Sonographic Identification of Needle Tip by Specialists and Novices

A Blinded Comparison of 5 Regional Block Needles in Fresh Human Cadavers

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Background and Objectives: Needle visibility using ultrasound remains problematic at steep insertion angles. Despite modified techniques, steep approaches are still needed, particularly in the obese, neuraxial anesthesia or pain blocks around the spine. We describe a novel technique for objective assessment of needle-tip identification and present data on a new needle.

Methods: Five needles were compared for accuracy of tip position identification. Pajunk facet-tipped, Tuohy-tipped, Polymedic Ultrasound, Hakko EchoStim, and a new intermittently textured needle (T). Static ultrasound images were obtained of the needles in first-thaw, unembalmed cadavers at shallow, moderate and steep angles. Actual tip position was defined. Images were presented in blinded, random order to 10 experienced and 10 novice anesthetists who estimated tip position. Distance between true tip position and estimated position was measured ("tip error"). Secondary objectives included subjective measures of visibility and differences between needles at shallower insertion angles and between novice and expert observers.

Results: At steep angles, study needles varied significantly with regard to tip error ($P < 0.0001$). Needle T scored highest for confidence and subjective visibility at moderate and steep angles. There was no significant difference between novice and experienced anesthetists for tip error or visibility. Experts were more confident in their estimates.

Conclusions: Needle T demonstrated good properties even at steep insertion angles. Tip location was accurate, and observers rated it highly visible. Ability to identify needle-tip position can be objectively assessed.

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Ultrasound guidance for regional anesthesia enables visualization of relevant anatomy during peripheral nerve blockade. Many of the potential benefits, however, are dependent on visualization of the block needle. Identification of needle-tip position is important but may be difficult, especially at steeper needle insertion angles.[1–3]

Previous studies in regional anesthesia have investigated the visibility of a variety of needles, some of which have been specifically modified to improve echogenicity,[1,4] and one of which has used a piezoelectric actuator to enable visualization using color Doppler.[5] Assessments of needle shaft and tip visibility have mainly included subjective assessments by observers, although 1 study examining regional anesthesia needles describes objective measures of needle brightness using pixel intensity calculation.[3] Substrates have included water bath models,[4] synthetic phantoms,[3,6] and animal tissue.[4]

The purpose of this study was to compare a variety of regional anesthesia needles using an objective measurement of the accuracy with which clinicians were able to localize the needle tip on static ultrasound images. Fresh, unembalmed human cadavers were used to optimally represent the heterogeneity of tissue acoustic interfaces seen in clinical practice.

The primary study objective was to establish whether at steep angles of insertion any difference could be observed between the study needles with regard to the accuracy and confidence of tip localization on ultrasound imaging. Secondary objectives included investigation of differences between the needles at moderate and shallow angles and differences between novice and expert groups.

METHODS

The study was conducted after ethical approval from the Fresh Frozen Cadaver Committee of the University of Western Australia has been obtained. The primary aim of the study was to perform an objective assessment of tip localization using 5 regional anesthesia needles, including one still in development, in human cadavers.

Study Needles

Four of the 5 needles tested are marketed specifically for use in regional anesthesia.

1. 20-Gauge Pajunk (Geisingen, Germany) UniPlex Nanoline, facet tip (PF)
2. 18-Gauge Pajunk PlexoLong Nanoline, Tuohy tip (PT)
3. 20-Gauge Polymedic (te me na, Carrieres sur Seine, France) Ultrasound, facet tip; echogenic coating last 2 cm of shaft (PM)
4. 21-Gauge Hakko EchoStim, facet tip; ultrasound reflectors distal shaft (E)

The fifth, needle T (textured needle), has recently been developed locally by one of our anesthesia trainees. It features texturing of the majority of the needle shaft, with an untextured segment 5 mm in length, 5 mm from the tip of the 20-gauge needle. This modification is designed to assist the operator to identify whether the entire length of the needle is in view, that is, whether the tip is truly imaged. The use of pattern recognition

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The anesthesia trainee who designed and made the prototype needle T worked within the same Department of Anesthesia as the authors. He was not given any opportunity to contribute to the design, execution, data analysis, or conclusions of the study. The authors have no financial or other interest in the needle. The echogenic technology used in needle T has been adopted by Pajunk, and with slight modification is now marketed as the SonoPlex Nanoline regional anesthesia needle. The authors have no financial or other affiliation with Pajunk.

