Comparison of the Force Required for Dural Puncture with Different Spinal Needles and Subsequent Leakage of Cerebrospinal Fluid

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An *in vitro* model was used to determine the force required to pierce bovine dura with a range of new spinal needles and to measure the subsequent leakage rate of cerebrospinal fluid (CSF). A significantly greater force was required to pierce the dura with pencil-point style needles compared to Quincke needles of the same size. Quincke needles caused a greater loss of CSF than their pencil-point equivalents. The results suggest that there is not likely to be a significant reduction in postdural puncture headache (PDPH) using a 27-gauge pencil-point needle compared to a 25-gauge needle that may be easier to use. Different makes of the same design and gauge of needle showed significant differences in the amount of CSF leakage, which may influence the clinician's choice of needle.

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Spinal anesthesia has become increasingly popular as the technique of regional anesthesia for operative obstetrics where its speed of onset, combined with its predictable and dense analgesia are particularly reliable. It is now frequently used as part of the combined spinal epidural technique (1) both for cesarean section and for pain relief in labor.

One of the principal concerns regarding spinal anesthesia is the incidence of post-dural puncture headache (PDPH). The main determinants of the frequency of PDPH are the external diameter and tip design of the spinal needle; smaller gauges and pencil-point style tips are associated with less PDPH. The smaller the needle the more technically difficult it is to use with delayed appearance of cerebrospinal fluid (CSF), reduced feel on dural puncture, and difficulty on aspiration and injection of local anesthetic. Nevertheless, 29-gauge spinal needles have been used successfully with low failure rates and low incidence of PDPH (2,3). Needle manufacturers have been quick to produce a range of sizes and designs of spinal needles so that anesthesiologists now have the choice of 22-, 25-, 26-, or 27-gauge needles with either Quincke or pencil-points and 29-gauge only with Quincke points. Clinical trials to evaluate all these different needles would be difficult and would require a large number of patients. However, as PDPH is associated with the rate and duration of CSF loss through the dura, an *in vitro* model can be used to compare the performance of different needles (4,5).

The aim of this study was to examine the leakage of CSF through holes made in fresh bovine dura with some of the new range of spinal needles. In addition, the force required for dural puncture was recorded to see whether this correlates with CSF leakage. In the single space combined spinal epidural technique, where the spinal needle is passed through a guide (Tuohy needle) as far as the dura, the force required will also give a particularly good indication of the sensation the anesthesiologist will detect on dural puncture.

It was important for this study to have available large quantities of dura that could be studied postmortem without delays that might alter tissue characteristics. The delays involved in securing dura from human cadavers resulted in samples that were 24–48 h postmortem. It was therefore decided to use bovine dura as a plentiful supply could always be obtained and studied within 2 h postmortem. As this study was designed to compare CSF leakage and puncture force between needles, it was considered valid to use this animal model. The comparative results between needles, rather than absolute values of leakage and force, were under study.

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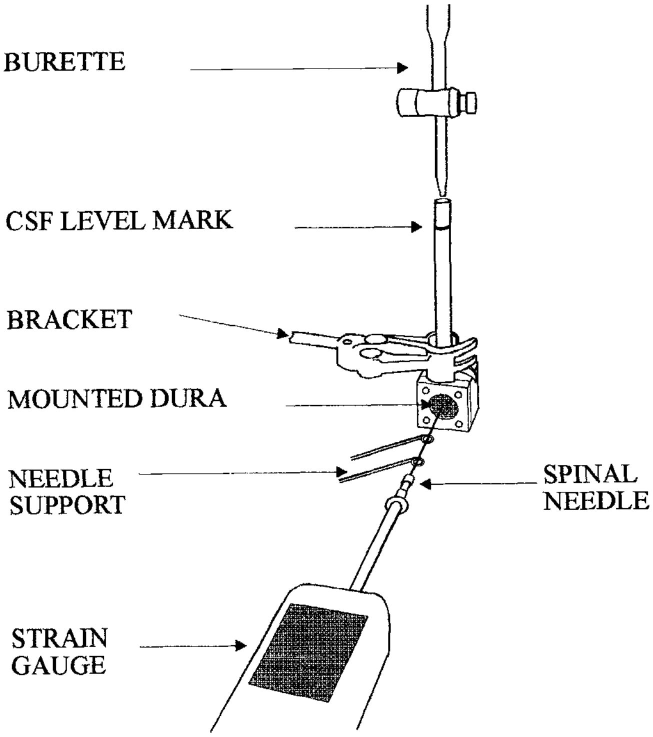

Figure 1. Diagram showing apparatus used. CSF = cerebrospinal fluid.

Methods

A Bovine Offal Movement Permit was obtained in accordance with The Bovine (Offal Prohibition) Regulations 1989. Normal human CSF was obtained from spinal drains inserted for craniofacial surgery and refrigerated until use.

