Dislocation rates of perineural catheters: a volunteer study

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Editor’s key points

Background. Dislocation rates of continuous peripheral nerve block are poorly described even though this technique is frequently used in clinical practice. The present study was designed to evaluate dislocation rates over time of interscalene and femoral nerve catheters under defined experimental circumstances. Ultrasound (US) monitoring was used to detect the position of the perineural catheters.

Methods. Twenty volunteers received US-guided interscalene and femoral nerve catheters. The volunteers performed standardized physical exercises in regular intervals and the position of both catheters was examined by US confirmation of the spread of fluid. The maximal time of investigation in each volunteer was 6 h. The main outcome parameters were the overall dislocation rates and the cumulative dislocation rates at a given time point.

Results. We observed an overall dislocation rate of 15% (5% for interscalene catheters, 25% for femoral nerve catheters) and a significant correlation between time and rate of dislocations ($r=0.99$, $P=0.001$). US visualization of the spread of fluid was possible in all cases.

Conclusions. This is the first dedicated evaluation of dislocation rates of peripheral nerve catheters (PNCs) via US investigation. Both movement and time are considerable factors for perineural catheter displacement. US is useful for the performance of PNCs and for the continuous detection of the spread of fluid relative to the nerve and adjacent anatomical structures. Translational research is required to confirm the study results in the clinical practice.

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Continuous peripheral nerve block is a standard anaesthetic technique for perioperative pain therapy.1 2 Despite the broad use of the various techniques for continuous upper and lower limb block, the dislocation rates remain unclear. There are no sufficient reports in the literature regarding this important issue.

Ultrasound (US) is a bedside diagnostic method to observe the spread of local anaesthetic (LA) around neuronal structures.3–5 Peripheral nerve catheters (PNCs) are only irregularly visible in US,6 but the spread of LA which is administered through a catheter can always be detected by US. Thus, it is obvious that this technique should be used for this indication.

The main objective of this prospective, open, and uncontrolled volunteer study was the evaluation of dislocation rates over time for upper and lower limb PNCs in a standardized, experimental study setting. Two PNC techniques were investigated in this study: interscalene and femoral. Both are popular regional anaesthetic techniques in clinical practice, and easily approachable by US. Additional findings were expected regarding the practicability of the detection of PNC positions via US and the mechanism of dislocation of PNC.

Methods

The study was approved by the Ethical committee of the Medical University of Vienna (EK 1121/2011) and by the Austrian Agency for Health and Food Safety (EudraCT...
2011-005530-19). Trial registration was performed via the German Clinical Trials Register (DRKS00003494).

**Screening visit**

Twenty volunteers were included in this study. Each volunteer was scheduled to receive an interscalene and a femoral nerve catheter. Before inclusion in the study, we informed them about the nature, scope, and the procedures of the study and about the particular study-related risks.

Exclusion criteria were defined as follows:

- Anatomical abnormalities of the upper or lower limbs.
- BMI ≥ 30 kg m$^2$.
- Use of non-steroidal anti-inflammatory drugs during the last 2 weeks.
- Known allergy or hypersensitivity to mepivacaine or amino-amide LAs.
- Participation in another clinical study within the last 4 weeks before study.
- Clinically relevant coagulopathy.
- Abnormalities in ECG that are considered clinically relevant like AV-block or bradycardia.
- Inability to perform the standardized physical exercises (see below).

Each enrolled healthy volunteer was scheduled to undergo a general physical examination, including an anamnesis and drawing of blood for the laboratory (red and white blood count, haemoglobin, haematocrit, platelet count, and blood coagulation parameters). In addition, an ECG, arterial pressure, and heart rate were performed (after 5 min rest in supine position). A US investigation of the interscalene portion of the brachial plexus and the femoral nerve in the inguinal area was performed to exclude anatomical variations which may interfere with successful placement of the perineural catheters. The screening visit took place within 3 weeks before the study day.

**Study day**

In the morning of the study day, the volunteers were admitted to the clinical research ward. One 18-G plastic cannula (Venflon™, Becton Dickinson, Helsingborg, Sweden) with a switch-valve was inserted into an antecubital vein. The US-guided performance of continuous interscalene block and continuous femoral nerve block (in direct sequence, all techniques on the left side) was performed (see below). US observations of the spread of saline were performed after each of the four cycles of physical examination.