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attempts to improve the confidence that what is being seen is the whole length of the needle. It appears sonographically as a "white/dark/white" pattern. This is clearly seen in the example ultrasound image of this needle (Fig. 1; bottom left). The texturing is specifically orientated to increase reflection of ultrasound at steeper insertion angles when it is needed most. At shallower angles, the needle itself reflects sufficient ultrasound to be visible, as with virtually any needle. The 5-mm untextured segment also demonstrates how the needle would appear without the surface treatment. The technology in this prototype needle has been slightly modified since study completion and is now marketed as the Pajunk SonoPlex Nanoline regional anesthesia needle.

The Hakko EchoStim (needle E; Havels, Cincinnati, Ohio) also has a design aimed at enabling identification of the needle tip; 3 "corner cube reflectors" (angled indentations of the needle shaft) are located equally spaced (1 mm apart) on the shaft. The needle tip is 2.5 mm from the most distal reflector. At steep angles where the majority of the needle shaft may be difficult to see, the reflectors are visualized as 3 bright dots on the ultrasound image enabling identification of tip position even if the needle shaft is not completely seen (Fig. 1; bottom right).

Needles PF and PT are those currently used as standard for regional anesthesia in the study center. The other needles were selected as representative of designs aimed at increasing needle visibility under ultrasound. Example images of all study needles at moderate insertion angles are shown in Figure 1.

Image Acquisition

All images were generated using a SonoSite M-Turbo system (SonoSite, Bothell, Wash), high-frequency 13- to 6-MHz linear array transducer, standard ultrasound gel, and variable angle needle guide (CIVCO, Kalona, Iowa). Image depth and software settings ("nerve" and "resolution") were kept constant. Needles were inserted into the subgluteal region of first-thaw, unembalmed cadavers, avoiding areas of previous needle insertion, to a needle depth of 4 cm. We standardized the length of needle inserted and isolated the angle of insertion as the only variable. A protractor was used to confirm needle insertion angle relative to the skin. No attempt was made to place the tip next to any particular structure as this may have provided additional information about tip location to observers. The subgluteal region was used to provide adequate muscle depth, allowing steep insertion angles within the same area as shallow angles. Most needle trajectories in clinical practice will pass through muscle to the nerve; hence, this was chosen as the best tissue in which to image the needle. The depth would be comparable to infraclavicular or sciatic blocks, both of which often require steep approach angles, depending on technique.

A total of 45 images were obtained, consisting of 3 images for each test needle at 3 different insertion angles: steep (55–65 degrees), moderate (35–45 degrees), and shallow (15–25 degrees) relative to skin. The shallow angle would be comparable to those required for interscalene or supraclavicular blocks. The moderate angle would be similar to that used for a femoral nerve block. All images were generated by 1 researcher experienced in the use of ultrasound for regional anesthesia (G.H.). Needle and transducer were manipulated to obtain the best image of the needle and bevel in a long-axis view before saving. The 2 authors marked their best estimate of the needle-tip position based on the dynamic study, hydrolocation techniques if necessary, and their expertise. For simplicity of expression, this will be described as "actual tip position" throughout the study, although this will be discussed in the

