Post-dural puncture headache in young adults: comparison of two small-gauge spinal catheters with different needle design

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Background. To reduce the risk of post-dural puncture headache (PDPH) in continuous spinal anaesthesia, small-gauge spinal catheter systems with different techniques of dural perforation have been developed.

Methods. Two systems, the catheter through-needle technique (MicroCatheter, Portex, UK) and the catheter over-needle technique (22G Spinocath®, B. Braun, Germany), were used in 18 young healthy volunteers (age 18–30 yr), who were enrolled in a neuroendocrinological investigation for analysis of neuropeptides in cerebrospinal fluid (CSF). After intermittent sampling of CSF (17±0.5 ml over 4 h), the catheter was removed and the development of PDPH and pain intensity were documented prospectively by the subjects in a standardized headache assessment (11-point numerical rating scale [NRS]).

Results. The study revealed a high overall incidence of PDPH (78%) with no significant differences between groups (P=0.26). However, the over-needle group showed a significantly shorter duration of PDPH (2.4 [SD 2.3] vs 5.1 [3.1] days, P=0.050) and lower maximum pain intensity (3.1 [2.9] vs 7.3 [3.4] NRS, P=0.014) than the through-needle group.

Conclusions. The results demonstrate a potential benefit of the catheter over-needle technique for the reduction of the duration and intensity of PDPH.


Keywords: anaesthetic techniques, over-needle technique; complications, post-dural puncture headache; equipment, catheters, spinal

Accepted for publication: December 17, 2004

The risk of post-dural puncture headache (PDPH) can be crucial for the acceptance of a particular neuroaxial anaesthetic technique, since it has the potential for considerable disabling morbidity.1 Great progress has been made in single-dose spinal anaesthesia with the reduction of the diameter of the spinal needle and improvement of the needle tip configuration. In a meta-analysis of PDPH in parturients, a group considered to be at the highest risk, the incidence of PDPH from small atraumatic spinal needles (Whitacre 27G) was calculated to be 1.7%.2

However, in continuous spinal anaesthesia (CSA) the risk of PDPH remains controversial, ranging from very low3 to over 30%.4 No large-scale prospective studies on the incidence of PDPH in young adults have been reported, and no studies have compared the efficacy of different needle configurations in preventing PDPH.

This study of spinal catheters was part of an endocrine study of neuropeptides which required the use of spinal catheters for intermittent cerebrospinal fluid (CSF) sampling after the administration of intranasal neuropeptides in a young healthy study population. The intrathecal placement of a spinal catheter without the influence of local anaesthetic drug administration or treatment of a disease or surgery made the associated symptoms directly attributable to the technique.

The assumption of a high frequency of PDPH under these conditions led us to compare two small-gauge spinal catheter systems with different designs and techniques of dural puncture (through-needle vs over-needle design) to analyse possible benefits with regard to PDPH. After removal of the spinal catheter, the participants were requested prospectively to document the onset, duration and intensity of
posture-dependent headache using a standardized headache assessment.

Methods
After approval from the local ethics committee and written informed consent, 18 young healthy adults (seven female, 11 male) were enrolled in a prospective neuroendocrinological study of the administration of intranasal neuropeptides and the use of two spinal catheter systems for the intermittent sampling of CSF. Inclusion criteria for the volunteers were that they were non-smokers, not pregnant and aged 18–30 years. The subjects received no anxiolytic premedication. A spinal catheter system using either a catheter through-needle technique (MicroCatheter, Portex, UK) (through-needle group, n=9) or a catheter over-needle technique (22G Spinocath, B. Braun, Germany) (over-needle group, n=9) (Fig. 1) was positioned by an experienced anaesthetist at the level of lumbar vertebral interspace 4/5 or 3/4.

The external diameter of the dural perforation was comparable in both groups, being caused either by the 23G spinal needle in the through-needle group or by the 22G spinal catheter in the over-needle group. Spinal puncture was performed with the participant in the lateral decubitus position using a midline approach after aseptic preparation and infiltration of the tract with mepivacaine 1%. In both groups the bevel direction of the spinal needles was parallel to the axis of the spinal cord and the catheter was positioned to an intrathecal length of 3 cm.

