Objective and subjective comparison of the visibility of three echogenic needles and a nonechogenic needle on older ultrasound devices

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A R T I C L E   I N F O

Article history:
Received 16 July 2014
Received in revised form 29 November 2014
Accepted 11 December 2014

Key words: echogenic needle; needle visibility; ultrasound-guided nerve block

A B S T R A C T

Objective: This study evaluated the visibility of echogenic needles with older ultrasound devices in an in vitro phantom study.

Methods: We compared three echogenic needles from B. Braun (BB), Unisis (UN), and Hakko (HK) with a nonechogenic needle. Each needle was inserted into an ultrasound phantom 10 times at 30° and 45° with the bevels up. The captured images of the needle and background contrast were digitally analyzed, and the median of 10 insertions for each angle was calculated to determine objective needle visibility. Needle images were also shown to 12 anesthesiologists to evaluate subjective needle visibility on a five-point Likert scale.

Results: The shafts of all the echogenic needles were significantly more objectively visible than the nonechogenic needle. Subjective visibilities of the BB and UN needles were significantly higher than that of the nonechogenic needle. Therefore, the BB and UN needles were judged to have more than fair subjective visibility. However, subjective visibility of the HK needle was consistently and significantly lower than that of the BB and UN echogenic needles. At 45°, the HK needle had nearly the same poor visibility as the nonechogenic needle.

Conclusion: The results of our study indicate that the BB and UN needles are more visible than nonechogenic needles in an ultrasound phantom, even on older devices.

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1. Introduction

Many echogenic needles, with a variety of textured needle surfaces designed to reflect the ultrasound waves back to the transducer, are available. We investigated whether echogenic needles maintain their high visibility when visualized with older ultrasonic devices.

Ultrasound guidance can significantly improve nerve block quality and help avoid complications associated with traditional nerve block procedures that are performed in a blinded manner and depend on surface anatomic landmarks or electrical stimulation. 1 It enables an anesthesiologist to accurately position the needle in the target nerves and surrounding tissue in real time. Recent advances in ultrasound devices are thought to have made ultrasound-guided nerve blocks safer because of the ability to obtain high-quality images. However, the newer ultrasound devices are prohibitively expensive for many institutions, and older devices are still used in many blockade procedures. As older devices produce grainy images, they cannot fully achieve the safety and reliability that are possible to attain in ultrasound-guided nerve block procedures when newer technology is employed. However, these shortcomings can be overcome by the use of an echogenic needle with high visibility.

There have been some studies on echogenic needle visibility,2 but little has been reported from the viewpoint of their use with older ultrasonic devices. In this study, we investigated whether echogenic needles objectively and subjectively have better visibility than nonechogenic needles when used in older ultrasound devices.

2. Methods

2.1. Ultrasound device

Imaging was performed with an older portable all-purpose ultrasound device, the LOGIQ Book Xp (R2.1.2), which was manufactured in 2005, and a linear probe (8L-RS) that attached the needle guide bracket (H78162P) (GE Healthcare Clinical Systems, Wauwatosa, WI, USA). The ultrasonic conditions were for preset small parts and were not optimized. The preset conditions were as follows: frequency, 10 MHz; depth, 40 mm; gain, 62; and acoustic output, 100%. The focus was set at one point at 36 mm. All time-gain-compensation sliders were fixed at the center position.

2.2. Study needles

The following echogenic needles (22-gauge) are widely available in Japan (Fig. 1): Stimuplex Ultra (B. Braun, Melsungen, Germany), hereafter referred to as the BB needle; the Uniever echogenic neural blockade needle (Unisis Corporation, Tokyo, Japan), referred to as the UN needle; and the Sonolect Needle USG (ultrasound guide) type CCR (corner cube reflector) (Hakko Co., Ltd, Nagano, Japan), referred to as the HK needle.

The nonechogenic needle was a 22-gauge neural blockade needle from Hakko Co., Ltd with a stylet. Only the nonechogenic needle had a stylet. We used the same conditions as those employed for clinical use. Only the BB needle was insulated.

