International Journal of Obstetric Anesthesia (2010) **19**, 261–265
0959-289X/$ - see front matter
doi:10.1016/j.ijoa.2010.02.002

ELSEVIER
www.obstetanesthesia.com

ORIGINAL ARTICLE

Sensory testing of spinal anaesthesia for caesarean section: differential block and variability

M. Kocarev,[a] E. Watkins,[a] H. McLure,[a] M. Columb,[b] G. Lyons[a]
[a] *Department of Obstetric Anaesthesia, St. James' University Hospital, Leeds, UK*
[b] *Acute Intensive Care, University Hospital of South Manchester, Wythenshawe, UK*

ABSTRACT
Background: The aim of this study was to determine if sensory block following spinal anaesthesia, measured with a range of devices, corresponded to the hierarchy of nerve fibre size in the area of differential block, and to compare the distribution and variability of recorded measurements.
Methods: Women with singleton pregnancies >36 weeks of gestation undergoing elective caesarean section under combined spinal–epidural anaesthesia were recruited. An identical spinal anaesthetic was given to all. A single researcher with no clinical role assessed block height at 20 min from the time of spinal injection. Six tests were used in random order to measure four sensory modalities: ethyl chloride (cold), calibrated Neuropen (sharp), standardized monofilament 10 g (pressure), Neurotip stroking (light touch), monofilament stroking (light touch), cotton wool (light touch). The cost of each method of testing was noted.
Results: The median differences between the four modalities were significant (Friedman test, $P < 0.0001$), but paired tests failed to find significant differences between Neuropen (sharp) and monofilament (pressure), monofilament (pressure) and Neurotip (light touch), and between tests for light touch. The tests for light touch had the least dermatomal spread and produced a unimodal distribution. The coefficient of variation was highest with ethyl chloride (24.1%) and the lowest with cotton wool (10.4%).
Conclusions: Sensory fibre hierarchy could be identified. Tests for light touch showed the least variability. More expensive tests do not appear to have any advantage over the least expensive test, cotton wool.

Keywords: Spinal; Anaesthesia; Caesarean section; Sensory testing; Differential nerve block

Introduction

Spinal anaesthesia results in nerve root blockade that extends in a cephalad manner to an area where the concentration of local anaesthetic wanes. Greene called this area the ''differential zone'', where the extent of sensory fibre blockade is dependent on local anaesthetic concentration, the modality of sensory testing and corresponding fibre size hierarchy.[1] In this differential zone of spinal anaesthesia there is an average difference of two dermatomes, with a range of as much as six, between a sponge soaked in ether and pinprick.[1] Cold may be transmitted via C fibres and Aδ fibres, whilst pinprick may be transmitted via Aδ fibres that give a lower level.

Modality testing includes relatively sophisticated devices that deliver standardised touch and pressure, such as the Neuropen (Owen Mumford, Oxford UK), as well as simple devices such as cotton wool. There are potential difficulties in applying cold, pinprick and touch in a manner that evaluates only that specific sensation. Greene was the first to note variability with sensory testing[1] and Rocco et al. acknowledged that knowing the level of one sensory modality did not allow prediction of another.[2] Russell confirmed both these findings in a more recent study.[3] The current assumption is that the popular tests are valid determinants of a particular sensory modality. The aim of this study was to take a variety of devices that test four sensory modalities to determine if measured block levels corresponded to the hierarchy of nerve fibre size in the area of differential block. We also sought to determine whether the best test could be identified using a novel plot that displayed distribution of dermatomal spread rather than simply the limits. We made no attempt to link this to comfort during caesarean section.

Accepted February 2010
Correspondence to: M. Kocarev, Department of Obstetric Anaesthesia, St. James's University Hospital, Beckett Street, Leeds LS9 7TF, UK. Tel.: +44 1132065371.
E-mail address: mkocarev@yahoo.com

Methods

Local Research (Ethics) Committee approval and written informed consent were obtained for this prospective,

randomised, observational study. Women, ASA Physical Status Class I–II, between 18 and 40 years of age, who had a normal singleton pregnancy beyond 36 weeks of gestation, were 50–110 kg in weight and 150–190 cm in height and undergoing elective caesarean section under combined spinal–epidural anaesthesia were recruited.

