, and subsequent epidural injections to restore and maintain analgesia [3]. The doses of drugs involved were such that walking in labour was possible.

However, this technique still has disadvantages. Following the initial intrathecal injection, motor blockade is present for up to 20 min. Furthermore, some have questioned the safety of ambulation without intact proprioreception [4].

The aim of this study was to attempt to improve the initial intrathecal component of a CSE technique. A standard intrathecal injection of alfentanil–bupivacaine was compared with an intrathecal injection of alfentanil alone. The sensory effects, motor blockade and fetal effects were evaluated in detail.

Methods

Following Research Ethics Committee permission and written informed consent, 30 women in labour requesting regional analgesia were invited to participate in the study. An intravenous infusion of 1 l of Hartmann's solution was started and, with the women in the sitting position, an 18 G Tuohy needle was inserted at the L_{2-3} or L_{3-4} interspace. The epidural space was identified by loss of resistance to saline. A 119-mm, 27 G Whitacre needle (Becton-Dickinson) was advanced through the Tuohy needle into the subarachnoid space, with its aperture cephalad. When cerebrospinal fluid (CSF) was observed at the hub, the appropriate intrathecal solution was injected over a period of 10 s. The spinal needle was removed and an epidural catheter passed to lie 3 cm inside the epidural space. The position of the catheter was checked by aspiration for blood or CSF.

Using a computer-generated random number table, the 30 women were randomly allocated to receive one of two intrathecal injections. Those in the alfentanil–bupivacaine group received plain bupivacaine 2.5 mg combined with alfentanil 0.25 mg in a total volume of 1.5 ml. Those in the alfentanil–saline group received alfentanil 0.25 mg made up to 1.5 ml with 0.9% saline. Although not currently licensed for use in spinal anaesthesia, intrathecal alfentanil has been a routine component of combined spinal–epidural analgesia in our obstetric unit for some years and no problems with its use have been encountered. In view of this, the need for a Trial Exemption Certificate was waived by our regional Research Ethics Committee.

Observations

The observer (anaesthetist) was present with the mother continuously throughout the study period. All observations were carried out by one of two anaesthetists. Both the patient and the observer were blinded to the content of the intrathecal injection. The study period commenced following the intrathecal injection and finished at request for further analgesia by epidural bolus.

Fetal effects

Monitoring of mother and fetus was started before regional analgesia. The cardiotocogram (CTG) was recorded continuously throughout the study period. Fetal heart rate abnormality was defined by the midwife or obstetrician, who were also unaware of the study treatment. Following subarachnoid block, any episodes of fetal bradycardia of less than 110 beat.min^{-1} were recorded.

Maternal effects

The mother's heart rate and blood pressure were measured noninvasively at 2-min intervals for the first 20 min, and thereafter at intervals of 5 min. Hypotension was defined as a decrease of systolic blood pressure of 20% from baseline, and was treated with boluses of ephedrine 6 mg every 2 min until blood pressure returned to within 10% of the baseline value.

Characteristics of analgesia

The time to the first painless uterine contraction was recorded as the onset of analgesia. The duration of analgesia was defined as the interval between intrathecal injection and request for epidural top-up.

The quality of analgesia was assessed using a four-point verbal rating score:

0 = no pain, pressure or tightening;
1 = aware of tightening or pressure but not painful;
2 = slight pain or pressure but not distressing;
3 = distressing pain or pressure.

These assessments were carried out at 5-min intervals throughout the study period. The number of recordings of each score was summed from all women in each study group to produce a total for each of the four pain scores. This was then expressed as a percentage of the total number of pain assessments for each study group (cumulative analgesia score (%)) [5].

Neurological assessment of subarachnoid block

Sensory testing to cold and pinprick was carried out at

2-min intervals for the first 20 min, and thereafter at intervals of 5 min.

Vibration sense was assessed with a tuning fork tested at both the knee and the ankle. Proprioreception was assessed by testing joint position sense of the metatarsal–phalyngeal joint of both big toes. Both these variables were tested, with the women's eyes closed, at 2-min intervals for the first 20 min, and thereafter at intervals of 5 min.

Motor blockade was detected by weakness of hip flexion. The women were asked to lift each leg in turn, straight off the bed, and hold it against resistance [3]. This was assessed at 5-min intervals.

