Needle Echogenicity in Sonographically Guided Regional Anesthesia
Blinded Comparison of 4 Enhanced Needles and Validation of Visual Criteria for Evaluation

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Objectives—Needle visualization is important for sonographically guided regional anesthesia procedures. Needle characteristics that improve needle visualization are therefore important to anesthesiologists. This study compared several echogenic needle designs by defining characteristics of needle echogenicity and assessing regional anesthesiologist preferences for these characteristics across various needle angles.

Methods—Twelve blinded regional anesthesiologists graded 5 randomized block needles (1 nonechogenic control and 4 echogenic) on 4 predefined characteristics (overall brightness of the needle, overall clarity of the needle, brightness of the needle tip, and clarity of the needle tip). In-plane needle images in a gel phantom were obtained at 4 needle angles (15°, 30°, 45°, and 60°). Participants rated specific needle characteristics for each needle at each angle and then ranked their overall needle preferences.

Results—Significant differences in all 4 needle characteristics were found across needle types (P < .01). Clarity of the needle tip was significantly associated with overall needle rank (P = .009). Other needle visualization characteristics were not significantly correlated with needle rank. The SonoPlex Stim needle (Pajunk Medical Systems, Tucker, GA) was rated highest in all 4 predefined needle characteristics as well as overall needle rank.

Conclusions—This study shows that anesthesiologists prefer certain visual characteristics of needles used in sonographically guided regional anesthesia procedures. Specifically, needle tip clarity most closely predicted clinician needle preferences. These results support the idea that all echogenic needle designs do not uniformly enhance needle visualization. Further studies are needed to determine whether needles with superior tip clarity predict not only clinician preferences but also improved sonographically guided regional anesthetic outcomes.

Key Words—anesthesiology; brightness; clarity; echogenicity; needle

Needle echogenicity and visualization characteristics are important to sonographically guided regional anesthesia procedures because these techniques require simultaneous visualization of the needle and neuroanatomy during placement of local anesthesia. Needle design characteristics that improve echogenicity and the proceduralist’s continuous visualization of the needle have the potential to affect the speed, safety, and success of regional anesthesia. However, previous studies have shown a fundamental limitation of ultrasound physics: the deterioration of needle visualization at steeper angles of insonation due to increased reflective signal losses. In 2000, a team of interventional radiologists found that “echogenic brightness units” of standard needles decreased...
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below the threshold of good visibility with steeper needle angles. Recognizing this problem, manufacturers have introduced echogenic needle modifications intended to improve visualization at steeper angles. For example, a previous investigation showed that “texturing” of the needle increases needle visibility. Other examples of echogenicity-enhancing features have included “dimpling,” “roughening,” “scoring,” “wire guides,” “Teflon,” and “polymer coating.”

Despite the number of studies evaluating echogenic needle modifications, to our knowledge, no study has correlated predefined echogenic needle characteristics with clinician preferences for needles. Although needle echogenicity has been linked to subjective and objective assessments of needle brightness at multiple needle angles, there has not been an evaluation of detailed, clinically relevant characteristics of needle echogenicity among providers routinely performing regional anesthesia. The intent of this study was to compare several new echogenic needle designs introducing predefined characteristics of needle echogenicity (needle brightness, needle clarity, needle tip brightness, and needle tip clarity) and assess regional anesthesiologist preferences for these characteristics across various needle angles.

Materials and Methods

After Mayo Clinic Institutional Review Board approval was obtained, participants were recruited to evaluate needle image characteristics of a control (nonechogenic) needle and 4 echogenic regional anesthesia needles at 4 different needle angles. Participant inclusion criteria were fellowship training in regional anesthesia and at least 5 years of experience performing sonographically guided peripheral nerve blocks. All participants were blinded to the needle manufacturer and model.

Study Needles

Manufacturers of echogenic regional anesthesia needles were contacted by letter and invited to send samples for use in the study. B. Braun Medical, Inc (Bethlehem, PA), Pajunk Medical Systems (Tucker, GA), and Havel’s Inc (Cincinnati, OH) elected to participate. One 5-cm control needle (nonechogenic insulated needle) and four 5-cm echogenic needles were sonographically evaluated in a Blue Phantom (Redmond, WA) Select Series sonographically guided nerve block model. The following needles were evaluated: (1) B. Braun Stimuplex A (control, 22 gauge, insulated, 30° bevel); (2) B. Braun Stimuplex D Plus (echogenic, 22 gauge, insulated, 15° degree); (3) Pajunk SonoPlex Stim (echogenic, 22 gauge, insulated); (4) Havel’s EchoStim 4x4 (echogenic, 21 gauge, insulated); and (5) Havel’s EchoBlock 4x4 (echogenic, 21 gauge, noninsulated, 30° bevel).