2.3. Ultrasonic phantom

An ultrasonic phantom was specially made to strictly mimic the acoustic properties of soft tissue (OST, Chiba, Japan). The phantom properties were as follows: $1.6 \times 10^4$ kg/m$^2$ s acoustic impedance, 0.4 dB/cm/MHz attenuation coefficient, 1540 m/s ultrasonic velocity, 10 kPa hardness (Young’s modulus), and $140 \times 100 \times 100$ mm$^3$ rectangular parallelepiped, prepared with a high-polymer hydrogel.8–10

2.4. Objective visibility

For the needle guide setting at a shallow $30^\circ$ insertion angle against the phantom surface, the needles were inserted to a depth...
Visibility of echogenic needles on older devices

of 35 mm in the phantom with bevels up (Fig. 2). The needles were inserted 10 times, each time avoiding prior insertion sites. The captured images were stored digitally. Insertion and capture were similarly performed for the needle guide setting at a steep 45° insertion angle. Objective visibility of the needle was digitally estimated as the difference in the mean luminosity between the needle area and the adjacent background (1 mm width) in the captured image. The mean luminosity was verified using Photoshop computer software (Elements 11; Adobe Systems Incorporated, San Jose, CA, USA) and was defined as a gray scale value between 0 (darkest, black) and 255 (brightest, white). The median contrasts of the 10 insertions for each angle were calculated to determine the objective visibility. The region 1 mm from the needlepoint was considered the tip, and the region 2–5 mm from the needlepoint was considered the shaft. Objective visibility was evaluated by separating the needle’s tip and shaft. Two expert anesthesiologists judged the sampling positions by enlarging the image (5× magnification). None of the echogenic needle tips were treated to heighten echogenicity. The regions 1–2 mm from the needlepoints were not evaluated because these regions include nonechogenic portions.

2.5. Subjective visibility

The images were printed on a glossy paper (Xerographic Photo Paper L-size 89 × 127 mm²; Fuji Xerox Co., Ltd, Tokyo, Japan) using a high-resolution printer (DocuCentre-II C4300MP; Fuji Xerox Co., Ltd). The photos were randomly rearranged, and the images of the entire needle were assessed on a 5-point Likert scale by 12 anesthesiologists. The assessment did not divide the tip from the shaft. The scale was 0 to 4 (0 = invisible, 1 = poor, 2 = fair, 3 = good, and 4 = very good). The anesthesiologists were required to judge the visibility as quickly as possible, as they do in clinical settings. The means of the 12 scores for each image were calculated as the image scores. The median of 10 insertion image scores were calculated to determine subjective visibility.

2.6. Statistical analysis

All data are expressed as medians (first quartile – third quartile). For each angle, we used the Kruskal–Wallis test, along with the Steel–Dwass test for post hoc analyses to compare visibility differences among the four needles. Correlations between objective and subjective visibilities were analyzed by Spearman’s rank correlation coefficients. A p value < 0.05 was considered significant. All statistical analyses were performed using R (software environment for statistical computing and graphics, version 3.0.2.; R Foundation for Statistical Computing, Vienna, Austria) with its add-in software EZR (version 1.23, Kanda Y, Jichi University Saitama Medical Center, Saitama, Japan) on R commander (version 2.0-3; Fox J and Bouchet-Valet M, McMaster University, Ontario, Canada).

3. Results

3.1. Objective visibility at the shaft

At each insertion angle, objective visibilities of all the echogenic needles were higher than the corresponding value of the non-echogenic needle (Fig. 3A, Table 1). At 30°, there were no remarkable differences between the three echogenic needles. At 45°, the UN needle was objectively the most visible; however, there was no significant difference between the echogenic needles. Objective visibility of the BB and HK needles dropped at a steeper insertion angle. However, objective visibility of the UN shaft was not affected by the insertion angle.

3.2. Objective visibility at the tip

At each insertion angle, objective visibility was greatest for the BB needle among the echogenic needles (Fig. 3B, Table 1), but was not significantly greater than for the nonechogenic needle. Objective tip visibilities of the UN and HK needles were lower than that of the nonechogenic needle at each insertion angle. The value for the UN needle at 45° was significantly lower than that of the nonechogenic needle (p = 0.01). By contrast, the values for the HK and nonechogenic needles did not differ significantly at 30° (p = 0.07).

3.3. Subjective visibility of the entire image

Subjective visibilities of all the echogenic needles, except the HK needle at 45°, were significantly higher than the value of the nonechogenic needle at each angle (Fig. 3C, Table 1). With the exception of the HK needle at 45°, the echogenic needles were more easily observed than the nonechogenic needle. The BB and UN needles were judged to have more than fair subjective visibility at each angle. Subjective visibility of the HK needle at 30° was markedly lower than that of the BB and UK needles. The HK needle at 30° was judged to have less than fair subjective visibility. Subjective visibility of the HK needle at 45° was poor. This value was similar to that of the nonechogenic needle (p = 0.99). Moreover, the BB and UN needles were significantly more visible than the HK needle at each angle (p < 0.01).

