

Ultrasound Characteristics of Needles for Regional Anesthesia

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Background and Objectives: Needle visibility is a crucial requirement for successful and safe ultrasound-guided peripheral nerve blocks. We performed a prospective study on the ultrasonic imaging quality of various commercially available needles. We tested the hypothesis that different nerve block needles would have different ultrasonic appearances. Furthermore, we examined the influence of needle angle with regard to the ultrasound plane, 2 types of media surrounding the needle, and the impact of 3 different ultrasound machines.

Methods: Twelve needles were prospectively tested for 3 ultrasound planes (longitudinal, axial tip, and axial shaft) at 2 different angles (0 degrees and 45 degrees). Quality of needle visibility and ultrasound scans were described by using 6 criteria (visibility score range 0-10): (1) visibility of needle; (2) visibility of surrounding media; (3) consistency of needle surface; (4) formation of artifacts; (5) degree of shadowing; and (6) detection and distinction of the needle from the surrounding media. Additionally, every ultrasound scan was performed in 2 media (water bath and animal model) with 3 ultrasound devices and evaluated by 2 investigators. Evaluation of the ultrasound scans was blinded with regard to needle but not to the ultrasound machine and media.

Results: In the animal model, visibility was good at 0 degrees (visibility score greater than 6) but was decreased for all needles at a 45 degree angle (criterion 6). In this setting, 2 needles were difficult to identify (score less than 3; criterion 6) and only 3 of 12 reached a score of 7 or more (criterion 6). Depiction quality for all 3 planes was significantly lower in the animal model when compared with the water bath ($P < .001$) and at an angle of 45 degrees when compared with 0 degrees ($P < .001$). There was no significant impact of the ultrasound machine on image quality.

Conclusions: In a tissue-equivalent model we found significant differences among different types of needles at a 45 degree angle. In clinical use, angles between 30 degrees and 60 degrees are required. Because visibility of the needle is a keystone of ultrasound-guided peripheral nerve blocks, our results suggest the need to optimize the echogenicity of needles used for ultrasound-guided nerve blocks. *Reg Anesth Pain Med* 2007;32:440-447.

Key Words: Ultrasound, Regional anesthesia, Needle visibility.

Efficacy of ultrasound-guided regional anesthesia depends critically on image quality of the target organ, the needle, and of the ultrasound (US) devices themselves. In contrast to the development of US machines, needle design has not yet been equally adapted to the special needs of ultrasonic waves. This despite the fact that as early as 1990, interventionalists were seeking better ultrasonic needle visibility in clinical practice.^{1,2} Currently little is known about ultrasonic differences of com-

monly used needles for regional anesthesia. We designed this study to answer this question for single-shot regional anesthesia (RA) needles from different manufacturers. Our objectives were (1) to characterize the differences in echogenicity of different needles; (2) to assess the image quality of needles with different ultrasound machines; (3) to examine the impact of different insertion angles, and (4) media (water bath, animal model) on image quality.

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Table 1. Characteristics of the Examined Needles

Number	Manufacturer*	Name of Needle	Dimensions†		
			Diameter (Gauge)	Length (mm)	Bevel (Degrees)
1	Havel's	Chiba Type Needle	22	152	30
2	Pajunk	Uniplex Nanoline	22	80	n.a.
3	B. Braun	Plexufix	24	50	45
4	Portex	Prolong	19	50	30
5	Polymedic	UPM	22	50	45
6	Vygon	Locoplex	22	50	n.a.
7	Pajunk	Plexolong UPS	19.5	60	n.a.
8	B. Braun	Stimuplex A	22	50	30
9	B. Braun	Stimuplex D	22	50	30
10	B. Braun	Stimuplex D	22	50	15
11	Polymedic	Polymedic US Needle	22	50	45
12	Arrow	Stimuquick	21	90	n.a.

Abbreviation: n.a., data are not available.

*Manufacturer locations: Arrow, Erding, Germany; B. Braun, Melsungen, Germany; Havel's, Cincinnati, OH; Pajunk, Geisingen, Germany; Polymedic, te me na, Carrières sur Seine, France; Portex, Keene, NH; Vygon, Aachen, Germany.

†According to original needle package of manufacturer.