Foot temperature was measured continuously using adhesive liquid crystal temperature scales. Bilateral sympathetic block was defined as a temperature rise in both feet of more than 0.5 °C.

Adverse effects

The incidences of pruritus, nausea and sedation were assessed by direct questioning at 5-min intervals. Sedation was rated on a three-point scale: 1 = drowsy; 2 = asleep; 3 = unrousable.

Maternal satisfaction

A retrospective measurement of the degree of pain relief was carried out at the end of the study period. This took into account any painful periods occurring at times not assessed by the pain rating scores. Satisfaction was scored by the parturients as: 1 = satisfied; 2 = dissatisfied; 3 = very unhappy.

Statistical analysis

Data analysis was carried out using Graphpad Prism version 3.00 for Windows, GraphPad Software, San Diego, USA. Statistical analysis included Student's *t*-test, Chi-squared test and the Mann–Whitney *U*-test. $p < 0.05$ was regarded as statistically significant. For clarity, a proportion of the results are expressed as percentages, but statistical calculations were performed on numerical data. With 15 women in each group, the study had 80% power to detect a difference in duration of analgesia of 12 min, and had 80% power to detect a difference of analgesia onset time of 2.3 min.

Table 1 Patient characteristics. Results are given as median (range) or mean (SD).

	Alfentanil–bupivacaine (*n* = 15)	Alfentanil–saline (*n* = 15)
Age; years	27 (18–35)	26 (18–33)
Height; m	1.61 (0.07)	1.57 (0.03)
Weight; kg	74.2 (16.2)	67.7 (11.3)
Gestation; weeks	39 (38–40)	39 (38–41)
Dilatation of cervix at request for analgesia; cm	3.0 (2–5)	3.0 (2–5)
Parity	0 (0–4)	0 (0–2)

Table 2 Characteristics of analgesia. Results are given as mean (SD).

	Alfentanil–bupivacaine (*n* = 15)	Alfentanil–saline (*n* = 15)
Time to analgesia; min	3 (1.6)	4.5 (2.6)
Duration of analgesia; min	55.8 (9.0)**	40.5 (16.2)

** $p < 0.01$.

Results

Patient baseline and obstetric characteristics are shown in Table 1. There were no significant differences between the two groups.

Onset and duration of analgesia

Following the intrathecal injection, the onset of analgesia was similar in both groups. Satisfactory analgesia was achieved after a mean time of 3 min in the alfentanil–bupivacaine group and 4.5 min in the alfentanil–saline group. The mean duration of analgesia was significantly longer in the alfentanil–bupivacaine group compared with the alfentanil–saline group (55 min vs. 40 min; Table 2).

Quality of analgesia

The cumulative analgesia scores for both groups of women are shown in Table 3. Chi-squared analysis applied to these data revealed a significantly lower cumulative analgesia score in the alfentanil–bupivacaine

Table 3 Quality of analgesia, expressed as a percentage of all pain assessments for each score in each group. 0 = no pain or awareness of contractions; 1 = awareness of pressure or tightening; 2 = slight pain or pressure; 3 = distressing pain or pressure.

	Alfentanil–bupivacaine (*n* = 15)*	Alfentanil–saline (*n* = 15)
Cumulative analgesia score (%)		
0	85	67
1	11	21
2	3	10
3	0.6	1.6

* $p < 0.05$ between groups.