In the through-needle group a 28G styletted MicroCatheter was inserted through a cutting 23G Crawford spinal needle after an introducer had been placed in the interspinous ligament. The Spinocath used in the over-needle group is a combination of catheter and needle with the catheter positioned over a cutting 27G Quincke spinal needle. It was inserted using an 18G epidural needle as an introducer, which was placed in the epidural space by a loss-of-resistance technique with saline. The inner spinal needle was withdrawn after the puncturing of the dura and CSF backflow had been identified in the Spinocath. The subjects were instructed to report any paraesthesia during these procedures.

For the period of the study, the subject lay in a supine position with the upper body slightly elevated and received an i.v. infusion of 0.9% sodium chloride solution (1000 ml). After randomized intranasal application of a neuropeptide, samples of CSF were collected intermittently (total of 8.5 ml CSF in 0.5-ml fractions at intervals of 15 min) and venous blood samples were taken through an i.v. cannula (255 ml in 15-ml fractions) over a period of 4 h. Serum and CSF samples were analysed for various peptides (melanocortin, vasopressin, insulin, orexin-A, interleukin-6). During a pre-study test, no volunteers developed headaches or other clinical problems after the nasal applications of neuropeptides. After 4 h, the spinal catheter and i.v. cannula were removed and the subjects were immediately mobilized. On the following day, they took up their daily routine.

The study participants had been informed that posture-dependent headache, i.e. one that was aggravated by sitting...
and standing and relieved by lying down, was regarded as PDPH. After withdrawal of the spinal catheter, the subjects received a standardized headache assessment form and were instructed with regard to its completion. The maximum experienced pain intensity of PDPH had to be noted daily for at least 7 days or until symptoms ceased. This self-assessment was documented on an 11-point numeric rating scale (NRS) ranging from 0 (‘absence of pain’) to 10 (‘maximum conceivable pain’). If the subjects did not return the completed form within 10 days, they were reminded by telephone.

Before the study, the potentially high rate of headache, the expected time course and the limited therapeutic options, except for an epidural blood patch to seal the puncture site, had been discussed. The subjects were encouraged to lie in a comfortable position if a headache developed. A contact telephone number was available in case any of the subjects needed help (i.e. relief by performing an epidural blood patch); no one took up this option.

Data are expressed as mean (SD). They were analysed using the Mann–Whitney U-test or the χ²-test. Differences between groups were considered as statistically significant at \( P<0.05 \). The effect size \( d \) was calculated using Cohen’s formula \( d=M_1-M_2/SD_{pooled} \), where \( M_1 \) and \( M_2 \) are the means, to express the magnitude of group differences. The effect size quantifies differences between two groups in a variable. The difference is calculated in units of standard deviation; accordingly, an effect size of 0.2 was considered small, 0.5 medium and 0.8 large.6

### Results

The groups were similar in age, gender and BMI. The mean age was 25.6 (range 18–30) yr in the through-needle group and 24.8 (21–30) yr in the over-needle group (Table 1). A similar incidence of paraesthesia (total 72%) was encountered during the application of both catheter systems (Table 2).

The study found a high overall incidence of PDPH (78%) in this young adult population, with no statistically significant differences between groups (\( P=0.26 \)). However, in the over-needle group, the maximum pain score of PDPH was significantly less intense (3.1 [2.9] vs 7.3 [3.4] NRS, \( P=0.014 \)) and the duration of PDPH was significantly shorter (2.4 [2.3] vs 5.1 [3.1] days, \( P=0.050 \)) compared with the through-needle group (Table 2). The effect size of the group differences was \( d=1.35 \) for pain intensity (NRS scale) and \( d=0.98 \) for the duration of pain. Data concerning the intensity and the duration of the PDPH refers to all subjects, not just those who developed headache.

No participant reported the development of headache immediately after the procedure and there were no group differences in the onset of headache (\( P=0.68 \)) (Table 2). Seven participants experienced the onset of headache in the evening of the procedure, three on the second day, three on the third day and one on the fourth day; four participants did not have any headache. In all cases, the headache resolved spontaneously within 10 days; epidural blood patch to treat diagnosed PDPH was not performed. Subjects without posture-dependent headache did not have other types of headache.

### Discussion

In this study, a strikingly high overall rate of PDPH, with a total frequency of 78%, was encountered after the application of small-gauge spinal catheter systems in young healthy adults. With respect to the incidence of PDPH, no significant difference could be demonstrated between the two systems with different techniques of dural perforation. However, analysis revealed a significantly shorter duration and reduced severity of headache in the over-needle group as assessed by the standardized headache assessment method.