Methods

Twelve needles for single-shot RA were examined. Type and characteristics of these needles are provided in Table 1. Needles were scanned using 3 ultrasound systems (Logic® 500, GE Healthcare®, Solingen, Germany, linear array, LA39, 11.2 MHz; MyLab® 25, Esaote® Biomedica GmbH, Halbermoos, Germany, linear array 539, 5-14 MHz; Titan®, SonoSite® GmbH, Erlangen, Germany, linear array HST, 10 MHz). Needles were examined in 2 media (water bath and animal model) and at 2 angles (0 degrees and 45 degrees). The water bath was an aquarium filled with 35 liters of saline solution with a needle holder installed to fix the needle. For the animal model, we used a leg of pork at least 10 cm in diameter. A setsquare was used to adjust the needle to the appropriate angle. For acoustic coupling between the US transducer and the leg of pork, we used standard ultrasound gel (Aquasonic® 100, Parker Laboratories, Fairfield, New Jersey). All needles were primed with water in order to achieve the same examination conditions.

Image Acquisition

Needle shaft and tip were scanned axially; the shaft was also scanned longitudinally. These 3 scans were taken at every setting (water bath, animal model, 0 degrees, 45 degrees, and with each machine). Receiver-gain and target-gain control of the ultrasound machines were set to obtain the best image quality of the needle. Zones of focus were set to the appropriate needle depth. Scanning at the 0-degree angle was at a depth of 2 cm. For depiction of the needle tip (different bevels), the needle was slightly rotated until optimal visibility was obtained. Ultrasound images were recorded to hard disk for

later analysis. Using a video switch, we were able to record each setting (e.g., 45 degrees, water bath) using each machine without the need to reposition the needle. The first investigator performed all ultrasound scanning; the second investigator performed all video-sequence recording. Both operators were experienced in ultrasound-guided regional anesthesia (fully licensed in ultrasonography; German Society for Ultrasound in Medicine; European Federation of Societies for Ultrasound in Medicine and Biology; International Society for Ultrasound in Regional Anesthesia).

After complete data acquisition of the 12 needles, files were randomly assigned a protocol number to blind the recordings for analysis. Type of needle was blinded but not media and ultrasound machine (sequence recording). The 2 operators assessed the video files separately on the same computer and in the same ambient conditions (closed room with shaded light).

Review Process

Six criteria were defined to describe the quality of different aspects of every video sequence: (1) needle visibility; (2) visibility of the surrounding area; (3) consistency of the needle surface; (4) formation of artifacts; (5) shadowing; and (6) the detection and distinction of the needle from the surrounding area. Criteria were rated using a categorical visibility score (VS) on a scale ranging from 0 to 10. Details and an extensive explanation of the criteria and scores are provided in Table 2. In summary, every needle was described by 2 operators, in 2 media, at 2 angles, using 3 US machines, at 3 aspects of the needle and assessed by 6 criteria for

Table 2. Visibility Score Definitions of Criteria

Number	Criteria	Definitions of Criteria and Notes	Visibility Score (Range 0 to 10)
1	Visibility of the needle	Describes the overall quality of the depiction of the needle alone.	A high value describes a highly visible needle. A low value describes an almost invisible needle.
2	Visibility of the surrounding media	Describes the quality of the surrounding area of the test media (e.g., muscles, nerves, or other tissue in the animal model). The surrounding media has an enormous impact on needle depiction due to different ultrasonic impedances.	A high value expresses a good visibility of the vicinity of the needle. A low value describes a very poor depiction.
3	Consistency of the needle surface	Describes the sharpness and integrity of the ultrasonic depiction of the needle surface.	A high value means a clear, sharp, and continuous depiction of the rim of the needle. A low value is associated with an interrupted or diffuse (blurred) depiction of the needle surface. In this case there would be no clear border between media and needle in the image.
4	Artifact formation	Describes the amount and degree of artifact formation. Possible artifacts are scattering, reverberation, and multiple echoes. "Shadowing" is excluded.	A low value is rated as good. A high value is associated with marked decreased depiction of the vicinity.
5	Degree of shadowing	Describes the amount and degree of shadows. Note: although "shadowing" is an artifact, this criterion is of special clinical interest: especially in the longitudinal view shadowing can extinguish important aspects of the scan and therefore decrease the safety of the puncture process.	A low value is rated as good (good visibility dorsal of the needle). A high score describes a pronounced extinction dorsal of the needle.
6	Detection and distinction of the needle from the surrounding media	Describes the overall depiction of the needle inside the model. This criterion is of special clinical relevance: success and safety of the ultrasound-guided puncture process relies on good visibility of the needle AND the surrounding area.	A high value means good visibility. Scores of 7 or higher are regarded as acceptable. A low value characterizes a needle which is very hard to see and to distinguish from the surrounding media.