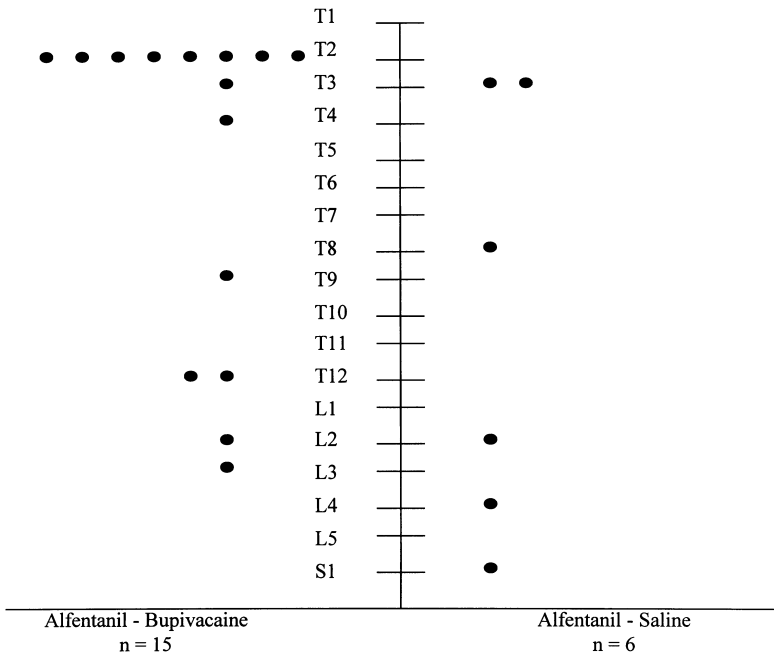

Figure 1 Distribution of maximum sensory levels (loss of sensation to pin-prick).

treatment group ($p = 0.003$). Overall analgesic efficacy was good, with only three women reporting distressing pain during the study period, two in the alfentanil–saline group and one in the alfentanil–bupivacaine group.

Maternal satisfaction

All 30 women reported their analgesia as satisfactory. Those in the alfentanil–saline group commented on how they appreciated the ability to feel their contractions yet without undue pain.

Neurological assessment

All women in the alfentanil–bupivacaine group, and six in the alfentanil–saline group, developed loss of sensation to cold and pinprick (Fig. 1). This difference was statistically significant. The duration of sensory block (tested by pin-prick) at T_{10} or above was significantly longer in the alfentanil–bupivacaine group (Table 4).

Table 4 Neurological assessment following analgesia. Results are given as number of patients or mean (SD).

	Alfentanil–bupivacaine (*n* = 15)	Alfentanil–saline (*n* = 15)
Sensory level to pin-prick	15**	6
Duration of block $>T_{10}$; min	50.2 (13.9)**	28.6 (14.8)
Bilateral sympathetic block	12**	4
Loss of proprioreception	0	0
Loss of vibration sense	0	0
Impaired Straight Leg Raising	9**	0

** $p < 0.01$.

Bilateral sympathetic block was observed in four women in the alfentanil–saline group and in 12 women in the alfentanil–bupivacaine group. This difference was significant ($p < 0.01$). Proprioreception and vibration sense were preserved in all women in both groups during the study period (Table 4).

Motor block, as assessed by straight leg raising against resistance, was impaired in nine women in the alfentanil–bupivacaine group, whereas all women in the alfentanil–saline group retained normal motor power ($p < 0.01$; Table 4). The mean duration of motor block when it occurred was 28 min.

Maternal and fetal effects

Maternal mean blood pressure recordings and heart rates did not differ significantly between or within the two groups (Table 5). Although two women in the alfentanil–bupivacaine group experienced a drop in mean blood pressure of greater than 20%, each was corrected with a single bolus of ephedrine 6 mg.

Analysis of continuous fetal heart rate monitoring revealed no significant difference between the groups (Table 6), with one case of bradycardia below 110 beat.-min^{-1} in each group. Both fetal heart rates recovered spontaneously within several minutes.

Adverse effects

Although nausea, pruritus and sedation occurred more

Table 5 Maternal effects. Maternal mean blood pressure (BP) and heart rate (mean (SD)). No significant difference between or within groups.

	Alfentanil–bupivacaine Mean BP (mmHg)	Heart rate (beat.min^{-1})	Alfentanil–saline Mean BP (mmHg)	Heart rate (beat.min^{-1})
Prior to spinal injection	97 (12.9)	91 (10.7)	90 (10.6)	81 (13.0)
After spinal injection; min				
2	90 (13.3)	89 (11.6)	85 (11.1)	77 (13.2)
4	86 (14.3)	92 (14.6)	82 (11.5)	72 (8.1)
6	86 (16.9)	86 (14.9)	82 (9.4)	73 (8.7)
8	87 (13.4)	87 (14.2)	82 (12.6)	74 (10.1)
10	90 (13.6)	88 (11.8)	83 (12.0)	73 (9.9)
12	83 (16.1)	87 (9.2)	86 (10.6)	74 (9.7)
14	85 (15.3)	84 (8.3)	84 (10.1)	76 (8.4)
16	88 (15.1)	83 (8.6)	84 (11.3)	73 (9.0)
18	89 (16.6)	84 (8.6)	86 (12.7)	77 (9.6)
20	88 (16.9)	84 (10.6)	86 (9.7)	74 (9.5)
25	90 (14.7)	83 (11.1)	86 (9.0)	73 (10.0)
30	91 (13.3)	84 (10.6)	86 (9.5)	71 (8.2)
35	92 (15)	83 (11.6)	85 (7.7)	73 (10.7)
40	91 (15.6)	83 (10.1)	83 (6.8)	68 (9.1)
45	93 (12.9)	83 (9.7)	85 (9.5)	73 (7.1)
50	90 (14.7)	83 (11.2)	85 (8.8)	72 (8.6)
55	91 (12.1)	84 (11.1)	85 (8.5)	73 (9.4)
60	87 (13.7)	88 (9.6)	87 (12.5)	76 (11.1)
65	91 (16.2)	88 (2.8)	81 (11.3)	70 (12.0)