The limitation of this study is the small group size, which may mask group differences. Absence of relevant data did not allow statistical sample size calculation prior to the study. On the basis of our results, this can now be carried out and may be useful for further studies. Group differences in the main dependent variables are large (\( d=1.35 \) for pain intensity and \( d=0.98 \) for pain duration). If the type II error (\( \beta \)) is set to 0.2 (power=80%), the type I error (\( \alpha \)) to 0.05 and \( d=1.35 \), the number of subjects needed in each group can be calculated to be \( n=8 \) (one-sided test). Assuming \( d=0.98 \), the same sample size calculation recommends \( n=14 \) in each group. The incidence of PDPH in the through-needle group was 89% and in the over-needle group 67%. To

### Table 1

Characteristics of participants experiencing the application of small-gauge spinal catheter systems with two different techniques of dural perforation. Data are expressed as mean (range) or mean (SD). *Mann–Whitney U-test; †χ²-test

<table>
<thead>
<tr>
<th></th>
<th>Through-needle group (n=9)</th>
<th>Over-needle group (n=9)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>25.6 (18–30)</td>
<td>24.8 (21–30)</td>
<td>0.48*</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>5/4</td>
<td>6/3</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>175.9 (8.0)</td>
<td>180.8 (13.6)</td>
<td>0.31*</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.1 (7.6)</td>
<td>74.2 (12.9)</td>
<td>0.69*</td>
</tr>
<tr>
<td>BMI (kg m⁻²)</td>
<td>23.1 (1.2)</td>
<td>22.7 (2.6)</td>
<td>0.99*</td>
</tr>
</tbody>
</table>

### Table 2

Paraesthesia and post-dural puncture headache after small-gauge spinal catheters in young healthy adults: through-needle group vs over-needle group. Data are expressed as mean (SD) except onset of PDPH which is mean (range). *χ²-test; †Mann–Whitney U-test; ‡day 1 is day of procedure

<table>
<thead>
<tr>
<th></th>
<th>Through-needle group (n=9)</th>
<th>Over-needle group (n=9)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraesthesia during spinal puncture</td>
<td>6</td>
<td>7</td>
<td>0.60†</td>
</tr>
<tr>
<td>Post-dural puncture headache</td>
<td>8</td>
<td>6</td>
<td>0.26†</td>
</tr>
<tr>
<td>Onset of PDPH (day)†</td>
<td>2.0 (1–4)</td>
<td>1.7 (1–3)</td>
<td>0.68‡</td>
</tr>
<tr>
<td>Duration of PDPH (days)‡</td>
<td>5.1 (3.1)</td>
<td>2.4 (2.3)</td>
<td>0.050‡</td>
</tr>
<tr>
<td>Maximum pain intensity (NRS)</td>
<td>7.3 (3.4)</td>
<td>3.1 (2.9)</td>
<td>0.014‡</td>
</tr>
</tbody>
</table>

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confirm this difference as being statistically significant, the sample size in a further trial should be \( n=43 \) in each group (type I error=5\%, power=80\%, one-sided test). This recommended sample size is impractical in a study with healthy volunteers and, furthermore, introduces an ethical problem in view of the results of the present study and the effect on the subjects.

The special conditions of this neuroendocrinological investigation with its high overall rate of PDPH are favourable for comparing spinal catheter systems. In this study, 14 out of 18 subjects experienced PDPH. In a different clinical setting with a PDPH rate of 1\%, 1400 patients would have been necessary to obtain the same number of affected patients.

Another advantage of our clinical setting is that the reported symptoms clearly fulfilled the criteria of PDPH. When the occurrence of PDPH is low, the reported symptoms are generally mild and it can be difficult to distinguish posture-dependent headache from other forms of headache. This was the case in a study comparing 27G Whitacre and Quincke needles for spinal anaesthesia in 676 outpatients in which an overall incidence of headache (PDPH and non-specific) of 20.0\% and an incidence of PDPH of 1.51\% was reported. Some of the non-specific headache was probably caused by the dural lesion, but the aperture was too small to cause symptoms that completely satisfied the criteria of PDPH. In contrast, all the patients with headache in our study satisfied the criteria for PDPH as recommended by the International Headache Society.