NOTE. Visibility score definitions of the criteria to qualify different aspects of the needle and the ultrasound scan. All criteria were applied to every ultrasound sequence.

every scan ($2 \times 2 \times 2 \times 3 \times 3 \times 6 = 432$ data points).

Statistics

Excel (Microsoft Corporation, Redmond, Washington) was used for data input and table generation. χ^2 tests were performed when appropriate with Statistica 7.1 (StatSoft, Tulsa, Oklahoma). A significance level was defined as $P < .05$.

Results

There were no significant differences between the 2 operators evaluating the needles (Fig 1). We found substantial differences in visibility between the 12 needles using the animal model: the visibility score for the criterion "detection and distinction of needle from the surrounding area" was good for all needles at a 0-degree angle (score 6 or higher), but lower in *all* tested needles at a 45-degree angle (Fig 2). Only 3 needles reached a score greater than 7 at an angle of 45 degrees (Pajunk [Geisingen, Germany] Plexolong UPS, B. Braun [Melsungen, Germany] Stimuplex A and Stimuplex D with 15-degree bevel).

At a 45-degree angle, detection and distinction of the needle from the surrounding was very difficult in 3 needles (Pajunk Uniplex Nanoline: VS less than 3; B. Braun Plexuffix: VS less than 4; and Portex [Keene, NH] Prolong: VS less than 2).

The results of this score between the 2 angles were in contrast to the results in the water bath. Visibility scores were good for *both* angles for all needles (VS 6 or greater, Fig 3). Within the water bath, 3 needles displayed an even higher visibility score at a 45-degree angle (Pajunk Plexolong UPS: VS 7; B. Braun Stimuplex A: VS greater than 8; Stimuplex D with 15-degree bevel: VS greater than 8).

To answer the question of whether there is a needle with good visibility and no or fewer negative-associated artifacts, we examined the 12 needles using the criteria "formation of artifacts" and "degree of shadowing" (Table 2, numbers 4, 5). Four needles displayed strong artifact formation in the longitudinal view of the shaft (Pajunk Plexolong UPS, and 3 B. Braun needles: Stimuplex A and the 2 needles of the Stimuplex D series). Artifact formation for those 4 needles was lower in the axial view of the tip of the needle (Fig 4). Seven needles displayed low artifact