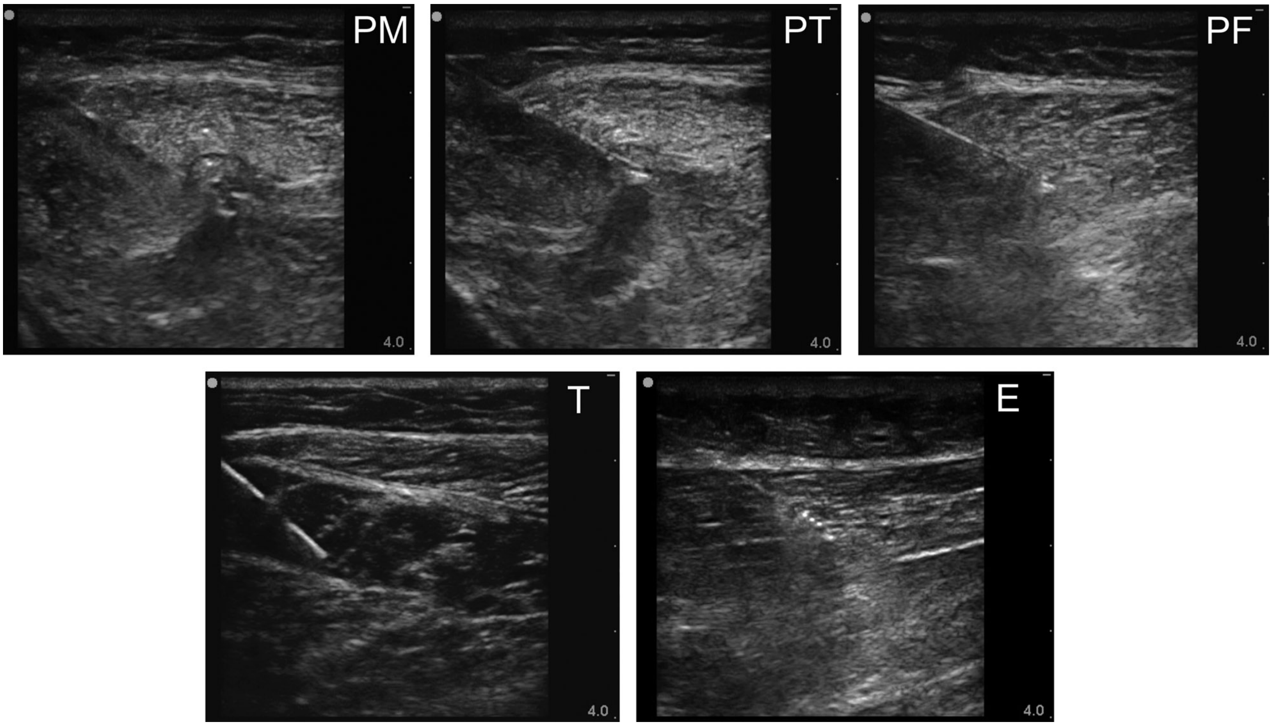

FIGURE 1. Example sonographic images of study needles in cadaveric tissue. The image of needle T (new textured needle; bottom left) demonstrates the white/dark/white pattern of the textured shaft. The image of needle E (Hakko EchoStim; bottom right) shows the 3 bright dots from the ultrasound reflectors near the tip.

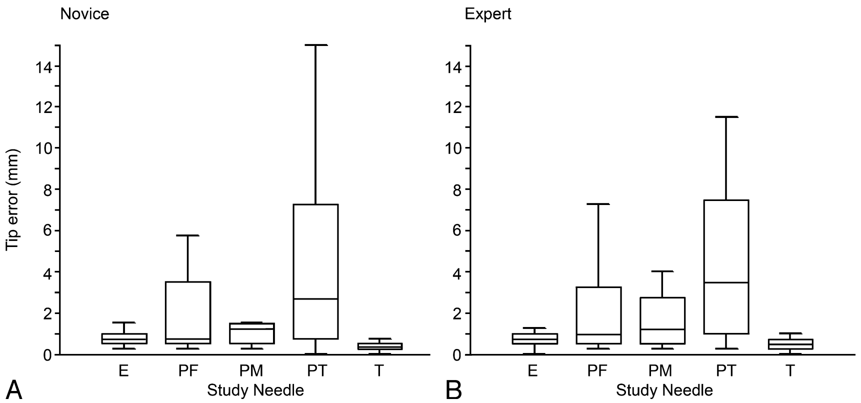

FIGURE 2. A and B, Tip error (in millimeters) for needles at all insertion angles. The horizontal line represents the median, the box represents the interquartile range, and the error bars represent the 90th centiles.

limitations. Images were saved both with and without the tip marked for use in the presentation.