An identical standardised combined spinal–epidural anaesthetic was given to all women. Routine antacid prophylaxis with lansoprazole 30 mg was given on the morning of surgery, followed by 0.3 M sodium citrate 30 mL on arrival in the anaesthetic room. Heart rate was monitored by electrocardiography, blood pressure with automatic oscillotonometry, and oxygen saturation with pulse oximetry. After establishing intravenous access with a 16-gauge cannula, 0.9% w/v saline 500 mL was given. An epidural catheter was placed in the second lumbar interspace with women in the sitting position, using an 18-gauge Tuohy needle and loss of resistance to saline. A 1-mg/kg test dose of lidocaine 2% w/v was given through the catheter; if negative for intravascular and intrathecal location, a 27-gauge Whitacre needle was placed in the third lumbar interspace followed by an injection of 0.5% w/v hyperbaric bupivacaine 13 mg with diamorphine 400 μg.[4] All women were then placed supine with left tilt. Epidural bupivacaine 0.5% w/v was administered if any subsequent sensory tests for light touch showed that the block had failed to reach the T5 dermatome 20 min after intrathecal injection.

A prophylactic vasopressor infusion of ephedrine 30 mg and phenylephrine 400 μg in 0.9% w/v saline 500 mL was started after the spinal injection and titrated to maintain blood pressure close to baseline values.[5]

A single researcher with no clinical role was responsible for all assessments 20 min after spinal injection. The anaesthetist responsible for clinical management witnessed the test but did not interfere. If there was any doubt as to whether light touch was blocked to T5 or above, the clinical anaesthetist would test independently until satisfied. All assessments were applied bilaterally in the mid-clavicular line in a caudal to cephalad direction. To determine block height accurately, normal sensation at the C2 dermatome (forehead) for each test was demonstrated initially. Block height was established by comparing abdominal, thoracic and cervical sensations, on the both sides, with the forehead, until both tests produced identical sensations.[6] A dermatomal map (Cook, Canada) was used to avoid inaccuracies regarding the location of identified dermatomal level.[7]

To prevent potential bias from the patient 'learning' as the tests progressed, the six tests were performed in a random order on each occasion. The six tests were:

1. Ethyl chloride spray to assess cold;
2. Calibrated Neurotip test using the Neuropen (Owen Mumford, Oxford UK), which exerts a standard force of 40 g to assess sharp sensation;
3. Monofilament test using the Neuropen mounted monofilament which is calibrated to exert a standardised pressure of 10 g when it is pressed at a 90° angle to the skin surface until it bows, to assess pressure;
4. Neurotip stroking which was performed gently across the skin with the plastic probe of the Neurotip to assess light touch;
5. Monofilament stroking which was performed gently along the skin to assess light touch;
6. Cotton wool ball swept gently along the skin to assess light touch.

The costs of the methods of testing were noted.

Using an estimated two dermatomes as a clinically relevant difference and a standard deviation of two dermatomes,[3] it was calculated that 60 subjects would be needed to give the study a power of more than 95% with statistical significance defined for overall α error at the 0.05 level with two-sided P values.

For statistical analysis, dermatomes from C2 to S5 were numbered from 1 to 29 and considered as ordinal data. Data were expressed as mean (SD), median (range) and count. Friedman analysis of ranks for repeated measures and Dunn post-tests for multiple comparisons were performed to compare dermatomal levels. Distributions of sensory data were plotted using violin plots, which depict median, interquartile range (IQR), adjacent value (1.5 times IQR) and frequency distribution. Analyses were performed using Prism 4.0 (GraphPad Software Inc., San Diego, CA) and Number Cruncher Statistical System (NCSS 2004, Kaysville, UT). Significance was arbitrarily defined as $P < 0.01$ (two-sided).

Results

Sixty women were recruited. Their personal and obstetric characteristics are shown in Table 1. Two women, in whom intrathecal block failed to reach T5 to light touch at 20 min after spinal injection, received a 10-mL epidural dose of bupivacaine 0.5% w/v after the block tests.

There were no differences in block height between left and right sides for any sensory test in any individual. Median differences between the four modalities, (cold, sharp, pressure and light touch) were significant (Friedman test, $P < 0.0001$). The significance of the trend was

Table 1 Patient characteristics

Age (years)	29.9 (5.8)
Height (cm)	164.3 (7.4)
Weight (kg)	80.9 (12.9)
Gestation (weeks)	39 [37–42]
Parity	1 [0–5]
ASA class	1 [1–2]
Duration of surgery (min)	40.7 (10.2)

Data are mean (SD) or median [range].

