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Original Article

Placement of coiled catheters into the paravertebral space*

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Summary

There are conflicting results with regard to the use of catheter-based techniques for continuous paravertebral block. Local anaesthetic spread within the paravertebral space is limited and the clinical effect is often variable. Discrepancies between needle tip position and final catheter position can also be problematic. The aim of this proof-of-concept study was to assess the reliability of placing a newly developed coiled catheter in human cadavers. Sixty Tuohy needles and coiled catheters were placed under ultrasound guidance, three on each side of the thoracic vertebral column in 10 human cadavers. Computed tomography was used to assess needle tip and catheter tip locations. No catheter was misplaced into the epidural, pleural or prevertebral spaces. The mean (SD) distance between catheter tips and needle tips was 8.2 (4.9) mm. The median (IQR [range]) caudo-cephalad spread of contrast dye injectate through a subset of 20 catheters was 4 (4–5[3–8]) thoracic segments. All catheters were removed without incident. Precise paravertebral catheter placement can be achieved using ultrasound-guided placement of a coiled catheter.

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Paravertebral blockade is a regional anaesthetic technique that can be used for analgesia after thoracic surgery [1–4], cardiac surgery [5], breast surgery [6–8] or upper abdominal surgery [9], or for chronic pain therapy [10]. A thoracic paravertebral block is performed by injecting local anaesthetic solution into the paravertebral space, which contains the thoracic nerves, their branches and the sympathetic trunk.

Unilateral multisegmental anaesthesia after single-shot paravertebral injection of local anaesthetic is a well-established technique [11–13]. However, there are conflicting results with regard to the use of catheter-based techniques because of the variable and often limited extent of local anaesthetic spread within the paravertebral space [14–17]. One explanation could be a discrepancy between needle tip position and final catheter position [18, 19]. A possible reason for this discrepancy concerns the catheter material; catheters in current use are stiff and designed to avoid kinking, and may bypass the initial needle tip position, away from the targeted paravertebral compartment. We designed and developed an alternative catheter, which coils up as soon as it is advanced beyond

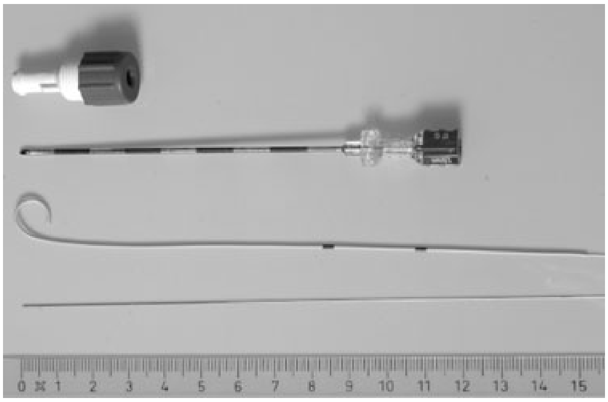

Figure 1 The catheter set contains a 17-G Tuohy needle, guide wire, syringe-connector and catheter with markings. The distal marking indicates that the catheter tip is at the needle orifice, the proximal marking indicates the mandatory introduction depth required to achieve a complete coil.

the needle tip. This allows the catheter tip to remain close to the initial needle tip position [20].

In this imaging cadaver study, we tested the new catheter (Fig. 1) to assess whether: (i) a blindly introduced, self-coiling catheter remained in the paravertebral space after ultrasound-guided needle tip placement [19]; and (ii) contrast dye injected through the coiled catheter reached the intercostal nerves in all cases.

Methods

The newly developed coiled catheter has an outer diameter of 1.0 mm and consists of soft, radio-opaque material. After the catheter emerges from the Tuohy needle tip, a coil forms due to the memory effect of the material. The coil tip is closed and there are three side-holes located on both sides of the catheter coil. The catheter has been designed by the authors of the study and a catheter similar to that prototype has recently been approved for clinical use (SonoLong Curl Sono Set; Pajunk Holding GmbH, Geisingen, Germany).

Ten cadavers in legal custody of the Institute of Anatomy, University of Bern, Switzerland were evaluated with institutional approval for this study. The study was performed according to the ethical guidelines of the Swiss Academy of Medical Sciences for investigations using human cadavers [21]. The cadavers were embalmed using Thiel's method [22], which renders cadaveric tissue similar in texture to that of live humans, enabling sonographic studies to be performed [18, 23, 24].