frequently in the alfentanil–bupivacaine group, the differences did not reach statistical significance (Table 6).

Restoration of analgesia at end of study period

Once additional analgesia was requested, it was restored with an epidural bolus of 0.1% bupivacaine 10–12 ml and alfentanil 0.04 mg.ml^{-1}. Analgesia was then maintained with an infusion of the same solution. In all women the epidural phase of analgesia was introduced successfully.

Discussion

The two main aims of regional analgesia in labour are rapid onset of pain relief and absence of motor block [3].

Table 6 Fetal and maternal adverse effects. Number of patients.

	Alfentanil–bupivacaine (n = 15)	Alfentanil–saline (n = 15)
Fetal heart rate < 110 beat.min^{-1}	1	1
Abnormal CTG pattern	0	0
Pruritus	12	10
Nausea	1	0
Sedation:		
1 = Drowsy	3	0
2 = Asleep	0	0
3 = Unrousable	0	0

Both intrathecal techniques achieved rapid onset of analgesia but 60% of women who received alfentanil–bupivacaine developed motor block, which lasted up to 45 min in some cases. For a technique that is popularly known as an 'ambulatory epidural', the incidence of leg weakness is substantial. Intrathecal alfentanil alone caused no motor block and ambulation would have been possible for all women in that group.

Although the alfentanil–bupivacaine group had significantly lower cumulative pain scores, reflecting more profound analgesia, quality of pain relief was satisfactory in both groups. The women in the alfentanil–saline group rated their pain for the majority of assessments as either grade 0 'unaware of contractions' or 1, defined as 'awareness of tightening or pressure but no pain'. Many of these women commented how they appreciated being aware of their contractions. Despite more pain assessments in the alfentanil–saline group being recorded as 2 or 3, maternal satisfaction with analgesia remained high. Only three women experienced distressing pain during the study period, two in the alfentanil–saline group and one in the alfentanil–bupivacaine group.

There has been controversy in the literature regarding a postulated loss of proprioreception with techniques that allow ambulation in labour [4–7]. They argue that loss of posterior column sensation occurs readily even with low dose local anaesthetic solutions. This study did not support this contention. No women in either group lost proprioreception, even those who developed substantial motor block. It

would have been interesting to continue monitoring proprioreception into the epidural phase of the technique to establish if it was ever abolished.

The most interesting finding was the development of a sensory level in six women in the alfentanil–saline group. The loss of sensation was to both cold and pinprick and in two women extended to the third thoracic dermatome. Although it has been shown clinically that pethidine, fentanyl and sufentanil have weak local anaesthetic action [8], no previous studies have investigated this phenomenon with alfentanil. This study demonstrates that intrathecal alfentanil has some degree of local anaesthetic action, an additional reason for its potent analgesic effect following intrathecal injection.

The concept of selective spinal analgesia in labour has been investigated before [9] when the use of epidural alfentanil boluses followed by infusions of alfentanil alone provided excellent pain relief for early labour but was inadequate for pain relief in later labour in a significant number of women. There was also an unacceptable level of sedation, and epidural alfentanil was deemed unsatisfactory for labour analgesia. In contrast, we found intrathecal alfentanil to provide satisfactory pain relief in all women studied and sedation was not a problem. This may be explained by the different route of administration and the much lower dose of drug used. However, all the women in this study were in relatively early labour when the alfentanil was given, and all had epidural analgesia established by the start of the second stage of labour.

