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Published in:
Anaesthesia

DOI:
10.1111/anae.13053

Publication date:
2015

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Rothe, C., Steen-Hansen, C., Madsen, M. H., Lundstrøm, L. H., Heimburger, R., Jensen, K. E., & Lange, K. H. W. (2015). A novel suture method to place and adjust peripheral nerve catheters. *Anaesthesia*, *70*(7), 791-796. https://doi.org/10.1111/anae.13053

Anaesthesia 2015, 70, 791–796 doi:10.1111/anae.13053

Original Article

A novel suture method to place and adjust peripheral nerve catheters*

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Summary
We have developed a peripheral nerve catheter, attached to a needle, which works like an adjustable suture. We used in-plane ultrasound guidance to place 45 catheters close to the femoral, saphenous, sciatic and distal tibial nerves in cadaver legs. We displaced catheters after their initial placement and then attempted to return them to their original positions. We used ultrasound to evaluate the initial and secondary catheter placements and the spread of injectate around the nerves. In 10 cases, we confirmed catheter position by magnetic resonance imaging. We judged 43/45 initial placements successful and 42/43 secondary placements successful by ultrasound, confirmed in 10/10 cases by magnetic resonance imaging.

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Accepted: 1 February 2015
Presented in part at the 4th World Congress of Regional Anaesthesia and Pain Therapy, Cape Town, South Africa, November 2014.

Introduction
Continuous peripheral nerve blocks can provide good postoperative analgesia [1–3]. However, existing techniques for placing peripheral nerve catheters are difficult and often fail. Failure is caused by poor initial placement, the inability to adjust subsequent catheter position and displacement [4]. We have developed a prototype to overcome these three problems (patent pending), which is essentially a large suture with the catheter attached to the base of the needle [5]. The curved needle allows fine precise adjustment, guided by ultrasound. Two holes through which local anaesthetic exits the catheter are sited at a junction in the catheter that is visible on ultrasound, so their position can be adjusted close to the nerve. Primary placement and subsequent repositioning are achieved by pulling either end of the through-and-through catheter, both of which can be secured to the skin.

In this study, we investigated the new device in cadaver legs. We chose the femoral, saphenous, sciatic and distal tibial nerves for catheter placement.

Methods
The director of the body donation programme approved this study of perineural catheter placement in

thawed frozen cadavers, at the University Department of Cellular and Molecular Medicine, Copenhagen.

We have developed prototypes for suture-placement of perineural catheters that consist of three parts: a needle; a catheter; and a hub (Fig. 1). The short bevelled 19-G suture needle is supplied in different lengths and curvatures, joined to a 19-G nylon catheter within a detachable hub. The catheter adjacent to the hub is not patent: its lumen is interrupted by alternating regions of air and glue to increase echogenicity. Two exit holes signal the start of the patent section of the catheter that extends to the Luer-lock injection port. The hub serves as a handle when the needle is advanced in the tissue. It has two channels. One channel holds the catheter. We did not use the second channel during cadaveric studies: it allows local anaesthetic injection through the hollow needle during clinical use.

Five authors (CR, CS-H, MHM, LHL or KHWL) used a 6–18 MHz linear ultrasound transducer to identify peripheral nerves (Flex focus 500 and 8870 transducer; BK Medical, Analogic Ultrasound Group, Peabody, MA, USA). We identified four nerves: the femoral nerve at the level of the inguinal ligament [6]; the saphenous nerve lateral to the femoral artery at mid-thigh level [7]; the sciatic nerve close to its bifurcation in the popliteal fossa [8]; and the distal tibial nerve 2–3 cm proximal to the medial malleolus [9].