**US guided performance of continuous interscalene block**

The puncture area and the US transducer were prepared in a sterile manner and a skin wheal was raised with 2 ml Mepivacaine 1% (BBraun Melsungen AG, 34209 Melsungen, Germany). We used the Polymedic® polyplex C90 K US 18G PNC set (te me na, Z.I. des Amandiers, Corrèièrs sur Seine, France) with an 18-G facette tip cannula and a 20-G catheter with one terminal hole with a guide wire. The catheter was marked at distances of 1 cm for determination of the penetration depth.

Once the C5–7 nerve roots were identified by US (SonoSite Edge™, SonoSite, Inc., Bothell, WA, USA) with a high frequency US transducer (38 mm active area, 15 MHz frequency), the puncture was performed as previously described in an out-of-plane technique. After optimal visualization of the nerve roots, the needle was introduced 2 cm cranial the US transducer to increase the subcutaneous distance from the injection site to the nerve structures. Once the tip of the needle was placed between the anterior scalene muscle and the C5–7 nerve roots, 5 ml saline was administered to confirm that the tip of the cannula was in the correct position with a subsequent saline distribution around the nerve structures. Thereafter, the catheter was advanced through the cannula 30 mm beyond the tip of the cannula and retracted under permanent slow saline administration and US guidance until the spread of the fluid was confirmed as optimal relative to the C5–7 nerve roots. The introduction length of the catheter was recorded and the catheter was fixed with sterile transparent tapes (Fig. 1). A 0.2 μm filter was connected at the proximal site of the catheter to provide sterile administration of saline throughout the duration of the study.

**US guided performance of continuous femoral nerve block**

Sterilization procedures and skin wheal were performed, and catheter and US equipment were used as described above. Once the femoral nerve was identified by US, the puncture was performed as described with an out-of-plane needle guidance technique and a needle introduction site 2 cm caudal to the US transducer. Five millilitres of saline were administered to confirm that the tip of the cannula was in the correct position. The catheter was advanced through the cannula 30 mm beyond the tip of the cannula and retracted under permanent slow saline administration and US guidance until the spread of saline was confirmed as optimal (Fig. 2). A 0.2 μm filter was connected at the proximal site of the catheter to provide sterile administration of saline throughout the duration of the study.
spread of the fluid was confirmed as optimal relative to the femoral nerve. The introduction length of the catheter was recorded and the catheter was fixed with sterile transparent tapes (Fig. 2). A 0.2 mm filter was connected at the proximal site of the catheter to provide sterile administration of saline throughout the duration of the study.

Standardized physical exercises and subsequent US investigations
The following standardized physical exercises were performed 60, 120, and 180 min after placement of both PNCs (all time points are relative to the placement and initial US confirmation of the catheters). Between the time points the volunteers had to lie down as still as possible.

- Twenty abductions of the arm up to 90°, 20 anteflexions of the arm up to 90°, and 20 retroflexions of the arm up to 30° (sitting position).
- Ten abductions of the leg with a 45° flexed hip up to 60°, 10 anteflexions of the leg up to 60° with parallel knee flexion (supine position).
- US investigation: administration of 5 ml saline through both catheters under direct US control (interscalene area and femoral nerve area) (supine position).

Thereafter the volunteers performed unstandardized movements including walking, food intake, etc. during a period of 120 min.

Time point 300 min:
- US investigation: administration of 5 ml saline through both catheters under direct US control (interscalene area and femoral nerve area) (supine position).

Positive catheter placement control was defined as contact of the fluid with the C5–7 nerve roots for continuous interscalene and the femoral nerve for continuous femoral nerve block.

In addition, the length of insertion of the PNC was monitored at all time points.
All US-observed procedures were recorded on the internal hard disk of the SonoSite Edge as MPEG4 10 s movies and finally stored on an external hard disk. The movies were evaluated by an anaesthesiologist with extensive experience in US-guided regional anaesthesia who was not otherwise involved in the PNC placement procedure. In cases of catheter displacement (when the distribution of LA was apart from nerve structures in 2D US) the particular catheter was removed immediately. All other catheters were removed after the final US investigation.

Post-study investigations
Twenty-four hours after the removal of the second catheter, volunteers underwent a final examination regarding clinical signs of nerve damage, inflammation, or infection of the puncture areas.