3.4. Correlation between objective and subjective visibility

The correlation coefficient of objective visibility at the shaft and subjective visibility was 0.65. At the shaft, there was a significant correlation between the subjective and objective visibility values (p < 0.01). The correlation coefficient of objective visibility at the tip and subjective visibility was 0.08, indicating no significant correlation (p = 0.50).

4. Discussion

In an older ultrasound device, the BB and UN echogenic needles had subjectively better visibility than the nonechogenic needle.
regardless of the insertion angle, and they had objectively better visibility at the shaft.

There were nonechogenic portions of the echogenic needles, including the tips. As nonechogenic portions affect the mean luminosity of a needle image, we divided the tip and the shaft in the objective assessments. However, subjective visibility was assessed for the entire needle. While needle tip visualization is fundamental in ultrasound-guided nerve blocks, visualization of the needle shaft is also important for identifying the needle position in these blocks. Moreover, anesthesiologists must complete the procedure as quickly as possible to reduce pain and anxiety of patients in clinical settings. In contrast to the artificial determination of objective visibility, in which operators can take time to discriminate between tip and shaft, practicing anesthesiologists judge visibility too quickly to make such discriminations. Therefore, we asked them to evaluate the visibility of the entire needle image during the subjective evaluation. Consequently, there is good correlation between the subjective and objective visibilities of the shaft.

Many BB reflectors are thick. The reflecting grooves of UN needles are thick double spirals. By contrast, the HK reflectors are sparsely placed. Therefore, we conclude that thick or dense reflectors are more easily visualized by older devices, regardless of the insertion angle.

Objective visibility of the BB needle tip was similar to that of the nonechogenic needle. The BB needle’s echogenic portion was dispersed rather than continuous, to allow for determination of the needle depth on the image (Fig. 4). This is termed as the safety code pattern, and it accurately indicates the tip position. In addition, the

Fig. 3. Objective and subjective visibility of four needles. Medians of four echogenic needles were compared. (A) Objective visibility at the shaft. At each insertion angle, objective visibilities of all the echogenic needles were significantly higher than that of the nonechogenic needle. There were no significant differences between the three echogenic needles. (B) Objective visibility at the tip. At each insertion angle, objective visibilities of all the echogenic needles were similar to or lower than that of the nonechogenic needle. Only the value of UN needle at 45° was significantly lower than that of the nonechogenic needle (p < 0.05). (C) Subjective visibility of the entire image. Subjective visibilities of all the echogenic needles at each angle (except the HK needle at 45°) were significantly higher than the corresponding value of the nonechogenic needle. The median scores of the BB and UN needles indicated more than fair visibility at each angle. The median score of the HK needle at 30° was the lowest among the scores of all the echogenic needles, and it had less than fair visibility. The median score of the HK needle at 45° was nearly equal to the poor visibility of the nonechogenic needle. Moreover, the BB and UN needles were significantly more visible than the HK needle at each angle (p < 0.01). White circles indicate medians. * p < 0.05. ** p < 0.01. BB – B. Braun; HK – Hakko; UN – Unisis.
BB needle can be combined with electrical stimulation. Therefore, the safety and certainty of ultrasound-guided nerve blocks can be achieved with older devices, particularly when the BB needle is used.

Objective visibility at the shaft and subjective visibility of the UN needle were higher than that of the nonechogenic needle, and were not affected by the insertion angle (Fig. 4). A steeper insertion angle made it difficult to visualize the needle in ultrasonic images.\(^1\) The UN needle has the great advantage of visibility regardless of the insertion angle. Objective visibility of the UN tip was lower than that of the nonechogenic needle. Moreover, an insulated needle coating is not available on the engraved portion of the UN. Therefore, the UN needle should be used with the understanding that the tip is objectively less visible than that of the nonechogenic needle. However, the echogenic portion of the UN needle is close to the tip, making it easy to determine the tip’s position.

The objective assessment of the HK’s shaft was inconsistent with the subjective assessment at each angle. At 30\(^\circ\), the objective visibility at the HK’s shaft was judged to be high, but the subjective visibility was considered low. The bright part of the HK needle was depicted brightly at 30\(^\circ\), but the image was not sharp. This indicated that the HK needle was difficult to subjectively visualize at 30\(^\circ\). The HK needle’s shaft at 45\(^\circ\) was objectively similar to that of the BB needle at the same angle. However, the HK needle at 45\(^\circ\) had significantly less subjective visibility than the BB needle (\(p < 0.01\)) and the same visibility as the nonechogenic needle. The echogenic region of the HK needle is much shorter than that of the BB needle. The long reflected image of the BB needle led anesthesiologists to provide higher assessment values. Miura et al.\(^1\) compared insulated HK needles with nonechogenic needles in phantoms and patients using a portable all-purpose ultrasound device that hit the market around the same time as our device. Contrary to our results, the HK needle was clearly visible even at 45\(^\circ\) in their phantoms, as they optimized receiver gain and target-gain control. These optimizations are likely to be the cause of the discordance between our results. Insulation needles with the same echogenic alterations as on the HK needle are available. Therefore, electrical stimulation may partially compensate for the poor visibility of the HK needle.