We used a 160-mm long needle to place catheters near the femoral nerve, curved with a 75-mm radius. We held the needle shaft to pierce the skin, either lateral or medial to the nerve, after which we held the hub to direct the needle through the tissue. We used an in-plane technique to guide the needle tip anterior or posterior to the nerve. We then advanced the needle tip to exit the tissue, followed by the rest of the needle,

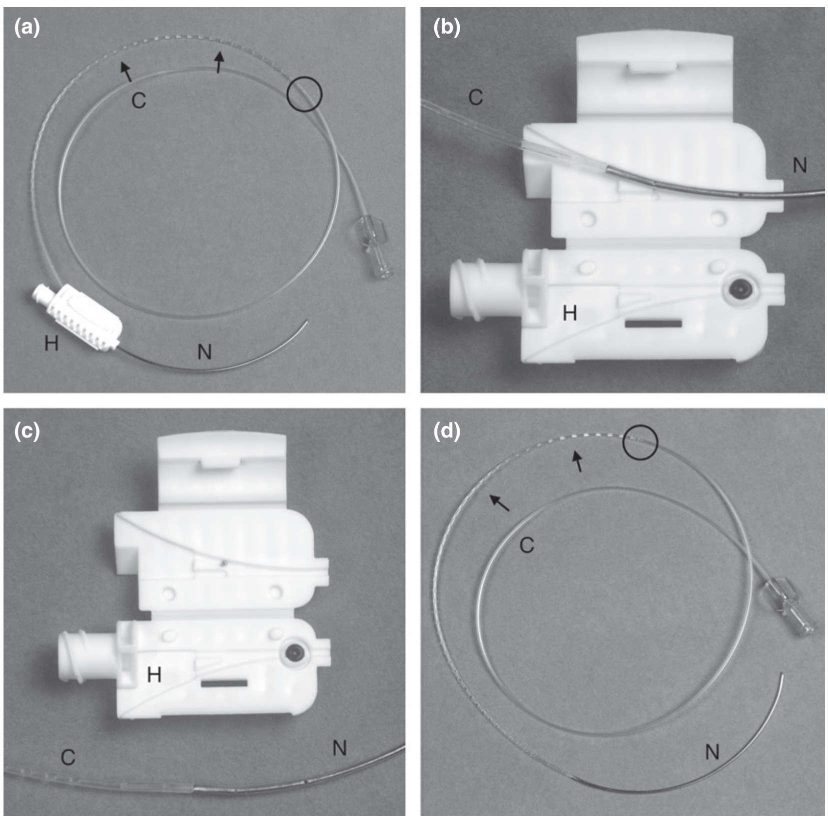

Figure 1 The prototype suture catheter: (a) integrated curved needle-catheter with attached hub; (b) the opened hub showing the needle and attached catheter in situ; (c) the opened hub separated from the needle and catheter; (d) detail of the occluded section of the catheter (arrows) and its junction with the patent catheter section (circle, identifying two exit holes). C, catheter; H, detachable hub; N, curved needle.