Statistical analysis
Time to dislocation, overall dislocation rates, cumulative dislocation rates at a given time point and spread of fluid were outcome parameters. All data are descriptively presented as mean (sd), median (range), or 95% CI as appropriate. The dislocation rates of continuous interscalene nerve block vs continuous femoral nerve block were analysed using Fisher’s exact test. A value of $P<0.05$ was considered statistically significant. Correlation between the time to dislocation and dislocation rates at a given time were investigated using the Spearman rank order correlation in an explorative manner (because of the low sample size). SPSS 16.0 was used.

Results
All interscalene and femoral nerve catheters were positioned successfully, which was demonstrated by the correct fluid distribution in relation to the relevant nerve structures (Figs 3 and 4).

The median (range) weight, height, and body mass index was 76 (68–85) kg, 182 (165–197) cm, and 24 (18–27) kg m$^2$.

One of 20 (¼ 5%, 95% CI 0.1–24.9) interscalene catheters and 5 of 20 (¼ 25%, 95% CI 8.7–49.1) femoral nerve catheters dislocated during the observation period ($P=0.18$ for interscalene vs femoral nerve catheter dislocation rate). The cumulative dislocation rate was 15% (6 of 40, 95% CI 5.7–29.8). One interscalene catheter was found to be dislodged at 60 min and the spread of fluid was detected in this case inside the anterior scalene muscle. Two femoral nerve catheters were found to be dislodged after 120 min, one femoral nerve catheter was found to be dislodged after 180 min and two femoral nerve catheters were found to be dislodged after the final US investigation. In all of these cases, the spread of fluid was detected superficial to the iliopectineal arch (Fig. 5).

The detection of the spread of fluid was possible in all 186 US investigations which were performed throughout the study. The site of maldistribution of fluid in dislocation cases could be clearly identified in all cases ($n=6$).
There was a significant correlation between the time and rate of dislocations ($r=0.99$, $P=0.001$, Fig. 6).

Data regarding the insertion length of the catheters are presented in Table 1. We did not detect any differences regarding the insertion length in correctly placed catheters when compared with dislocated catheters.

No perineural catheter-related side-effects occurred during the study period or at the follow-up examination.

**Discussion**

The present study investigated dislocation rates of PNCs in volunteers under standardized study conditions via US. We found a 15% overall dislocation rate of interscalene and femoral nerve catheters with a highly significant correlation between the time and rate of catheter dislocation. US was a useful technique to detect the dislocation of the spread of fluid through PNCs.

Despite the broad use of PNCs in the daily clinical practice, valid data regarding the mechanism, dislocation rates, time until catheters dislocate, and the influence of active or passive movements of patients with PNCs are unavailable. Theoretically, dislocation of PNCs can be influenced by various parameters. Catheter designs, the method of catheter placement, the method of fixation of the catheter, individual anatomical conditions, or movements of the patients are possible factors that might influence the effectiveness of PNCs.

All PNC studies are designed with the main focus to investigate pain reduction in the perioperative period. However, because of the fact that all patients in these studies received multimodal pain therapy, inadequate pain control is a problematic parameter to detect the position of the PNC. In contrast, direct visualization of the spread of LA relative to the relevant nerve structures via US is an appropriately useful technique for monitoring the position of PNCs. A large number of experimental and clinical studies confirm the

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**Fig 3** Cross-sectional US images of the interscalene portion (arrows indicate the C5–7 nerve roots) of the brachial plexus below the sternocleidomastoid muscle (SCM) before (A) and after 5 ml fluid (the hypoechoic area is indicated by the oblique grey arrow (a)), which is administered between the C5–7 nerve roots and the anterior scalene muscle. Left side of each image, medial.

**Fig 4** Cross-sectional US images of the femoral nerve (indicated by the oblique white arrows) slightly distal to the inguinal ligament before (A) and after administration of 5 ml fluid (a). The fluid (hypoechoic area) is indicated by the vertical grey arrow. Left side of each image, medial; FA, femoral artery.
The usefulness of US to facilitate the performance of single and continuous nerve-block techniques. Accordingly, US monitoring can also be used to detect the spread of LA relative to nerve structures via a catheter. In fact, the present study showed that US is an appropriate method for the monitoring of the spread of fluid which is administered via a catheter. It was possible to detect the spread of fluid in all 186 US investigations. Moreover, the fluid was also detected in the six cases of maldistribution (i.e. when the LA did not contact the relevant nerve structures).