In-patient comparisons of echogenic and nonechogenic needles on an older ultrasound device will provide more accurate assessments of echogenic needles, as phantom results cannot be fully extrapolated to living tissue. Needle visibility is particularly overestimated in agar, gelatin, and Blue Phantom (elastomeric rubber; Blue Phantom, Seattle, WA, USA) in comparison to human living tissue because these materials have very low background echogenicity due to low acoustic impedance.\(^14,15\) However, our phantom precisely mimicked the acoustic properties of living tissue, including acoustic impedance. Agar and gelatin are a kind of high-polymer hydrogel, but our material does not contain agar or gelatin. Therefore, it is unlikely that needle visibility was overestimated in this study because the background of our phantom has the same brightness as living tissue. Moreover, we used a homogeneous background in order to assess needle visibility in detail. There are

### Table 1

<table>
<thead>
<tr>
<th>Insertion angle (degree)</th>
<th>BB</th>
<th>UN</th>
<th>HK</th>
<th>Nonechogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective visibility of the shaft</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>37.4 (34.6–38.9)</td>
<td>38.4 (36.2–40.9)</td>
<td>38.8 (33.8–44.2)</td>
<td>5.9 (3.4–16.7)</td>
</tr>
<tr>
<td>45</td>
<td>30.5 (24.7–33.8)</td>
<td>39.1 (33.0–46.0)</td>
<td>25.5 (21.0–35.6)</td>
<td>5.6 (3.1–10.5)</td>
</tr>
<tr>
<td><strong>Objective visibility of the tip</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>61.3 (55.4–68.3)</td>
<td>43.6 (41.1–49.7)</td>
<td>34.8 (26.0–43.6)</td>
<td>63.8 (40.3–68.8)</td>
</tr>
<tr>
<td>45</td>
<td>57.4 (50.8–66.2)</td>
<td>39.9 (35.4–45.3)</td>
<td>38.3 (31.0–53.3)</td>
<td>56.5 (50.4–60.3)</td>
</tr>
<tr>
<td><strong>Subjective visibility of the entire image</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>3.0 (2.8–3.1)</td>
<td>2.6 (2.5–2.8)</td>
<td>1.7 (1.5–1.8)</td>
<td>0.8 (0.5–0.9)</td>
</tr>
<tr>
<td>45</td>
<td>2.6 (2.4–2.7)</td>
<td>3.1 (2.9–3.2)</td>
<td>1.0 (0.7–1.1)</td>
<td>1.0 (0.8–1.1)</td>
</tr>
</tbody>
</table>

Data are expressed as median (first quartile – third quartile).

Fig. 4. Typical images of three echogenic needles from BB, UN, and HK were presented with that of a nonechogenic needle: (A) 30\(^\circ\) insertion angle and (B) 45\(^\circ\) insertion angle. Bright and dark regions of the BB needle were imaged, and there were clear borders between the bright needle region and the dark background. The UN needle was uniformly bright with a clear border against the background. The HK needle was bright at an insertion angle of 30\(^\circ\), but it was not clear against the background. The HK was not imaged very bright at an insertion angle of 45\(^\circ\). The echogenic portions of the HK needle are very short. Only the tip of the nonechogenic needle was bright. BB – B. Braun; HK – Hakko; UN – Unisis.
heterogeneous backgrounds in meat and cadavers similar to living tissues because they contain various structures with different acoustic impedance. The patterns change when the needle is inserted repeatedly, and the same background image cannot be obtained with every insertion. Furthermore, cadavers present ethical limitations, and meat phantoms last for only 1 week.16 Our artificial phantoms avoid the problems associated with cadaver and meat phantoms, allowing us to assess each needle’s visual properties accurately and deliberately.

The four needles were evaluated in still images, not in real time (video). Movement in the surrounding tissues helps anesthesiologists determine needle position. Avoiding the effect of background movement, we were able to evaluate the genuine visibility of each needle in still images. Our results demonstrate that the echogenic needles, particularly the BB and UN needles, can maintain high visibility when used with older ultrasonic devices. However, the objective visibilities of the tip were no greater than that of the nonechogenic needle. Therefore, combination with electrical stimulation is strongly recommended for older devices to maintain the safety and certainty of ultrasound-guided nerve blocks.

References