It is widely accepted that the residual iatrogenic lesion in the dural and arachnoid components of the dural sac accounts for the development of PDPH. The underlying pathophysiology and especially the prevention and treatment of this effect remain a point at issue. Patient-dependent factors (age, gender) and technical features (diameter of needle and catheter, surface and shape of the needle tip) have been implicated in influencing the risk of developing headache.

Therefore to reduce PDPH, catheter systems with a smaller external diameter (small-gauge catheters) and a different technical concept (over-needle technique) have been developed. Data on this kind of spinal catheter system are scarce and, with regard to PDPH, do not provide a clinical comparison with other techniques of dural perforation.

Cases of cauda equine syndrome have been described after CSA with microcatheters, which led the US Food and Drugs Administration, in 1992, to ban the use of spinal catheters <24G in the USA. This decreased the application of CSA as a whole. Prevaling opinion today follows the interpretation that hyperbaric lidocaine 5\% administered over a microcatheter leads to inadequate mixing and neurotoxic concentrations of the substance. This would not occur with other local anaesthetics with more lipophilic physico-chemical properties and when additional safety measures are taken into account.

Reported incidences of PDPH following CSA in general range widely, differing from <1\% \( ^3 \) to >30\%, \( ^4 \) depending on the particular study conditions. Consideration of this background reveals the exceptionally high rate of PDPH in this study. Several factors may have contributed to increase the occurrence of PDPH, even though their particular impact remains controversial.

The youth of the volunteers (18–30 yr) may be one of the most important risk factors. Similar observations have been made for single-shot spinal anaesthesia with a spinal needle. Without exception, all studies of CSA have recruited older patients and correspondingly observed considerably lower incidences of PDPH. The problem of PDPH after the application of a spinal catheter in the young adult population (18–30 yr) is not sufficiently documented in the medical literature.\(^{10–12}\)

The CSF sampling may also have contributed to the development of PDPH. Various studies have suggested that the replacement of lost CSF affects PDPH. However, the sampling of a total amount of 8.5 ml CSF over a period of 4 h should be completely compensated at the normal CSF production rate (0.35 ml min\(^{-1}\)).\(^{14}\)

It is not clear whether the immediate mobilization of the subjects increased the occurrence of headache. No local anaesthetics were administered and no surgery was performed, in contrast to the clinical application of CSA where patients cannot be mobilized until the motor blockade has completely resolved. There is no evidence of benefit from prophylactic bed rest after dural puncture with a needle.\(^{15}\)

In vitro studies of CSF loss through membrane lesions have indicated that the largest losses occur during the first few minutes, when the lesion size is similar to the cross-sectional area of the needle used. CSF flow subsequently decreases exponentially as the lesion is retracted and sealed.\(^{16,17}\) The intrathecal placement of a catheter over a period of 4 h may sustainably separate the fibres of the membrane and hinder it from retracting immediately after the removal of the catheter. However, the time used here is too short for sufficient sealing effects by local oedema or inflammation around the lesion. Such repair processes are assumed to be responsible for the observation that the PDPH rate following subarachnoid catheter placement in obstetric patients is significantly lower when the catheter is left in place for 24 h after delivery, rather than being removed immediately.\(^{18}\)

According to Cohen’s classification,\(^{6}\) the group differences, expressed as effect size, were large in relation to pain rating (NRS, \( d=1.35 \)) and duration of pain (\( d=0.98 \)). The configuration of the needle tip, which accounts for the sharp cut of the membrane, may be responsible for this. Its size in the through-needle group was 23G and in the over-needle group only 27G, the latter decreasing the cross-sectional area to only 43\%. Reducing the size of the sharp cut and increasing blunt fibre tearing obviously produces a smaller residual aperture after the removal of the catheter. This advantage of the catheter over-needle
technique has been demonstrated in an electron microscope study in post-mortem lumbar dura.\textsuperscript{10} Because of the high overall incidence of PDPH, neither small-gauge spinal catheter system can be recommended in the young adult population (18–30 yr) apart from exceptional circumstances. The results show that an optimization of the needle design can have a significant influence on PDPH in spinal catheter systems, even though the external diameter of the dural penetration remains unchanged. This is encouraging, as further improvements to the needle-tip configuration (e.g. non-cutting) can probably be accomplished. Additional studies in a clinical setting are needed to evaluate the rates and modifying factors of PDPH in patients with spinal catheters.

References