The cadavers were placed in the prone position on a computerised tomography (CT) table with a cushion under the chest to induce kyphosis. A 17-G Tuohy needle was sited using real-time ultrasound (M-Turbo™; Sonosite, Bothell, WA, USA with a 2–5 MHz curved array transducer): the needle was inserted to contact the posterior-lateral border of a vertebral inferior articular process, using an out-of-plane approach, and then directed laterally past the bone edge and advanced a few millimetres further under direct sonographic views. Correct needle position was confirmed by injecting 1–5 ml saline 0.9% and observing anterior displacement of the pleura (which also expanded the paravertebral space, facilitating catheter introduction). Subsequently, catheters were threaded blindly through the needle until the tip of the guidewire reached the orifice of the needle, indicated when the first marking on the catheter reached the needle hub entrance. At this point, the guidewire was withdrawn at least 3 cm to allow the catheter tip to form a coil, and the catheter advanced a further 2.5 cm until the second marking reached the needle hub entrance. All needles were placed by the same operators (CL, UE), who are experienced in ultrasound-guided regional anaesthesia. The pre-assembled catheter set is shown in Fig. 1. If resistance was felt during introduction of the catheters, a second bolus of saline 0.9% was injected. If resistance continued, the needle was withdrawn and reintroduced at the same level. At least three catheters were placed on each side of the thoracic vertebral column (thoracic levels between T2 and T11) in all 10 cadavers, with a minimum distance between the puncture sites of three vertebral segments.

Analysis of the precise location of catheter tip relative to needle tip was confirmed using CT, after which, the needles were withdrawn and the catheters left in place. One catheter on each side of the thoracic vertebral column was used for the contrast dye portion of the study. According to a computer-generated randomised list, we injected 10 ml diluted contrast dye (Iopamidol, Iopamiro 300; Braco Suissa SA, Mendrisio, Switzerland; diluted 1:5 with saline 0.9%) through the two selected catheters of each cadaver and performed a second CT scan of the thoracic vertebral column to evaluate contrast distribution.

Imaging was performed on a 6-row multislice CT (MSCT) scanner (Somaton Emotion 6; Siemens Medical

Solutions, Siemens, Forcheim, Germany). Raw data acquisition of the thoracic spine was performed with the following settings: 110 kV; 100 mAs; collimation, 6×1 mm. Image reconstruction was carried out in a slice thickness of 1.25 mm with an increment of half the slice thickness, in soft tissue and bone-weighted reconstruction algorithms. Primary image review and 3D reconstructions were performed on a CT workstation (Leonardo, Siemens Medical Solutions, Siemens, Forcheim, Germany). For final evaluation, a special workstation (IDS5; Sectra AB, Linköping, Sweden) was used.

All images were assessed for the following variables by an independent forensic radiologist who was not involved during data acquisition (GH): (i) coil formation – complete/partial/none; (ii) catheter tip/coil position within the paravertebral space – in epidural space/vicinity of neuroforamen/anterior to intervertebral foramen near to sympathetic chain/lateral to intervertebral foramen/extrapleural, close to the intercostal space/not in paravertebral space (epidural, pleural, mediastinal, in the erector muscles of the spine); (iii) distance of the coil tip from the needle tip; (iv) localisation of the main volume (i.e. more than 50% of the total volume) of contrast dye – pre-vertebral/mediastinal/extrapleural along vertebral column/extrapleural intercostal/epidural/intrapleural/in the paraspinal muscles (i.e. behind the paravertebral space).

Normality distribution was tested by using the Kolmogorov-Smirnov test.

Results

Sixty catheters were placed in 10 cadavers (three on each side of the thoracic vertebral column). Ultrasound obsevation and identification of the paravertebral space was straightforward in all cases, enabling ultrasound-guided placement of all needles into the paravertebral space close to the emerging intercostal nerves. Catheter introduction was possible at the first attempt in 52/60 (86.7%) cases. A second bolus of saline was required for two cases. Two catheters could only be introduced after redirecting the needle tip orifice more caudally. Four catheters could only be introduced after reinsertion of the needles at the same puncture level.