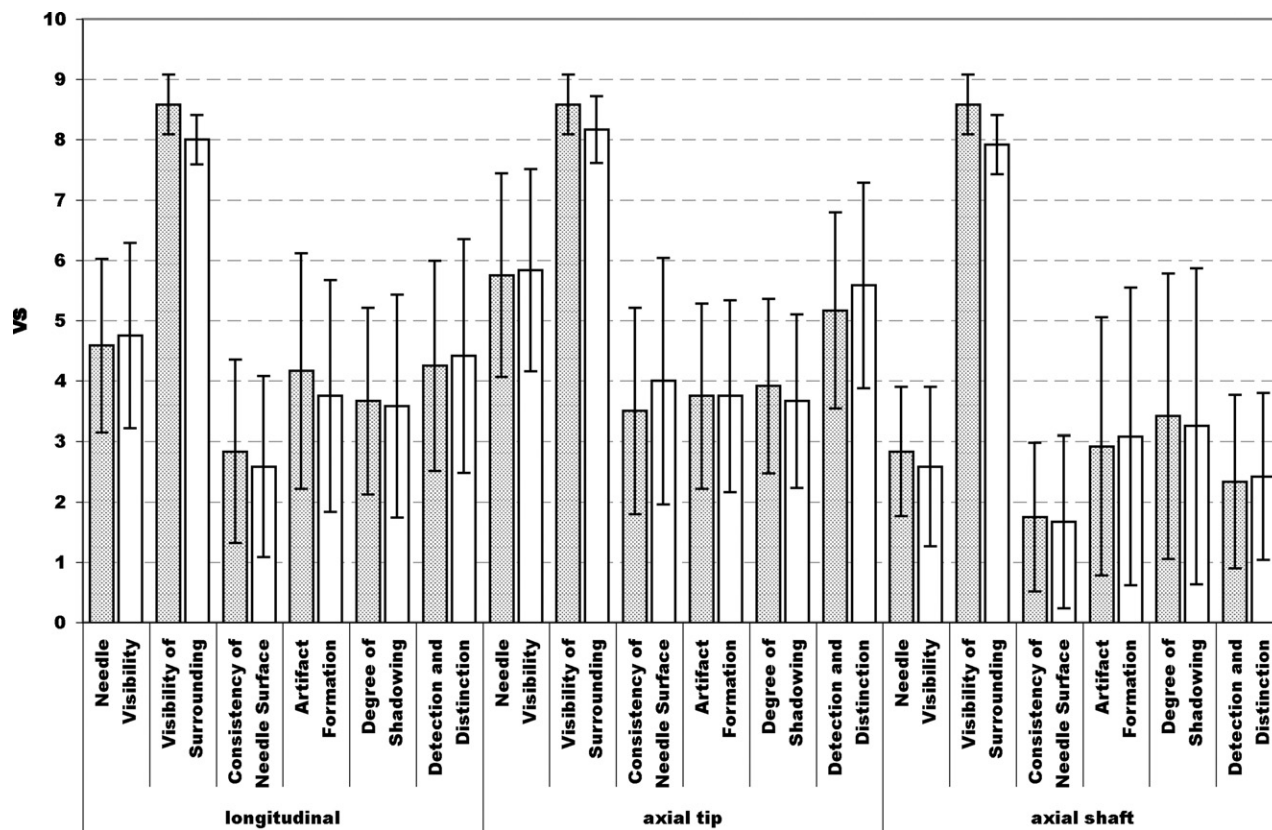


Fig 1. Visibility score (VS) of all 6 criteria differentiated by the 2 investigators (within the animal model at an angle of 45 degrees). Each column represents data points of all needles and all ultrasound systems. Gray columns: investigator A; white columns: investigator B. Results are presented as mean and standard deviation (bars). Differences are nonsignificant.

formation in the longitudinal and the axial view (score approximately 4 or lower): Havel's (Cincinnati, OH) Chiba type, Pajunk Uniplex Nanoline, B. Braun Plexifix, Portex Prolong, Polymedic (te me na, Carrières sur Seine, France) UPM, Vygon (Aachen, Germany) Locoplex, and Arrow (Erding, Germany) Stimuquick. Artifact formation was greater at the tip as compared with the needle shaft in 5 needles: Havel's Chiba type, Panjunk Uniplex Nanoline, B. Braun Plexifix, Vygon Locoplex, and Polymedic US Needle. The score of Arrow's Stimuquick needle was equal (VS 3.8) for artifact formation in the longitudinal view of the shaft and the axial view of the needle tip.

Needles with strong artifact formation in the animal model were associated with a high shadowing score (Pajunk Plexolong UPS, B. Braun Stimuplex A, B. Braun Stimuplex D [both 15-degree and 30-degree bevel]; Fig 5). Low artifact formation was associated with a low shadowing score (VS of 4 or less: Havel's Chiba type, Pajunk Uniplex Nanoline, B. Braun Plexifix, Portex Prolong, Arrow Stimuquick; Fig 5).

We found no significant impact of the ultrasound system on the visibility scores for all criteria. The US

system had marginal effect on image depiction for the single criterion "consistency of the needle surface" (Table 2, criterion 3), using either media at the 2 angles (χ^2 test, nonsignificant; Fig 6). In contrast, the test media had a large impact on image quality. We compared the water bath versus the animal model with regard to the image quality of the different needle scans (criteria 1 and 6, Table 2). At an angle of 45 degrees, image quality was significantly lower for all 3 parts of the needle in the animal model ($P < .001$). At 0 degrees, no significant differences in imaging quality were found between the 2 models with the exception of the needle shaft in the axial view ($P < .001$).