Apparatus was designed and built to mount the dura with a watertight seal and with the long axis of the dura running vertically (Figure 1). A column of CSF was maintained at 12 cm H_2O (1.2 kPa) above the dura and the temperature of the CSF kept at 37°C using a thermostatically controlled water bath (Radiometer, Copenhagen, Denmark).

The area of dura was divided into a grid, so that the needle insertion point could be randomized. Both the needle and puncture site were selected at random. The needle was then passed through a guide at right angles to the dura and advanced through the dura using a hand-held force transducer (7500 series; AIKOH Engineering Corp., Japan) Quincke-type needles were inserted with the bevel parallel to the long axis of the dura. The needle was then immediately removed and the rate of flow of CSF measured using a burette for the next 5 min. Ten measurements were taken for each needle studied using a new needle for each dural puncture. The external surface of the dura was kept moist throughout each experiment by the frequent application of lactated Ringer's solution.

The external diameter of each needle was recorded by averaging multiple micrometer measurements.

Data are expressed as mean ± SD. Each mean represents the results of 10 trials with each type and gauge of spinal. Differences in spinal needle external diameter, force required for dural puncture, and subsequent leakage of CSF were analyzed using one-way analysis of variance, with a *post hoc* Tukey's multiple comparison of means test. Relationships between needle external diameter, puncture force, and CSF flow were assessed using least squares linear regression analysis. Statistical significance was considered with P values <0.05.

Results

A summary of spinal needle external diameter, force required for dural puncture, and CSF flow after dural puncture is shown in Table 1. There were no significant differences in the external diameter of similar gauge spinal needles, regardless of needle type and manufacturer.

The pencil-point style needles required significantly more force to pierce the dura than the Quincke needle of the same external diameter. The CSF leakage using a 25-gauge Becton Dickinson (BD) Whitacre-needle is significantly less than that from a 25-gauge BD Quincke needle ($P < 0.01$). In addition, the CSF flow due to a 26-gauge Portex pencil-point needle was significantly less than that from a Steriseal 26-gauge Quincke needle ($P < 0.01$). The Steriseal 26-gauge Quincke needle required significantly more force to pierce the dura than the same design and diameter of needle manufactured by BD ($P < 0.01$) and leaked significantly more CSF.

The loss of CSF decreased with needle diameter for each design of needle, the lowest loss being from the 29-gauge Quincke needle. There was a significant decrease in the amount of force required for the 27-gauge Whitacre needle compared to the 25-gauge Whitacre needle, but no difference in the rate of loss of CSF.

Although there was no significant difference between the forces required for dural puncture with the 16-gauge Tuohy needle and the 20-gauge Quincke needle, the Tuohy needle resulted in six times greater CSF leakage.

CSF flow was measured as the total volume of CSF leakage over 5 min immediately after dural puncture. Although CSF flow was correlated with overall spinal needle external diameter, further analysis revealed that only after dural puncture with Quincke needles was external diameter significantly correlated with CSF flow ($r^2 = 0.963$; $P = 0.02$). With successively larger Quincke-type needles there was significantly more CSF leakage. There was no significant correlation between pencil-point needle external diameter and subsequent

Table 1. Comparison of Spinal Needle External Diameter, Force Required for Dural Puncture, and Cerebrospinal Fluid (CSF) Flow After Dural Puncture

Needle type and manufacturer	Gauge	External diameter (mm)	Puncture force (kg force, mean ± SD) (n = 10)	CSF flow[a] (mean ± SD) (n = 10)
Tuohy (Steriseal)	16	1.675 ± 0.006	0.23 ± 0.03	154.4 ± 14.7
Quincke (Steriseal)	20	0.901 ± 0.004	0.24 ± 0.03	25.6 ± 2.6
Whitacre (Vygon)	22	0.702 ± 0.005	0.21 ± 0.02	13.4 ± 3.1
Quincke (BD)	25	0.514 ± 0.005	0.04 ± 0.01	8.3 ± 1.9
Whitacre (BD)	25	0.516 ± 0.004	0.12 ± 0.02	4.3 ± 0.9
Pencil-point (Portex)	26	0.456 ± 0.004	0.11 ± 0.02	4.4 ± 1.4
Quincke (Steriseal)	26	0.450 ± 0.002	0.15 ± 0.03	8.7 ± 1.5
Quincke (BD)	26	0.450 ± 0.002	0.03 ± 0.01	4.6 ± 1.0
Whitacre (BD)	27	0.423 ± 0.005	0.09 ± 0.02	4.1 ± 1.3
Quincke (Vygon)	29	0.331 ± 0.004	0.04 ± 0.01	3.4 ± 1.1

BD = Becton Dickinson.
[a] CSF flow over the first 5 min after dural puncture.