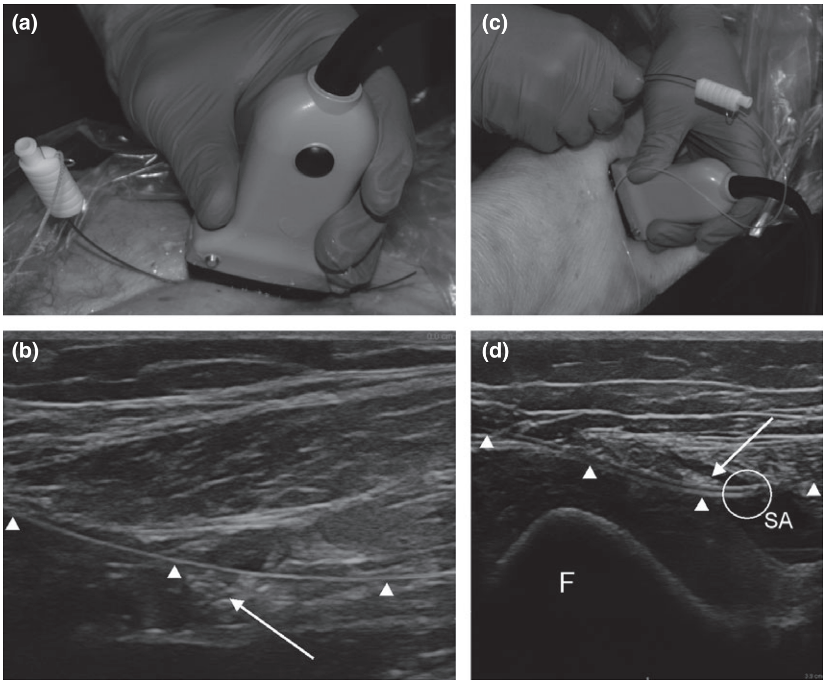

Figure 2 Ultrasound guided placement of femoral (a and b) and saphenous (c and d) peripheral nerve catheters in cadavers: (a) ultrasound probe scanning the needle longitudinally after its insertion from medial to lateral near the inguinal ligament; (b) the ultrasound image of the curved needle (triangles) passing above the femoral nerve (arrow); (c) ultrasound probe position during lateral to medial placement of a catheter below the saphenous nerve at mid-thigh level; (d) the ultrasound image of the catheter (triangles), nerve (arrow) and the two exit holes (circle), to the left of which the catheter is patent and to the right of which the catheter is intermittently occluded, resulting in a striped echogenic appearance. F, femur; SA, saline.

which we then discarded (Fig. 2a and b). The two exit holes in the catheter, which deliver local anaesthetic, lie at the junction between occluded and patent sections. We could see this junction with the ultrasound probe in line with the catheter. We positioned the junction close to the nerve by pulling either end of the catheter. When the five investigators agreed that the junction position was correct, we injected 5 ml isotonic saline through the catheter. We then decided whether we were satisfied with the spread of the injectate.

We inserted, adjusted and tested catheter placement in a similar way for the other three nerves. We used the same needle for catheter placement near the saphenous nerve. We passed the needle medially through the thigh from a lateral entry site. The needle tip passed lateral and anterior to the femoral artery (Fig. 2c and d). We used needles with three curvatures (radii of 75 mm, 100 mm or 400 mm) for sciatic nerve catheter placement. We pierced the medial or lateral side of the distal thigh, and passed the needle tip distal and close to the bifurcation of the sciatic nerve (Fig. 3a and b). We used a 50-mm long needle with 80-mm radius for catheter placement near the distal tibial nerve. We held the needle with a needle holder to pierce the skin, directed from lateral to medial above the ankle. The needle tip passed lateral and anterior to the distal tibial nerve (Fig. 3c and d).

We subsequently displaced all catheters by pulling the distal part at least 5 cm, guided by ultrasound aligned to the catheter. We then repositioned the exit holes near the nerve by pulling the catheter ends. We injected 5 ml isotonic saline through the catheter when the five investigators agreed that the junction was positioned correctly. We then decided whether we were satisfied with the spread of the injectate.

We used MRI (1.0 Tesla Harmony® scanner; Siemens AG, Munich, Germany), with 3D T1 weighted gradient echo sequences, to evaluate the initial and secondary placement of eight femoral and four sciatic