The US detection of fluid when it is administered through a perineural catheter provides important new insights into the mechanism of catheter dislocation. Clearly, the absolute number of catheter dislocations in the present study is too small for definitive conclusions. The only interscalene catheter dislocation was caused by catheter displacement inside the anterior scalene muscle, and all femoral nerve catheter dislocations were caused by catheter displacement superficial to the iliopectineal arch, which is the deep layer of the inguinal ligament. Thus, reposition of already (clinically) displaced catheters is not possible because of technical and hygienic aspects and an increase of the volume of LA would be without any clinical effect when the tip of the catheter is inside a muscle structure or superficial to a fascia layer.

An interesting observation of the present study is the constant insertion length of the PNCs during the observation period. Therefore, the insertion length of a PNC does not provide any information if a particular catheter is dislocated or not. On the other hand, the constant insertion length of the PNCs in the present study shows that our method of catheter fixation was appropriate. Under consideration of the findings which are described above, US seems to be the only option to detect catheter dislocation via the indirect visualization of the spread of fluid.

We detected an overall dislocation rate of 15% PNCs during the study period of 6 h. There seems to be a tendency that femoral nerve catheters dislocate more often than interscalene catheters (25% femoral nerve vs 5% interscalene catheters). Hip movements cause more direct transmission to the femoral nerve catheter than shoulder movements to the interscalene catheter, which is inherent to the system. In particular walking with femoral nerve catheters could be specified as an important reason for catheter dislocation. We observed in two cases dislocation of femoral catheters after unstandardized movements (e.g. walking), which is not an obvious increase of dislocation rates over time in comparison with standardized physiotherapy. Anyway, free walking will be a rare situation in patients with femoral nerve catheters which is attributable to quadriceps weakness.

This dislocation rate of PNCs in this study is higher than described in the literature. One reason for this difference to the previous literature is the method we used to diagnose catheter dislocation. Another explanation is the experimental study design. The study setting of immediate controlled movements imitates the clinical practice to some extent. Particular surgical procedures require immediate postoperative physiotherapy such as frozen shoulder surgery or continuous passive motion therapy after knee surgery. Other surgical procedures require postoperative immobilization, and it seems to be obvious that PNCs in those patients are associated with...
lower dislocation rates. Thus, the overall dislocation rate of PNCs in a mixed surgical patient population could be lower than detected in the present study. We believe that dislocation rates of PNCs could be more common than described in the previous literature, at least in patients undergoing physiotherapy. Thus, translational research is required to reinvestigate our results in a clinical setting.

The highly significant correlation between time and rate of dislocations (Fig. 6) is another mentionable finding in this study. We cannot predict if this trend exceeds the observation period of 6 h, but this result confirms the assumption that PNCs dislocate when patients are mobilized. Consequently, the monitoring of the spread of LA via US during the time of usage of PNCs should be considered.

The main limitations of this study are the administration of saline through the PNCs and the subsequent lack of a clinical block evaluation. Both factors are caused by the particular study design with repetitive standardized exercises in volunteers. The standardized exercises were performed in intervals of 60 min followed by 2 h of free movement to limit the overall investigation time. Repetitive administration of LA in intervals of 60 min would be impossible for pharmacokinetic and pharmacodynamics reasons. Another possible limitation of the present study design is the exclusive investigation of bolus administration of fluid via the PNCs. Both continuous and bolus administration of LA are described for continuous bolus administration of fluid via the PNCs. Both movement and time are considerable factors for perineural catheter displacement. US is useful for the performance of PNCs and for the continuous detection of the spread of fluid relative to the nerve and adjacent anatomical structures. We therefore recommend the use of US for the detection of a correct spread of LA through PNCs. Translational research is required to confirm the study results in the clinical practice.

Authors’ contributions

D.M., P.M. and M.Z. contributed equally to the conception and design of the study, analysis, interpretation of the data and drafting of the manuscript. M.Z. calculated statistics. M.Z. and M.W. (study nurse) contributed equally to the acquisition of the cases. P.M., L.T., M.L. (medical student) and M.W. (study nurse) contributed equally to the practical performance of the cases.

Declaration of interest

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