CSF flow (P = 0.10). Additionally, there was no correlation between the force required for dural puncture and subsequent CSF flow (P = 0.94).

Discussion

The aim of this study was to use an *in vitro* model to assess the likely clinical difference between various needles in the incidence of PDPH by measuring the rate of CSF loss through a dural puncture site. The use of a randomized insertion point for the needle was necessary because of the previously shown wide variation in dural thickness over any given area (6).

Needle manufacturers do not all follow the same gauge standards (7); some use the U.S. Gauge standard and others, the Standard Wire Gauge. Consequently needles labeled as the same gauge may not have the same external diameter. For this reason the external diameter of all needles was checked, and the results show that external diameters did not vary significantly for any given gauge. Thus any variation in force or leakage observed between needles of the same gauge is not due to differences in external diameter.

The *in vitro* study reported by Cruickshank and Hopkinson (4) clearly demonstrated an increase in CSF leakage using larger needles (22-gauge vs 26-gauge vs 29-gauge). However, they were unable to demonstrate any advantage to aligning Quincke needles with the long axis of the dura, nor any reduction in CSF loss with pencil-point needles compared to Quincke needles. The importance of Quincke needle alignment has been questioned (8) as all dural fibers do not run parallel to the long axis of the spine. However, clinical studies continue to show a significant reduction in PDPH when the needle is aligned parallel to the long axis of the spine (9,10).

This present study has shown that the CSF leakage from pencil-point style needles is significantly less than that from Quincke needles of the same external diameter. These results are in agreement with those of Ready et al. (5) who demonstrated reduced CSF loss from pencil-point style needles. It can be seen, however, that there is a surprising and significantly greater CSF loss with the use of a 26-gauge Steriseal Quincke needle than a BD 26-gauge Quincke needle ($P < 0.01$). This important difference is not due to external diameter, as both had identical measurements of 0.45 mm. On close examination of the tips, it can be seen that the bevel of the Steriseal needle is significantly shorter, and so blunter, than that of the BD needle. This would explain why the Steriseal needle required significantly more force to puncture the dura than the BD needle, suggesting that manufacturer as well as size and design may affect the incidence of PDPH.

These direct force measurements have shown a significantly higher force in the pencil-point group compared to the Quincke group. This might be expected, as these needles are "blunter." However, in their original paper, Hart and Whitacre commented that their needle (a 20-gauge) gave "little or no resistance on entering the dura" (11). It is likely that the Quincke needles used by these authors would have been resterilized and used several times, and so would not have been as sharp as modern disposable needles.

The fact that there was a significant reduction in the loss of CSF with 25-gauge as compared to 22-gauge Whitacre needles, but no such difference between the 27-gauge and 25-gauge Whitacre needles, suggests that although, in terms of PDPH, the 25-gauge may be preferable to the 22-gauge, the 27-gauge needle offers no clear advantage over the 25-gauge needle, which may be easier to use.

This study shows that pencil-point needles require more force to pierce dura but subsequently leak less CSF when compared to Quincke needles, confirming their superiority in reducing the incidence of PDPH. In addition, the different CSF loss for the same gauge of Quincke needle produced by different manufacturers may affect clinicians' choice of needle in clinical practice.

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References

1. Carrie LES. Extradural, spinal or combined block for obstetric surgical anaesthesia. Br J Anaesth 1990;65:225–33.
2. Dittmann M, Renkl F. Spinal anesthesia with extremely fine needles. Anesthesiology 1989;70:1035–6.
3. Carrie LES, Collins PD. 29-Gauge spinal needles. Br J Anaesth 1991;66:145–6.
4. Cruickshank RH, Hopkinson JM. Fluid flow through dural puncture sites. An in vitro comparison of needle point types. Anaesthesia 1989;44:415–8.
5. Ready LB, Cuplin S, Haschke RH, Nessly M. Spinal needle determinants of rate of transdural fluid leak. Anesth Analg 1989; 69:457–60.
6. Dittmann M, Schafer HG, Ulrich J, Bond-Taylor W. Anatomical re-evaluation of lumbar dura mater with regard to postspinal headache. Effect of dural puncture. Anaesthesia 1988;43:635–7.
7. Hoel TM, Lind B. Spinal needles, gauge and headache. Br J Anaesth 1987;59:808–9.
8. Hope A, Wilkinson K, Bloxham CA. Dural punctures. Anaesthesia 1989;44:164–5.
9. Tarkkila PJ, Heine H, Tervo R-R. Comparison of Sprotte and Quincke needles with respect to post dural puncture headache and backache. Reg Anesth 1992;17:283–7.
10. Mihic DN. Postspinal headache and relationship of needle bevel to longitudinal dural fibers. Reg Anesth 1985;10:76–81.
11. Hart JR, Whitacre RJ. Pencil-point needle in prevention of post spinal headache. JAMA 1951;147:657–8.