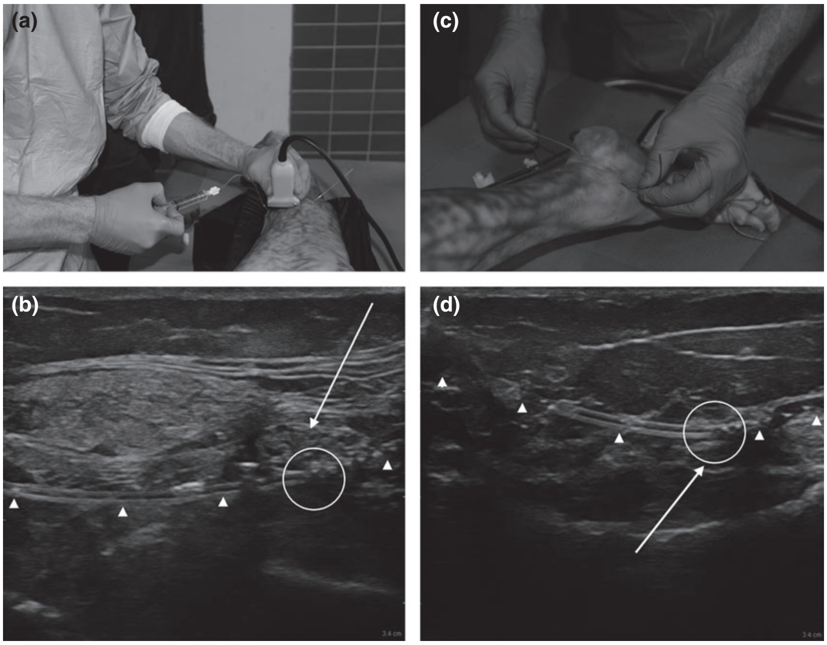

Figure 3 Ultrasound guided placement of sciatic (a and b) and distal tibial (c and d) peripheral nerve catheters in cadavers: (a) ultrasound probe position and isotonic saline injection during placement of a sciatic nerve catheter near the popliteal fossa with the leg prone; (b) the ultrasound image of the catheter (triangles), nerve (arrow) and the two exit holes (circle), to the left of which the catheter is patent and to the right of which the catheter is intermittently occluded, resulting in a striped echogenic appearance; (c) placement of a distal tibial catheter, showing how the injectate exit holes can be positioned by pulling either end of the catheter; (d) the ultrasound image of the catheter (triangles), nerve (arrow) and the two exit holes (circle), to the left of which the catheter is patent and to the right of which the catheter is intermittently occluded, resulting in a striped echogenic appearance.

catheters. Evaluation of the anatomical region containing the nerve of interest required a MRI pulse sequence that provided optimal tissue contrast between injected contrast fluid, nerve and surrounding tissue. We tested available pulse sequences in the MR-scanner software on the head or body array coils (transmit and receive coils). We evaluated the test image for optimal contrast and signal-to-noise ratio by examining a phantom. We used the following settings: T1 inversion time 1100 ms; slice thickness 3.5 mm; field of view 200 mm; repetition time 1740 ms; echo time 3.93 ms; scan time 10 min with a 256 × 256 matrix. This gave an in-plane resolution and voxel size of 0.78 × 0.78 × 0.78 mm. We injected 8 ml isotonic saline containing 27.9 mg gadolinium as gadoterate meglumine (Dotarem; Guerbet, Roissy, France) through the catheter (Fig. 4a–d). We re-evaluated catheter position after secondary placement with 0.44 mg iron oxide (2.5 ml Lumirem; Guerbet) that appeared black in the MRI (Fig. 4b and d). We compared ultrasound images of the catheter position with three-dimensional MR reconstructions.

Results

We placed 45 catheters in 13 cadaver legs on 52 attempts. We were unable to identify with ultrasound two femoral nerves and three saphenous nerves. We abandoned one distal tibial placement owing to lack of time and we deemed the tissue too fragile around one saphenous nerve. We were satisfied with the spread of injectate around all nerves after initial placement, except for one saphenous and one distal tibial injection. We were uncertain whether the nerve was distal tibial on one initial placement, the identification of which became clear on secondary placement after hydro-dissection. We did not reposition two femoral catheters in two cadavers with previously unidentified hip prostheses, seen on MRI scan. We were satisfied with secondary catheter placement and injectate spread in the remaining 43 catheters, except for one saphenous nerve. We

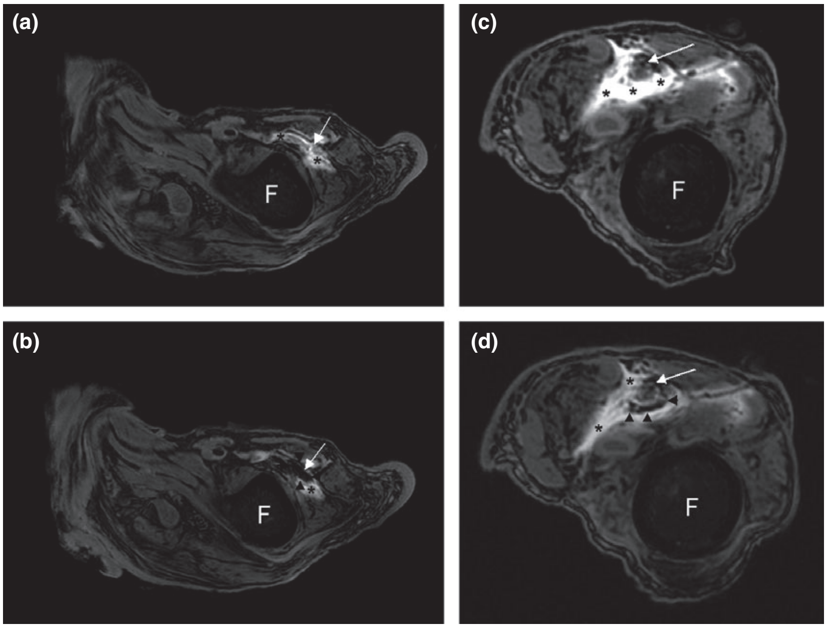

Figure 4 Magnetic resonance images of white injectate (asterisks) after first placement (a and c) and black injectate (triangles) after secondary placement (b and d), with the catheter exit holes near the femoral (a and b) and sciatic (c and d) nerves (arrows). F, femur.

were satisfied with the initial and secondary catheter placements in the six femoral and four sciatic catheters that we scanned twice with MRI (Fig. 4).