The CT analysis revealed that three catheters failed to form a coil and nine catheters formed a partial coil. Forty-three catheter tips were sited in the vicinity of the intervertebral foramen, eight were sited anterior to the intervertebral foramen at the level of the sympathetic trunk, and the remaining nine were sited lateral to the intervertebral foramen in the extrapleural space, close to the intercostal space (Fig. 2). No catheters were misplaced into the epidural space, the pre-vertebral space, the pleural space or behind the paravertebral space (for example, into the paraspinal muscles). In two cadavers (12 catheters), CT-scanning was unavailable until the following day, and the needles were withdrawn to avoid manipulation, but the catheters were left in place. In the remaining 48 cases, the mean (SD) distance from the needle tip to the catheter tip was 8.2 mm (4.9 mm). The median IQR [range]distance from the needle tip to the peak of the catheter coil was 9 (7–12 [5–20])mm. Figure 3 shows an example of a CT reconstruction, with needles and catheters placed into the paravertebral space.

Contrast dye injected through the 20 randomly selected catheters remained extrapleural in all but one case, in which the dye was observed mainly in the muscles behind the paravertebral space even though the catheter coil was sited in the paravertebral space close to the intervertrebral neuroforamen. The extrapleural distribution of contrast dye was mainly located at the level of the vertebral bodies or with a smaller extension at the level of the intercostal spaces. The intercostal nerves were reached in all cases by the contrast. The median IQR [range] cranio-caudal spread of dye was 4 (4–5 [3–8]) thoracic segments; in one case, a significant portion reached the pre-vertebral space. In 11/20 (55%) cases, a small amount of contrast dye (approximately 1 ml) could be detected in the epidural space with a median IQR [range] cranio-caudal spread of 4 (2–7 [1–15])thoracic segments.

Discussion

We have demonstrated that ultrasound-guided, coiled catheter placement enables accurate catheterisation of the paravertebral space and targeting of infusate (in this case, contrast dye) around the intercostal nerves in all cases.

This is the third of three studies detailing catheter placement in the paravertebral space. In our first study, we demonstrated that Tuohy needles could be accurately placed into the paravertebral space using ultrasound, but

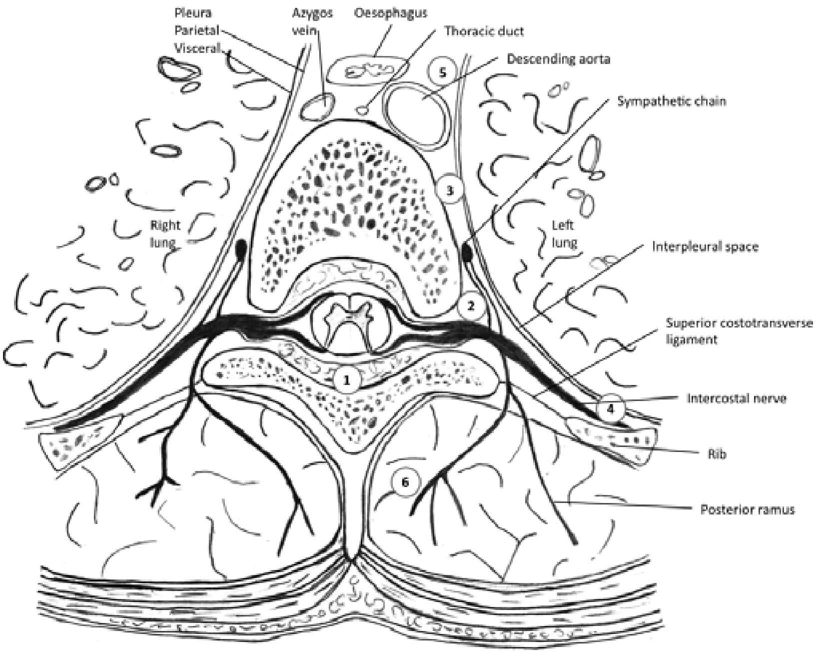

Figure 2 Possible catheter coil positions as evaluated by the radiologist. Catheters coils were found in vicinity of the intervertebral neuroforamen (position 2), anterior to the neuroforamen (position 3) or lateral to this point (position 4).