Table 2 Dunn's multiple comparison between each pair of sensory tests

	Cold	Sharp	Pressure	Light touch: Neurotip	Light touch: monofilament	Light touch: cotton wool
Cold		<0.001	<0.001	<0.001	<0.001	<0.001
Sharp	<0.001		>0.05	<0.01	<0.001	<0.001
Pressure	<0.001	>0.05		>0.05	<0.01	<0.001
Light touch: Neurotip	<0.001	<0.01	>0.05		>0.05	>0.05
Light touch: monofilament	<0.001	<0.001	<0.01	>0.05		>0.05
Light touch: cotton wool	<0.001	<0.001	<0.001	>0.05	>0.05	

confirmed with Cuzick's trend test, which was also highly significant ($P < 0.0001$). Dunn's multiple comparison of medians did not show significant differences between Neuropen (sharp) and monofilament (pressure), or between monofilament (pressure) and Neurotip (light touch). There was also no significant difference between the tests for light touch (Table 2).

The median dermatomal difference between cold and sharp was two dermatomes. There was no median dermatomal difference between pressure and sharp. There was one dermatomal difference between pressure and light touch to cotton wool (Fig. 1).

The distributions of data for each sensory test are shown in the violin plots (Fig. 2). The coefficient of variation was highest with ethyl chloride (24.08%) and lowest with cotton wool (10.5%) (Table 3).

Discussion

The devices chosen for comparison in the assessment of sensory blockade are believed to represent the modalities of cold, pain, pressure and light touch. Although differences between these modalities may be clear to the researcher, the subjective experience of the patient, for whom the testing procedure may be novel, is unknown. Confusion may arise because cold, transmitted by Aδ fibres, may not be distinguished from cold discomfort, transmitted by C fibres. Moreover, ethyl chloride spray, which is typically used to test cold sensation, has also been used as a test for light touch,[8] and possibly pressure, which is transmitted by Aβ fibres. As such, the patient's response to a specific testing device may not actually relate to the modality that is reportedly being tested.

Greene demonstrated that as an ascending intrathecal local anaesthetic becomes more dilute, the decreasing concentration ceases to block fibres, beginning with the fastest and largest.[1] Sensory testing demonstrates that this hierarchy of block extension corresponds to the nerve fibre being tested and the associated testing modality. From a clinical perspective, the range of

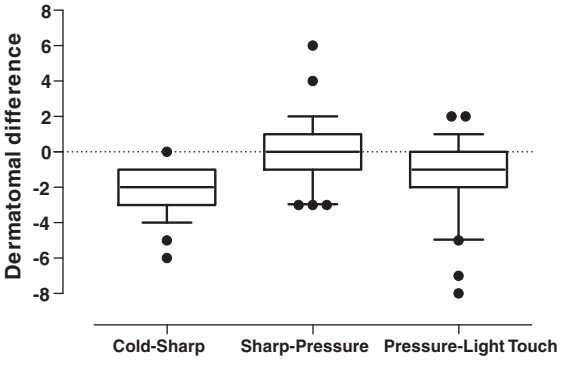

Fig. 1 Hierarchy differences in modalities used to test sensory level. Median dermatomal differences, interquartile and 5th and 95th centiles are shown. Negative differences indicate that block to cold is higher than sharp, and pressure is higher than light touch (cotton wool). Sharp and pressure are similar.

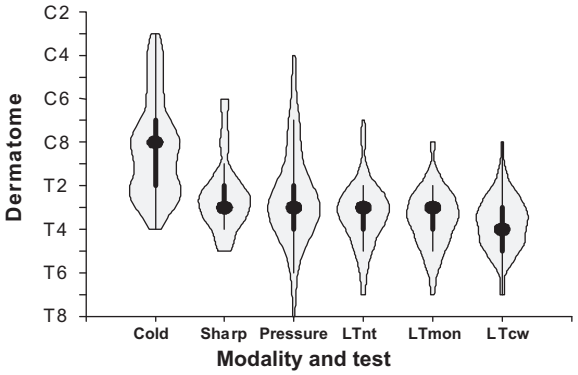

Fig. 2 Density of data for each of the sensory tests. Density of data for each sensory test is shown in violin plot. Dot: median value; Thick line: upper and lower quartiles; Whiskers extend to 1.5 times the interquartile range. LTnt: Light touch Neurotip; LTmon: Light touch monofilament; and LTcw: Light touch cotton wool.