Image Acquisition

In-plane needle sonograms were obtained by one investigator experienced in sonographically guided regional anesthesia using a linear probe (12L, 8–13 MHz, LOGIQ e; GE Healthcare, Milwaukee, WI). Each needle was inserted in a single pass, bevel toward the probe, to its hub at predetermined angles into a new gel phantom without prior needle tracks. The use of ultrasound machine protractor software ensured accurate needle trajectory lines at each of the 4 study angles. Needles were inserted at angles of 15°, 30°, 45°, and 60° relative to the probe-phantom interface to demonstrate imaging performance at various needle trajectories from shallow to steep.

The ultrasound probe was aligned to show the maximum needle length. The following parameters were initially adjusted for optimal imaging but remained constant during all data acquisitions: Gain, Edge Enhance, Tint Map, Dynamic Range, Automatic Optimization, XBeam, and NerveBlock setting. To reduce additional sources of image degradation, plastic probe covers were not used. Uncompressed digital videos showing in-plane needle imaging were obtained using the cine mode function for each needle and insertion angle. Videos were then reviewed on the sonographic monitor, frame by frame, and a single optimal in-plane needle image showing the full length of the needle was saved as an uncompressed file for printing and evaluation. Study investigators (H.P.S., K.A., J.A.D., and H.M.S.) collectively reviewed and selected the optimal image of each needle at each angle. Optimal images obtained are shown in Figure 1.

The probe frequency and image depth were adjusted depending on the angle of insertion to simulate clinical practice (Table 1). The specific frequency and depth chosen for each degree of angle insertion were chosen to achieve the optimal needle image quality and to ensure complete visualization of the needle shaft and tip, simulating clinical practice as closely as possible. These parameters were consistent for all needles.

Needle Evaluation

Images were printed in color on high-quality photo paper and shown to the study participants individually. Each participant graded the echogenic needles compared to the nonechogenic needle at each insertion angle on 4 characteristics: (1) overall brightness of the needle; (2) overall clarity of the needle; (3) brightness of the needle tip; and (4) clarity of
the needle tip. Brightness was defined as the ability to see the needle. Clarity was defined as the ability to distinguish the needle outline from the surrounding medium. The needle tip was arbitrarily defined as the distal 1 cm.

Participant grading was in reference to the nonechogenic control needle using the following scale: 0, unchanged; 1, marginally better; 2, moderately better; and 3, significantly better. Participants then ranked the needles based on preference for use in sonographically guided regional anesthesia (overall performance: 1 = worst; 4 = best).

Statistical Analysis
Overall needle rank was calculated as median and interquartile range (4 = highest; 1 = lowest). Comparisons across needle types were conducted using analysis of variance and the Pearson test on ranks. Post hoc subgroup analysis was performed using the Tukey Kramer honestly significant difference test after transforming the data to continuous variables. A logistic regression model was fitted using 4 characteristics (overall brightness of the needle, overall clarity of the needle, brightness of the needle tip, and clarity of the needle tip) versus overall needle rank. All statistics were performed with JMP version 9.0.1 software (SAS Institute Inc, Cary, NC). Statistical significance was regarded as $P < .05$.

Results
Twelve anesthesiologists met inclusion criteria and were recruited for study participation. All 12 anesthesiologists completed all evaluative components of the study. All needles were graded better than the control needle. Figure 2 shows the proportion of ratings for each needle characteristic (overall brightness of the needle, overall clarity of the needle, brightness of the needle tip, and clarity of the needle tip). Significant differences in all 4 needle characteristics were found across needle types ($P < .01$). Of the participants, 11 of the 12 rated the Pajunk SonoPlex Stim needle highest among the 4 echogenic test needles. Overall rankings of the 4 test needles with median (interquartile range) were as follows: Pajunk SonoPlex, 4 (3.75–4); Havel’s EchoBlock, 3 (2–3); Havel’s EchoStim;
2 (1–3); and B. Braun Stimuplex D Plus, 2 (1–3). Interestingly, the performance disparity became more pronounced at steeper needle angles (45° and 60°) with scores as follows: Pajunk SonoPlex, 4 (4–4); Havel’s EchoBlock, 2.5 (2–3); Havel’s EchoStim, 2 (2–3); and B. Braun Stimuplex D Plus, 1 (1–2).