Figure 3 A reconstructed 3D CT image showing needles and catheters placed in the paravertebral spaces, three on each side of the vertebral column. The catheter coils remain close to the needle tip and lie close to the intervertebral foramen.

that standard catheters were often malpositioned in the anterior paravertebral compartment or into the epidural space [18], possibly as a result of methodological problems with the puncture technique (slightly lateral to medial needle direction) or deep introduction of the catheters beyond the needle tip (5 cm). In our second paper, we developed a simpler approach to the paravertebral space, parallel to the vertebral column with a depth of only 1–3 cm [19]. Again, needle positioning was accurate but the catheters were misplaced in an unacceptable number of cases, with only 12 (17.6%) catheters remaining in the same compartment as the needle tip. The final positions of the classic 'stiff' catheters were highly variable, and were often within the anterior part of the paravertebral space, where reliable coverage of the intercostal nerves by injected local anaesthetic solution was far less likely.

Unilateral, multi-segmental anaesthesia after single-shot paravertebral injection of local anaesthetic solution has been previously reported [11–13, 25]. However, there are conflicting results in the literature concerning the efficacy of paravertebral catheter placement [14, 16, 17], possibly related to difficulties in viewing and guiding the position of the catheter tip using ultrasound [26]. These difficulties are even more prominent when targeting the paravertebral space, as closely situated bony structures reduce sonographic demonstration of the narrow, wedge shaped paravertebral space.

Using a classical blind insertion technique, the final position of 'stiff' catheter tips are not predictable and are suboptimal in 10–40% of cases [27–30]. In this study, none of the 60 introduced soft coiled catheters perforated the pleura or were misplaced into the epidural or prevertebral space. The newly developed pigtail catheter coils after introduction beyond the needle tip and therefore remains close to the needle tip position, all under direct sonographic observation. Placing the needle tip near the intervertebral foramen, which reliably introduces the catheter coil close to emerging nerve roots, offers two advantages over more lateral insertion. Firstly, the extrapleural cranio-caudal spread of injectate (contrast dye in this study) appears to be more extensive. Secondly, the injectate appears more likely to diffuse as far as the epidural space (55% of cases in this study), suggesting that this technique may be able to achieve a continuous epidural block without the need to place catheters directly into the epidural space.

There are concerns about the risk of coiled catheters. During the development of the catheters, a decision was taken to use only one coil to avoid wrapping or knotting of the catheters around nerves. Even if catheters loop the intercostal nerves, withdrawal of the soft catheters should not generate enough force to tear the nerves. Furthermore, it could be argued that using relatively large needles to introduce the catheter could be disadvantageous, but we suggest the contrary, that the larger the introducer needle is, the better its visibility with ultrasound [31], resulting in fewer attempts at insertion. Moreover, we suggest that the use of a Tuohy needle makes intrathecal injection through perforation of the dura at the level of the dural cuff [32] less likely when inserted via the paravertebral space approach we have described, in comparison with either the classical blind approach or the lateral paravertebral approaches suggested by Renes et al. [33].

We accept that there are limitations to this study. The tissue properties of living human subjects are different from cadavers and this may limit the validity of our findings with respect to clinical practice. However, it has been shown recently that among methods of preservation of cadavers, Thiel's embalming method seems to be as close to the situation in the living as is currently possible [34]. Thus, we believe the placement of the needle and the localisation of the catheters should correspond to the situation in living subjects. However, we accept that diffusion rates and absolute dispersal, and therefore clinical effect, may be affected by pharmacokinetic differences between the contrast dye we used and local anaesthetic agents used clinically [17].

We conclude that coiled catheters can be introduced blindly into the paravertebral space through Tuohy needles sited under ultrasound guidance, with a low risk of catheter misplacement outside the targeted compartment. These findings must be tested in further studies before introducing the new coiled catheter into clinical practice, and before comparison with other catheters in a clinical study.

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Competing interests

Pajunk GmBH in Geisingen, Germany is currently manufacturing a catheter according to the prototype catheter described in this present study and this catheter was recently approved for clinical use. During the study, neither funding nor patent licensing arrangements have been signed or discussed between the authors of the study and Pajunk GmBH. However, a non-disclosure agreement between Cédric Luyet and Pajunk GmBH has been formalised.

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