Table 3 Coefficient of variation for each sensory test

Sensory testing	Coefficient of variation (%)
Cold	24.08
Sharp	15.31
Pressure	18.88
Light touch: Neurotip	11.91
Light touch: monofilament	10.77
Light touch: cotton wool	10.45

spread between different sensory testing modalities may be so great as to mislead the anaesthetist in predicting comfort during surgery. As such, it would be beneficial to know if a constant difference existed between various testing modalities. It is unclear whether the spread in responses to testing modalities found by Greene represents physiological variability, differing subjectivity of the patients, or an interaction between tester and patient.

Although establishing a hierarchy of block height according to the size of the nerve fibre being tested does not present new information, it was necessary for this study to confirm that the selected devices evaluated a range of sensory modalities. Our findings suggest that cold, pain, pressure and light touch were all tested to a degree by the devices evaluated. The agreement between tests is generally shown using Bland–Altman plots, but the number of tests performed would have required 15 separate figures. Instead, we chose a more sophisticated means of summarising the differences in dermatomal levels between the devices (Fig. 1). The results are in broad agreement with those of Greene.[1]

The clinical anaesthetist might define the best sensory testing device as that most likely to predict comfort at caesarean section. There is an unresolved debate as to the dermatomal level and density of differential block needed to achieve this result. Additional factors affecting patient comfort might include operative technique and patient anxiety. It might appear that the way to select a sensory testing device would be to be to apply the test and assess efficacy and comfort. Although blocks have been tested before surgery for over 50 years, such a study has yet to be performed. Instead, robust outcome measures such as the need for rescue general anaesthesia or intravenous supplementation and the less robust visual analogue scores have been reported. By refining combined spinal–epidural anaesthesia, we have reduced the need for rescue general anaesthesia to 1 in 400 elective caesarean sections.[9] Unless a sample size of many hundreds is employed, general anaesthesia is invalid as an outcome measure for a comfort study. By setting the target block height at the xiphisternum or above, refining the dose of diamorphine and testing with light touch, we have reduced the need for anaesthetic supplementation to below an arbitrary target of less than 5%.[4] Without a considerably larger sample size, the supplementation rate is also unavailable as an outcome measure.

To ensure that comfort was maintained throughout this study and beyond, the anaesthetist responsible for clinical care followed the local protocol established by earlier studies. Providing less anaesthesia would have opened an ethical dimension and merely assigning a different sensory test to each patient might not have yielded new information. Because these difficulties of using comfort as an outcome measure are not readily overcome, other ways of comparing tests were explored. In addition to displaying the median dermatome and range, the violin plots show the distribution of data in a way that a traditional box and whisker plot does not. If variability in a test is undesirable, then the test with the least dermatomal spread is to be preferred. In addition, the better test will appear unimodal, indicating that the patient's responses are for a single sensory modality. The three tests for light touch perform best in these terms.

Conversely, a bimodal distribution suggests strongly that more than one sensory modality is involved, and this was observed in the violin plot of the ethyl chloride spray. Cold sensation, which produced data with bimodal distribution, is conducted by myelinated cold-specific Aδ fibres, but there is also evidence that C polymodal nociceptors participate in the mediation of painful low temperature stimuli.[10] Moreover, touch may be a common feature to all testing modalities, as all tests involve some contact with skin. It is likely that touch acts as a reference modality within the other tests. The extended distribution of pressure sensation may be due to inability to discriminate clearly between sharp and pressure in the area of differential block. By contrast, tests for light touch are unlikely to elicit cold and sharp responses, and with pressure responses minimised, these tests can produce data with simpler unimodal distributions.

In planning this study we tried to limit inter-patient variability by performing all tests on every patient. Because patients could potentially 'learn' responses as testing progressed, we applied the tests in a random order so that bias would be spread equally throughout the cohort. Each woman was blind to the testing modality applied and was asked only to indicate when the sensation on the torso was the same as that on the forehead (C2). It is possible that this could have also introduced bias, but it would have needed to be applied unevenly amongst the tests for this to make a difference. The tester had no role in clinical care and the anaesthetist responsible for clinical care had no role in the study. Clinical decisions were made according to the local protocol and were uninfluenced by the study.