The fetal effects in both groups were minimal. Previous work with intrathecal alfentanil–bupivacaine has shown a 20% incidence of transient fetal bradycardia [10]. Therefore, we would not have expected more than three abnormal fetal heart rates in each group. Fetal bradycardia has been reported following intrathecal sufentanil, pethidine, fentanyl [8] and epidural sufentanil [11]. The exact mechanism remains unknown. However, Alahuhta and colleagues, using Doppler ultrasound, demonstrated normal umbilical blood flow despite fetal bradycardia [11]. Some have hypothesised a disturbance in sympathetic tone causing abnormal uterine blood flow [12]. In this study, sympathetic block occurred in 80% of those women in the alfentanil–bupivacaine group, but was not associated with fetal heart rate changes.

In conclusion, this study demonstrates that alfentanil alone provides an effective alternative to the combination of bupivacaine with alfentanil for the initial intrathecal injection in a combined spinal–epidural technique for pain relief in labour. Intrathecal alfentanil alone achieves rapid analgesia of satisfactory quality with no detectable motor blockade. Although the duration of intrathecal analgesia is on average 15 min shorter than in combination with bupivacaine, there is no clinical disadvantage since analgesia is easily restored and maintained using the epidural catheter. Furthermore, the evidence of a local anaesthetic action of alfentanil remains, until now, unreported.

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FORUM

Ability of anaesthetists to identify a marked lumbar interspace

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Summary

Anaesthetists' ability to identify correctly a marked lumbar interspace was assessed in 100 patients undergoing spinal magnetic resonance imaging scans. Using ink, one anaesthetist marked an interspace on the lower spine and attempted to identify its level with the patient in the sitting position. A second anaesthetist attempted to identify the level with the patient in the flexed lateral position. A marker capsule was taped over the ink mark and a routine scan performed. The actual level of markers ranged from one space below to four spaces above the level at which the anaesthetist believed it to be. The marker was one space higher than assumed in 51% of cases and was identified correctly in only 29%. Accuracy was unaffected by patient position (sitting or lateral), although it was impaired by obesity ($p = 0.001$) and positioning of the markers high on the lower back ($p < 0.001$). The spinal cord terminated below L_1 in 19% of patients. This, together with the risk of accidentally selecting a higher interspace than intended for intrathecal injection, implies that spinal cord trauma is more likely when higher interspaces are selected.

Keywords *Anatomy*: vertebral column. *Anaesthetic techniques*, *regional*: spinal; subarachnoid; epidural. *Measurement techniques*: magnetic resonance imaging.

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Palpation is used by anaesthetists to identify a suitable vertebral level for epidural and spinal anaesthesia. A site below the level of the conus medullaris is necessary for spinal anaesthesia, to minimise the risk of spinal cord trauma. There is no element of self-correction in this process, as the selected site is not usually confirmed radiographically. Therefore, an experienced doctor may not be able to identify a particular vertebral interspace any more accurately than a beginner. Previous studies have demonstrated inaccuracies in 40–59% of subjects when attempting to identify lumbar interspaces [1–3]; on one occasion this led to neurological damage [4].

This study was conducted to determine whether anaesthetists are able to identify correctly a marked lumbar interspace (space between two spinous processes). The effects of obesity, the marker's position and the subjects' position on accuracy were also assessed.

Methods

This study was approved prospectively by the hospital research ethics committee. Patients undergoing diagnostic magnetic resonance imaging (MRI) scans of the lumbar spine were recruited. Subjects who thought they would be unable to adopt the required position or to tolerate palpation owing to bony tenderness, and those with