Discussion

The use of a suture is the key characteristic of this method. The path of the needle determines the path of the catheter. The two catheter exit holes can be positioned and repositioned next to the nerve by pulling on either end of the catheter: they are sited at the junction of the patent and occluded catheter sections, visible on ultrasound.

Most studies have been conducted with a 'through the needle technique' [3, 10, 11], which confounds interpretation of whether local anaesthetic infused through the catheter is effective as it is also used for 'hydro-dissection' through the needle. Displacement of peripheral nerve catheters is believed to be a major problem with existing techniques [4, 12], for which catheter repositioning is limited to retraction. Our new method allows repositioning in either direction and allows the catheter to be fixed at both ends, which could reduce the rate of displacement.

The needle curvature and stiffness allows one to position the needle, and therefore the catheter, precisely. We found that catheter placement near the distal tibial nerve was not difficult, having used a needle holder to grab and direct the needle. Although it seems counterintuitive, a curved needle has several advantages over a straight needle. A curved needle is inherently more echogenic than a straight needle. Needle tip manoeuvrability is also enhanced compared with a straight needle. This is best illustrated by holding the curved needle in the air. When the hub is twisted, the needle tip changes position, describing an arc compared with the straight needle where the tip stays in the same position. However, one has to practise using a curved needle. The orientation of the needle on insertion is important, because it limits where the needle can exit. The target nerve should lie within the radius of the needle's curvature, otherwise it may not be possible to exit the skin. A small ultrasound probe with a convex footprint could reduce the time it takes to learn the technique.

Standard approaches to some regional blocks might preclude the use of a suture catheter, for instance the interscalene brachial plexus block. Tissue damage is a concern as the through-and-through catheter may act as a string, so we recommend placement anterior to nerves and arteries. We are developing a posterior in-plane technique to place the local anaesthetic exit holes close to the C5 root. The needle is advanced close to and 'lateral' (posterior) to the C5 root, exiting the roof of the interscalene space without passing between the C5 and C6 roots. This should prevent nerve damage in case the catheter is pulled unintentionally. At present, we would not use our technique through the psoas compartment as it is too deep. We believe that the clinical success of this method will be tightly coupled to simplicity of use. We believe that this can be achieved for most blocks, including the transversus abdominis plane block and the pectoral nerve block.

Local anaesthetic leakage away from the nerve may cause catheter failure. This is more likely with 'through the needle technique' as the needle is thicker than the catheter, but it is reduced with 'over the needle techniques', where the catheter is thicker than the needle [13]. The needle and catheter have equal outer diameters in our current device, but we intend to make the catheter diameter slightly larger than the needle. Whether this will reduce or eliminate back leak remains to be investigated.

Our new technique might increase infection rates because the skin is breached in two places and the catheter passes through more tissue. Furthermore, repositioning will always pull one end of the catheter back under the skin. We did not define placement success, so our assessments of placement and saline spread were subjective and the assessors were not blinded or independent. However, spread of injectate around the nerve will always be a surrogate marker for successful catheter placement, which is determined by the absence of pain in patients.

In conclusion, we have used a suture to place catheters for continuous peripheral nerve blocks. Clinical studies are needed to determine the rates of infection and successful blockade.

Acknowledgements

We thank Professor Jørgen Tranum-Jensen for his anatomical advice and Frederik Sonnenborg and Arnt Larsen Lund for improving the prototypes. We thank BK Medical Ultrasound Systems and Transducers for providing ultrasound machines and probes.

CR and KHWL are working with Ferrosan Medical Devices A/S to develop the catheter design. This study was funded by grants from Nordsjællands Hospital, Hillerød, Denmark. No other external funding or competing interests declared.

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