It is a standard practice in our unit to test for intrathecal or intravascular placement of the epidural catheter before spinal anaesthesia. To avoid deviation from our standard practice and minimise risk, we maintained this routine during the study. It is unlikely that the test dose of epidural lidocaine had any impact on sensory testing between different modalities. Even if it had, this would affect all the sensory assessments equally.

Diamorphine is commonly added to intrathecal bupivacaine to improve patient comfort during caesarean section and provide postoperative pain relief. It

was previously demonstrated that the addition of intrathecal diamorphine does not appear to influence the dermatomal level of block,[11] so its use in this study does not invalidate the results.

The price of a 50-mL container of ethyl chloride spray is £16. This is sufficient to test approximately 100 patients: a cost of 16p per patient. A reusable Neuropen costs £17; the Neurotip, which is disposable, costs 10p. The price of monofilament, which is also mounted in a Neuropen, is £3.25. It is recommended for 100 uses and as multiple measurements are required for each patient it is suitable to test approximately 10 patients, representing a cost of 32p each. The price of a cotton wool ball is approximately 0.2p. If cost is introduced into the assessment, then testing for light touch using cotton wool appears to be the cheapest option. The ethyl chloride spray, Neurotip and monofilament used to test for cold, sharp and light touch sensations are more expensive options calculated on a per patient basis. These more expensive tests do not appear to offer any advantage.

In conclusion, six different tests of dermatomal spread of spinal anaesthesia associated with four sensory modalities were applied to women undergoing caesarean section. A sensory fibre hierarchy could be identified. Tests for light touch were unimodal and had the least dermatomal extension. The bimodal distribution and extended dermatomal spread observed with ethyl chloride suggest that more than one sensory modality was involved. The violin plots, which display the distribution of the data, offer a new way of assessing sensory tests.

References

1. Greene NM. *Physiology of spinal anaesthesia*. London: Baillière, Tindall & Cox; 1958, p. 8–9.
2. Rocco AG, Raymond SA, Murray E, Dhingra U, Freiberger D. Differential spread of blockade of touch, cold, and pinprick during spinal anesthesia. *Anesth Analg* 1985;**64**:917–23.
3. Russell IF. A comparison of cold, pinprick and touch for assessing the level of spinal block at caesarean section. *Int J Obstet Anesth* 2004;**13**:146–52.
4. Saravanan S, Robinson AP, Qayoum Dar A, Columb MO, Lyons GR. Minimum dose of intrathecal diamorphine required to prevent intraoperative supplementation of spinal anaesthesia for Caesarean section. *Br J Anaesth* 2003;**91**:368–72.
5. Ngan Kee WD, Khaw KS, Ng FF. Comparison of phenylephrine infusion regimens for maintaining maternal blood pressure during spinal anaesthesia for Caesarean section. *Br J Anaesth* 2004;**92**:469–74.
6. Yentis SM. Is my T2 your T2 too? *Int J Obstet Anesth* 2005;**14**(Suppl):O18.
7. Congreve K, Gardner I, Laxton C, Scrutton M. Where is T5? A survey of anaesthetists. *Anaesthesia* 2006;**61**:453–5.
8. Beale N, Evans B, Plaat F, Columb MO, Lyons G, Stocks GM. Effect of epidural volume extension on dose requirement of intrathecal hyperbaric bupivacaine at Caesarean section. *Br J Anaesth* 2005;**95**:500–3.
9. Sadashivaiah J, Wilson R, McLure H, Lyons G. Double-space combined spinal–epidural technique for elective caesarean section: a review of 10 years' experience in a UK teaching maternity unit. *Int J Obstet Anesth* 2010;**19**:183–7.
10. Campero M, Serra J, Ochoa JL. C-polymodal nociceptors activated by noxious low temperature in human skin. *J Physiol* 1996;**497**:565–72.
11. Akerman N, Saxena S, Wilson R, Columb M, Lyons G. Effect of intrathecal diamorphine on block height during spinal anaesthesia for Caesarean section with bupivacaine. *Br J Anaesth* 2005;**94**:843–7.