obvious spinal deformity, were not studied, neither were subjects under the age of 16 years. Voluntary, written consent was obtained. Height, weight and age were recorded. The subject sat on the edge of a trolley with the spine flexed. The first anaesthetist was instructed to mark in washable ink the skin overlying any interspace on the lower spine. The same anaesthetist then attempted to identify the marked interspace by palpation of the spinous processes and iliac crests. The subject moved to the left lateral position with the hips, knees and lumbar spine flexed as much as possible. A second anaesthetist then attempted to identify the marked interspace. The subject then assumed the straight, standing position. The anaesthetist's finger was kept on the interspace under study while the patient moved, to reduce the risk of error caused by movement of the skin. A fish oil marker capsule was attached with adhesive tape to the subject's back, overlying the studied interspace. The marker was attached with the patient standing (rather than flexed) because scans are performed with the patient in the supine, unflexed position. Anaesthetists examined patients in the sitting and lateral positions alternately. During the scan, the marker was visualised. If not directly over an interspace its position was checked afterwards. Following the scan, a radiologist identified the marked lumbar interspace and the level of the conus medullaris. Each anaesthetist reached a decision independently, with the radiologist unaware of the opinions of the anaesthetists. Anaesthetists were not informed of the results until the end of the study, to minimise the chances of improvement. One anaesthetist (C.R.B.) assessed all subjects, working in pairs with one of the other three.

Data were analysed using the chi-squared test for linear trend, and the Wilcoxon signed rank sum test. The strength of the agreement between pairs of anaesthetists was assessed by the weighted kappa statistic [5]. The statistics program SPSS® was used. Values of $p < 0.05$ were considered statistically significant.

Results

One hundred and four patients were recruited to the study. One subject was withdrawn because of lack of time in the MRI scanning schedule. Three were withdrawn following palpation and marking of the back, two because claustrophobia prevented MRI scanning and one because of extreme obesity. In this patient (body mass index [BMI] 44 $kg.m^{-2}$), the skin and marker were at such a distance from the lumbar spine that they were not visible on the scan, and the protocol stated that no extra scans would be taken during the study. This left 100 subjects, and therefore 200 observations, available for analysis.

Patients' median (interquartile range [range]) age was 52 (36–61 [18–87]) years; height was 167 (162–175 [137–190]) cm; weight was 73 (65–83 [48–112]) kg; and BMI was 26 (23–29 [19–40]) $kg.m^{-2}$.

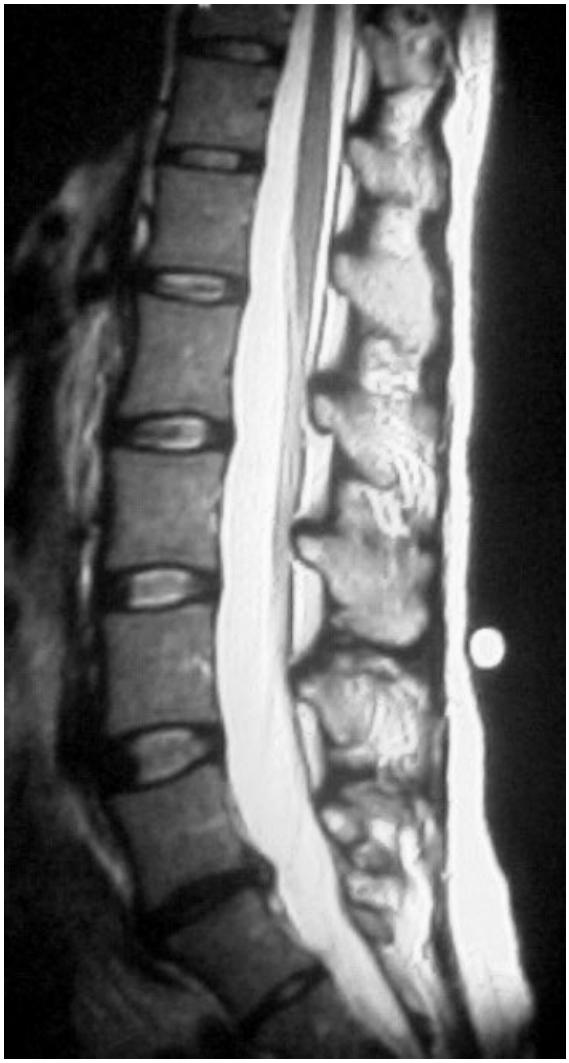

Figure 1 Typical magnetic resonance imaging scan obtained during the study. The marker can be seen overlying the L_{3-4} interspace.