Image Review by Clinicians

Twenty clinicians agreed to participate. Each received a brief standardized introduction during which they were shown the study needles, their characteristics, and example ultrasound images of each needle. Ten of the clinicians were fellows or specialists experienced in the use of ultrasound for regional anesthesia ("expert" group); the other 10 were trainees within or before their first year of anesthesia training ("novice" group).

Study images were digitally stored and presented in random order as a PowerPoint presentation (Microsoft Corporation, Redmond, Wash). The presentation was set up so that the 2 identical images (with and without the tip marked) were exactly superimposed, the unmarked on top. The observer was asked to move a marker on the screen to precisely where they felt the tip was located on the unmarked image and to express the confidence in their estimate ("very," "moderately," "not") for each image. They also gave a subjective view on the overall needle visibility for each image ("not seen," "poor," "acceptable," "very good"). Observers were not told which needle or insertion angle was used for any image. Presentations were viewed on a single, 15-in Mac Book Pro (Apple, Cupertino, Calif), under standard lighting conditions. In this way, image quality was felt to reproduce that seen on the ultrasound machine screen, rather than using printed images. No time limit was imposed, and all observers viewed all 45 images. At the end of the assessment, the unmarked images in the presentation were all deleted, leaving the marker overlying the concealed marked image. After completion of this exercise, the distance between estimated and actual needle-tip positions ("tip error") was measured for each image. Given the image magnification on the screen, we considered marker placement and measurements accurate to 0.25 mm. Microsoft Excel (Microsoft Corporation) was used for data input and Statview (SAS Institute Inc., Cary, NC) for analysis. Tip-error data were skewed and described using median and interquartile range. Where hypothesis testing was performed, a Kruskal-Wallis or Mann-Whitney *U* test was used where appropriate. Subjective

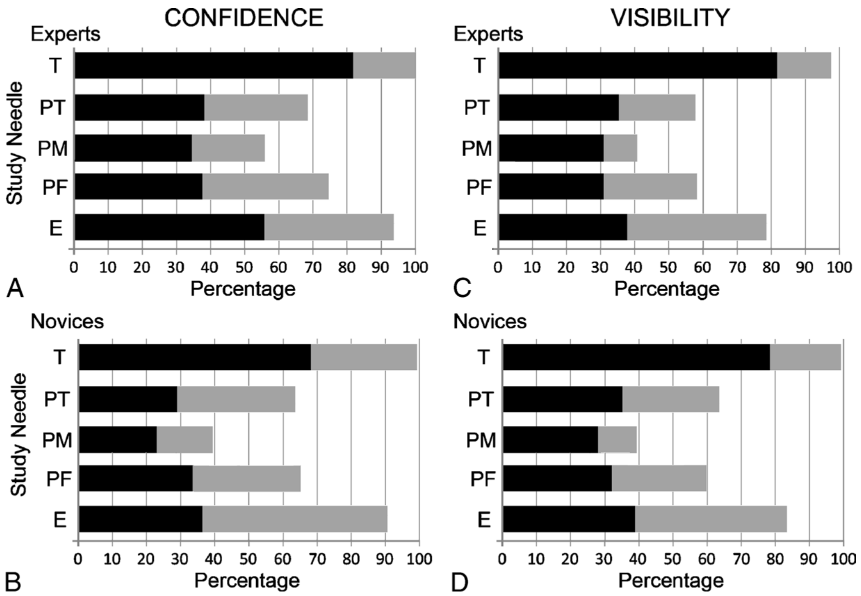

FIGURE 3. A and B, Percentage of confidence estimates rated "very confident" (black) or "moderate" (gray) for each study needle. C and D, Percentage of visibility estimates rated "very good" (black) or "acceptable" (gray) for visibility, for each study needle.

estimates of confidence and visibility were analyzed using χ^2 test. Where Kruskal-Wallis tests, or n $\times$ 2 χ^2 tests, indicated a significant difference, further analysis was performed with Mann-Whitney *U* tests, or 2 $\times$ 2 χ^2 tests, using a Bonferroni correction to adjust for multiple simultaneous comparisons.