Secondary analysis showed that the Pajunk SonoPlex Stim needle rated higher in overall brightness than the other 3 needles (P < .001). Similarly, in terms of overall clarity, the Pajunk SonoPlex Stim needle was rated higher than the other 3 needles (P < .001). In terms of needle tip brightness, the Pajunk SonoPlex Stim needle was rated higher than the Havel’s EchoBlock needle (P = .041) and the remaining 2 needles (P < .001), whereas the Havel’s EchoBlock needle was rated higher than the remaining 2 needles (P < .001). Finally, in terms of needle tip clarity, the Pajunk SonoPlex Stim needle was rated higher than the Havel’s EchoBlock (P = .012) and the other 2 needles (P < .001), whereas the Havel’s EchoBlock needle was rated higher than the B. Braun Stimuplex D Plus (P = .001) and Havel’s EchoStim (P = .012). In addition, there were differences between the needle types across all needle angles using the Pearson test of ranks at P < .05, but subgroup analysis was not conducted because of the limited sample size at each angle.

The logistic regression model created using 4 characteristics (overall brightness of the needle, overall clarity of the needle, brightness of the needle tip, and clarity of the needle tip) versus overall needle rank was significant (P < .001). The correlation of overall needle rank with clarity of the needle tip was significant (P = .009). The r² value

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Table 1. Probe Frequency and Image Depth as a Function of the Degree of Insertion

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<tr>
<th>Degree</th>
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<td>60</td>
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Figure 2. Proportion of ratings for each needle characteristic according to needle type. HE Block indicates Havel’s EchoBlock; HE Stim, Havel’s EchoStim; Pajunk, Pajunk SonoPlex Stim; and BBraun, B. Braun Stimuplex D Plus.
of the linear regression line was 0.30, reflecting a weak to moderate-strength correlation between clarity of the needle tip and overall needle rank. None of the other 3 characteristics were significantly related to overall needle rank.

**Discussion**

This study is the first to correlate predefined echogenic needle characteristics with clinician preferences across varying needle angles. Similar study models have compared needle echogenicity and characterized subjective and objective assessments of needle brightness at multiple needle angles but have not evaluated detailed, clinically relevant characteristics of needle echogenicity among providers routinely performing regional anesthesia. Several needle designs at various needle angles were used to delineate why clinicians preferred specific needles and echogenic characteristics over others.

Although the primary outcome was overall needle rank, the intriguing part of the study was delineating how clinician preferences influenced ratings of study needles. This study revealed that needle tip clarity was significantly related to overall needle rank. Thus, anesthesiologists preferentially place greater importance on being able to clearly identify the tip of the block needle over other needle characteristics. This concept is not entirely new, as sonographic characteristics of needle tips have been investigated for over 20 years. However, this study is the first to delineate clarity of the needle tip as a distinct characteristic. None of the other echogenic characteristics (overall needle brightness, overall needle clarity, and brightness of the needle tip) were significantly related to overall needle rank.

Previous investigations have shown that needle visibility decreases with increasing needle angles. Manufacturer modifications to echogenic needles have been intended to increase visibility at steeper angles by increasing the reflective signal. Echogenic needles evaluated in this investigation did, in fact, produce better visualization, as shown by consistently higher rankings than the control needle. Therefore, regional techniques requiring steeper needle angles to reach deeper anatomic targets may benefit from the use of echogenic needles. However, the results of this study also indicate that echogenic needle designs do not uniformly enhance needle visualization. The Pajunk needle scored the highest in all 4 needle characteristics measured and was ranked highest by 11 of the 12 participating anesthesiologists. The Havel’s EchoBlock needle was superior to the Havel’s EchoStim and B. Braun Stimuplex D Plus in both brightness and clarity of the needle tip. The Havel’s EchoBlock needle was the only noninsulated needle evaluated, and previous studies have shown that insulated needles were more visible than noninsulated needles, especially at greater insertion angles.

This study did have a number of limitations. Although the results are predicated on physician preferences, the data do not correlate needle echogenicity, clarity, or brightness with regional anesthetic outcomes. The use of static phantom gel images was essential for standardizing comparisons but has limited fidelity in reproducing the imaging conditions of sonographically guided nerve block performance in living tissue. Similarly, although the printed needle images had the same resolution as the on-screen images, point-of-care sonography is not viewed on paper but rather on screen displays. In addition, the study design did not attempt to account for surrogate or alternative indicators of needle tip localization (eg, hydrolocation, injection of air, tissue distortion, 3-dimensional sonography, and global positioning sensor tracking). Although a single linear ultrasound probe was used for standardization of images in this study, theoretically, some needles might be better visualized with certain sizes and shapes of ultrasound probes (eg, linear versus convex). Finally, during statistical analysis, ordinal data were converted into continuous data because we were more interested in the direction of any association than the magnitude of such an association.

In summary, this study of echogenic needle performance across various angles of insertion shows that needle tip clarity predicts echogenic needle preferences among experienced regional anesthesiologists. The Pajunk needle was rated highest in all 4 needle characteristic categories and ranked highest overall. Further studies must explore whether echogenic characteristics such as needle tip clarity are associated with safer, faster, or more efficacious regional anesthesia outcomes.

**References**