A typical MRI scan obtained is shown in Fig. 1. All anaesthetists placed markers at four or more different interspaces. Median level of marker placement varied between anaesthetists by only one interspace. The results for each anaesthetist were similar in terms of proportion of correctly identified spaces and distribution of errors. The marked space was correctly identified in only 58 cases (29%; Table 1). Only six markers (3%) were at a lower space than that estimated by the anaesthetist. Markers were one space higher than thought by the anaesthetist on 102 occasions (51%). However, on 31 occasions (15.5%) markers were two spaces higher; twice (1%) markers were

Table 1 Anaesthetists' opinions of vertebral level compared with actual marker levels (determined by radiologists) in 100 patients undergoing magnetic resonance imaging scans. Correct identification of the vertebral level is indicated by underlined type.

Actual level	Anaesthetists' opinions						
	T_{12}-L_1	L_{1-2}	L_{2-3}	L_{3-4}	L_{4-5}	L_5–S_1	S_{1-2}
T_{11-12}	2	3		1			
T_{12}–L_1		10	4	2			
L_{1-2}	1	16	39	24			
L_{2-3}		5	26	45			
L_{3-4}				13	5		
L_{4-5}					2		
L_5–S_1						1	1

three spaces higher; and once (0.5%) a marker was actually four spaces higher than the anaesthetist believed it to be. The two anaesthetists agreed on the level of the marker on 60% of occasions, although they had identified the correct level in only 17 of these 60 patients (28%). They disagreed by one interspace on 36 occasions and by two interspaces on four occasions. The strength of this agreement (measured by weighted kappa) between anaesthetist A and each of the other three was 0.42, 0.50 and 0.63, which represents 'moderate' to 'good' agreement [5].

There was no significant difference in accuracy between the sitting and lateral positions ($p = 0.41$) but obesity (defined as BMI $\geq$ 30 $kg.m^{-2}$) impaired accuracy ($p = 0.001$). Markers located at L_{1-2} or above were more likely to be misidentified than those at L_{2-3} or below ($p < 0.001$): of 102 estimations in which markers were actually at L_{1-2} or above, 34 (33%) were two or more spaces higher than realised, compared with none of 98 estimations where the marker was at L_{2-3} or below (Table 1). Although 20 of the 21 obese patients had markers placed high on the spine, accuracy was still impaired by high marker placement when only the non-obese patients were considered ($p < 0.001$). The level of the conus medullaris is shown in Table 2. In 19 patients it was below the body of the L_1 vertebra.

Table 2 Position of conus medullaris in 100 patients undergoing magnetic resonance imaging scans. Values are number of patients.

Position of conus medullaris	*n*
T_{12} vertebral body	5
T_{12}–L_1 interspace	4
L_1 vertebral body	72
L_{1-2} interspace	6
L_2 vertebral body	11
L_{2-3} interspace	1
Below L_{4-5} (tethered cord)	1

Discussion

This study demonstrates that anaesthetists cannot reliably identify a particular lumbar interspace by palpation. Accuracy is not improved by use of the sitting position and is worsened by obesity. Markers placed far from the level of the iliac crests (requiring counting of spinous processes) are more likely to be misidentified than those placed lower on the back, even when only non-obese patients are considered. The degree of agreement between two observers (60% of occasions) suggests a fault with the method, rather than its execution.

This study, involving 200 observations from 100 patients, is larger than other published clinical studies. All four anaesthetists participating in this study had at least 5 years' anaesthetic experience and each had performed several hundred spinal injections. We assessed clinical skills of anaesthetists in living subjects, who adopted an appropriate flexed position. Use of MRI enabled careful assessment of the vertebral level by one of two senior radiologists. Comparison of the sitting with the lateral position in the same patient allowed paired data to be collected, eliminating bias caused by between-patient variability. To allow this to occur, the first anaesthetist was told simply to mark any interspace on the lower back. An alternative approach, with both attempting to identify a predetermined space, may have introduced a bias whereby the second anaesthetist could be influenced by the first. Randomisation of the level of attempted marker placement may also have introduced bias. For example, if placement was randomised to L_{2-3}, L_{3-4} or L_{4-5}, the second anaesthetist, on finding a marker apparently at L_{1-2}, may have considered that L_{2-3} had been intended (because L_{1-2} or higher was not an option), potentially influencing his opinion.