RESULTS

Objective Assessment of Tip Error

Twenty clinicians viewed the 45-image presentation. In 18 of 900 estimates, the marker was left in the default position, as the clinicians had no idea where to place it and stated that this was their "best guess" position (E: n = 1, PF: n = 3, PM: n = 8, PT: n = 6, T: n = 0). No numerical value for tip error was imputed to these observations. For statistical treatment, the observations were ranked higher than the largest observed value.

There were statistically significant, but clinically unimportant, differences in tip error at shallow and moderate angles (all medians and 95% confidence intervals, <1 mm) except for needle PM (median, 2.4; 95% confidence interval, 1.25–5.75). Data for steep angles are presented graphically in Figure 2, split according to the experience of the assessor. Needle T had significantly less tip error compared with all other needles ($P < 0.001$). The result for each needle is based on 30 novice or 30 expert observations.

Subjective Assessments

Observers consistently rated needle T as the most visible and were more confident with their estimates for this needle than for all others. We combined data for all insertion angles because, in clinical practice, a needle will be used at all angles, and assessment should take this into account. These data are shown in Figure 3. Because the purpose of this study was specifically to assess the needles at steep angles, we present these confidence estimates in Figure 4. This shows a marked difference between needles at steep angles.

Novice Versus Expert Anesthetists

Figure 2 shows that novice and expert groups displayed similar accuracy in tip position estimates. Figures 3A and B show that the expert group displayed slightly higher levels of confidence in their estimates than did novices for all needles (P = 0.001). There were no differences between novice and expert groups in subjective needle-visibility scores (P = 0.83) as shown in Figures 3C and D.

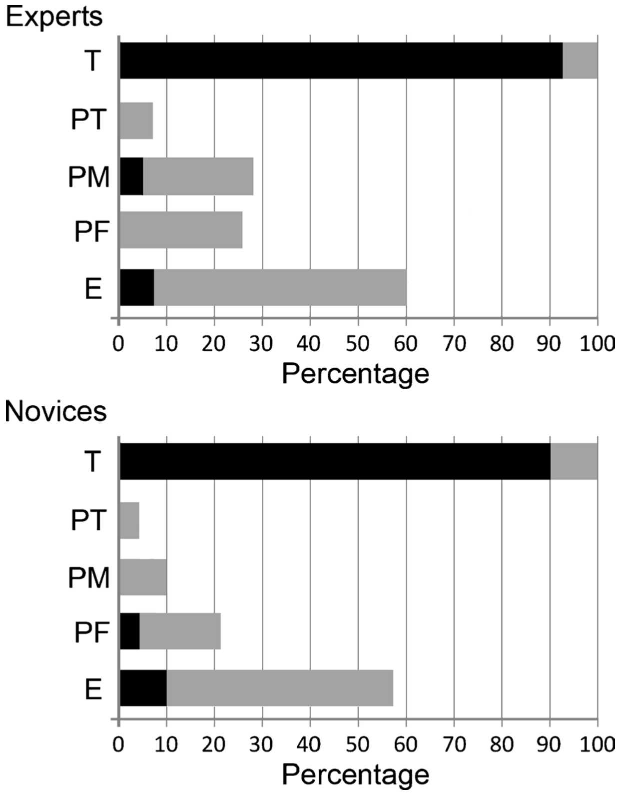

FIGURE 4. Percentage of confidence estimates rated "very confident" (black) or "moderate" (gray) for each study needle at steep angle only.

DISCUSSION

Development of needles for use in ultrasound-guided regional anesthesia has focused on technology to optimize needle visibility. Despite these efforts, needle visualization at steep insertion angles remains problematic. Modified approaches to some blocks have enabled shallow needle angles to be used, thereby improving needle visibility during the block. However, some deeper nerves still require a steep angle of approach. This is likely to become more frequent with the increasingly obese population and the increasing interest in ultrasound-guided neuraxial anesthesia or nerve blocks for chronic back pain. Most previous studies have used only subjective measures to assess needle visibility, most frequently based on the ability of the clinician to see the shaft of the needle down to what they believe to be the tip. It is possible that, in both experimental and clinical situations, the clinician may think they have seen the full length of the needle in error, because of the angle of the ultrasound beam being unintentionally oblique relative to the needle. This error could potentially increase the likelihood of unintentional injury to neural or other surrounding structures with obvious safety implications.

We have described a novel method to provide an objective measure of the accuracy with which a group of clinicians was able to assess needle-tip position using a variety of needles in unembalmed human cadavers.

The high levels of accuracy with which needles T and E were identified at steep angles of insertion may be related to the fact that these 2 needles have specific design modifications that are intended to enable the clinician to be certain about the tip location rather than to simply optimize shaft visibility. Despite relatively small differences between the two in tip localization accuracy, clinicians were more confident in estimating the position of needle T than of needle E. We speculate that increased clinician confidence may speed up learning curves and promote increased uptake of regional anesthesia.

Consistent with previous work, our study supports the view that all needles are relatively easy to visualize at shallow insertion angles. Although tip error was statistically different between needles at shallow angles, the clinical significance is unlikely to be great, given the high levels of accuracy with which all were identified. For this reason, we have not presented every observation.

A surprising finding was that needle PT performed worse than all other needles at a steep insertion angle, despite its larger diameter. This is in contrast to previous work that has suggested that larger-gauge needles are more easily visualized than smaller-gauge ones.[3,7] This discrepancy seems to be limited to steep insertion angle only. At shallow and moderate angles, needle PT performed similarly to the other needles. Apart from needle gauge, the other difference between needle PT and all the other study needles is the Tuohy tip. This tip shape may be less clearly identifiable at steep angles than the facet tip.

Comparison of novice and expert groups showed no significant differences in tip error or visibility rating, although the experts were more confident in their estimates. The lack of difference in tip error may result from the fact that the test was a nonclinical setup, although it is also possible that this finding reflects a genuine lack of difference between experts and novices in needle identification skills. We speculate that experienced regional anesthetists probably gain much of their information about needle position through other factors such as tissue movement in real time. The ability to identify needle tip on a static image does not seem to be a discriminator between the groups as it relates more to the properties of the needle than the observer. The use of static images was specifically used to test the properties of the needle in isolation.

Our cadaveric study has a number of limitations. Our criterion standard for identification of actual tip position was reliant on 1 operator, in agreement with the other author. Neither was blinded to which needle was being examined as this would have been difficult to achieve. Unintentional bias on the part of the operator therefore cannot be excluded. Static rather than real-time images were used. This differs from the clinical context where the operator would be able to gain additional information such as movement of tissue planes. Tip error is based on the difference between the authors' and the observers' estimates of tip position. Because the authors had the benefit of real-time scanning, we have assumed their estimates to be the closest to the actual tip position. The study design enabled all observing clinicians to view and rate identical images. Differences between operators were excluded, and it could be argued that the properties of the needle were tested in relative isolation. This is likely to account for the lack of observed difference between novice and expert groups in identifying tip position. Our study was performed using cadaveric tissue, not live humans. This is likely to be more representative than studies using animal tissue or gel/water–based phantoms but could still affect the sonographic visibility of textured or coated needles. These results may be different from that in clinical practice. Our use of first-thaw, unembalmed cadavers was an attempt to minimize this possible limitation.

On the basis of this investigation, it seems likely that needles designed with tip identification in mind, rather than shaft visibility only, may be more accurately localized using ultrasound. This is especially important at steep insertion angles. Needle T was the most promising of those tested for use at steep angles. It is more accurately identified, and clinicians are significantly more confident in their estimates of tip position. Further clinical investigation in patients is under way with a commercially available version of this needle (Pajunk SonoPlex Nanoline) to determine whether the advantages demonstrated in this study are translated into efficacy and safety in clinical practice.

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