Great care was taken to prevent displacement of the skin marker as the patient stood up. To minimise potential error further, it would have been preferable to perform the scan with the patient in the flexed position in which the mark was drawn and the back palpated. However, this was not possible owing to the limited diameter of the scanner bore. Most routine lumbar spine MRI scans were performed for low back pain. Easier palpation in subjects without muscle spasm or pain may have improved accuracy. Many of the subjects in our study were osteoporotic elderly patients. Some patients volunteered information of significant height loss; this was not recorded. Two of the three patients in whom the biggest errors were made claimed to have lost 7–10 cm in height. Such patients regularly present with a fractured neck of

Table 3 Percentage of spinal cords ending lower than L_1 or L_2 in studies spanning more than a century.

	No. of subjects	Percentage of cords ending below body of L_1	Percentage of cords ending below body of L_2
Thomson, 1895 [9]	198	48	2
McCotter, 1916 [10]	234	28	0
Needles, 1935 [11]	240	55	3
Reimann & Anson, 1944 [12]	129	58	5
Broadbent, 2000	100	19	2

femur, and are frequently offered spinal anaesthesia. Work is needed to determine whether height loss is a risk factor for unexpectedly high needle insertion.

Our failure rate (71%), is higher than that found by Van Gessel *et al.* (59%) in a smaller study of 29 patients [1]. Theirs was also a clinically based study. Spinal catheters were inserted and their position confirmed radiographically. A similar report by Moore [2] found a failure rate of 50% for correct needle placement during myelography. However, the number of patients studied was not reported. The presence of a percutaneous catheter removes the possibility of error caused by skin marker movement. This may explain the greater accuracy in these studies. In a study of epidural catheterisation in 27 cadavers, Ievins [3] demonstrated that in 40% of cases, the L_{3-4} interspace was not identified correctly; in 33% of cases, the catheter was placed too high. The failure rate was reduced to 22% by using a length of catheter physically to construct Tuffier's line. However, since these subjects were cadavers, the spine was presumably unflexed. Vertebral level was confirmed by dissection. Bony abnormalities may have been less obvious than on MRI scan. Withholding our results until the study was complete prevented anaesthetists from using feedback to improve their accuracy. Such blinding was not reported by Van Gessel *et al.* [1], Moore [2] or Ievins [3], and this may have improved their results. Render [6] showed that the iliac crests on 163 plain lumbar X-rays were not level with either the L_4 spinous process or the L_{4-5} interspace in 22% of cases. However, these films were taken with no lumbar flexion and only a little hip flexion, and it may be that this proportion increases with lumbar spine flexion. An alternative technique of identification was suggested, namely of counting down from the spinous process of C_7. However, this may be difficult, especially in obese patients. Our study suggests that counting spinous processes may introduce an additional source of error. Thavasothy [7], in response to that article, recommends Eriksson's method [8] of palpating the 12th rib in conjunction with the iliac crests. This is also likely to prove difficult, particularly in the obese.

The level of the conus medullaris was below the body of L_1 in 19% of our patients. This should not be surprising. Although many anaesthetists believe that the spinal cord terminates at the body of L_1 in an adult, Thomson in 1895 [9], McCotter in 1916 [10], Needles in 1935 [11] and Reimann & Anson in 1944 [12] demonstrated in a series of anatomical dissection studies that 28–58% of adult cords end below the body of L_1 (Table 3). Our results confirm that in a significant number of subjects the conus lies below the L_1 vertebral body.

Anaesthetists should not assume that a spinal or epidural needle is at the interspace they believe it to be, based on palpation of the iliac crests. It is likely to be at least one interspace higher, and possibly more. Use of other bony landmarks, e.g. the spinous process of C_7 and the 12th rib, may be impractical. It also cannot be assumed that the spinal cord ends at the level of L_1. Intrathecal injection above the level of the conus was implicated in the report by Rajakulendran *et al.* [4]. A combined spinal–epidural, believed to have been performed at the L_{2-3} interspace, produced a left lower limb paresis; MRI showed swelling and an increased signal in the spinal cord at the level of L_1. There is concern that the risk of neurological damage may be further increased with the use of atraumatic needles [13, 14]. For free flow of cerebrospinal fluid more of the needle must penetrate the dura, which may risk trauma if it is above the conus.

In conclusion, we recommend that if a choice of suitable interspaces exists, the lower one be selected for intrathecal injection, to reduce the risk of neurological damage from either misidentification of the vertebral level or an unexpectedly low conus.

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