Discussion

Requirements for the ideal needle for ultrasound-guided RA would include: (1) good needle visibility—in particular its tip; (2) suitability for all kinds of tissue; (3) good visualization at all angles; (4) sharp depiction of the rim of the needle; (5) low artifact formation; (6) no shadowing; and (7) extremely good detection and differentiation from the surrounding area. Such an ideal needle does not exist.

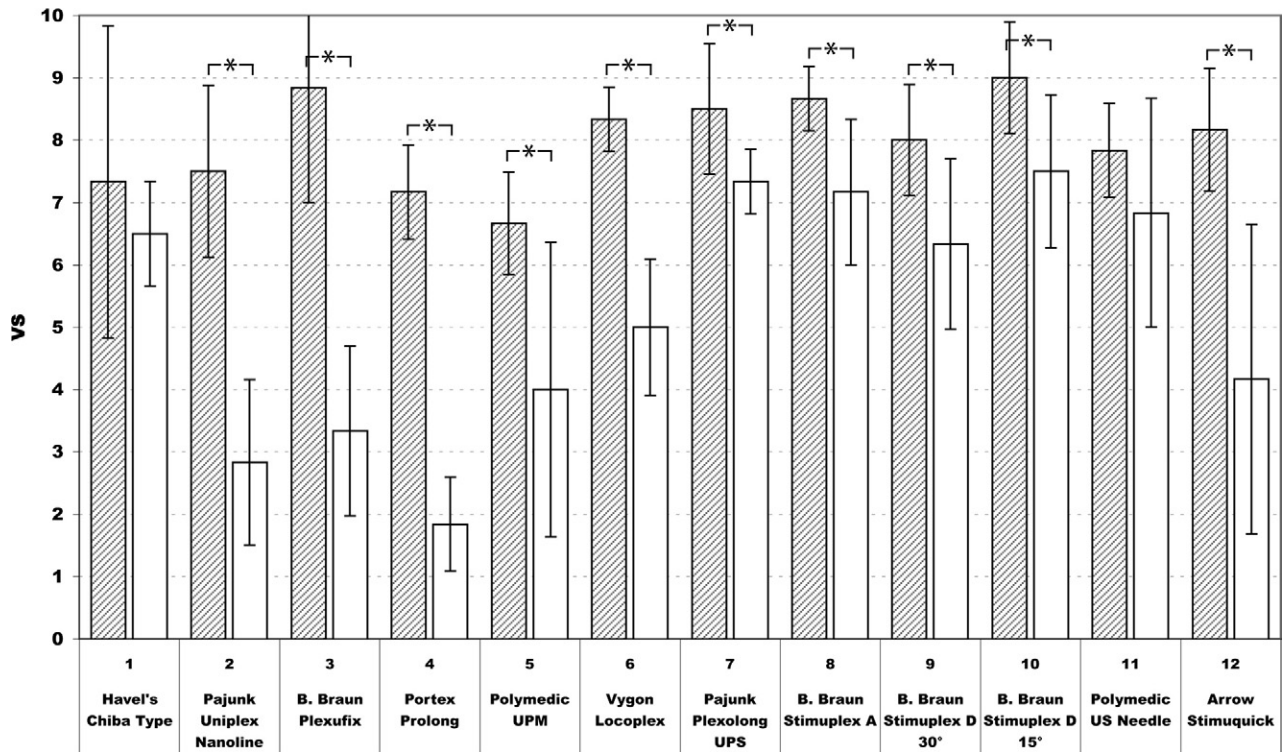


Fig 2. Visibility score (VS) of the criterion *detection and distinction of the needle from the surrounding* of all tested needles within the animal model. Differentiation of the 2 angles: gray columns, 0 degrees and white columns, 45 degrees. Each column represents data points of 2 investigators and 3 ultrasound machines. Results are given as mean and standard deviation (bars). Significant differences are marked with an asterisk ($P < .05$). Manufacturer information for each product is given in [Table 1](#).

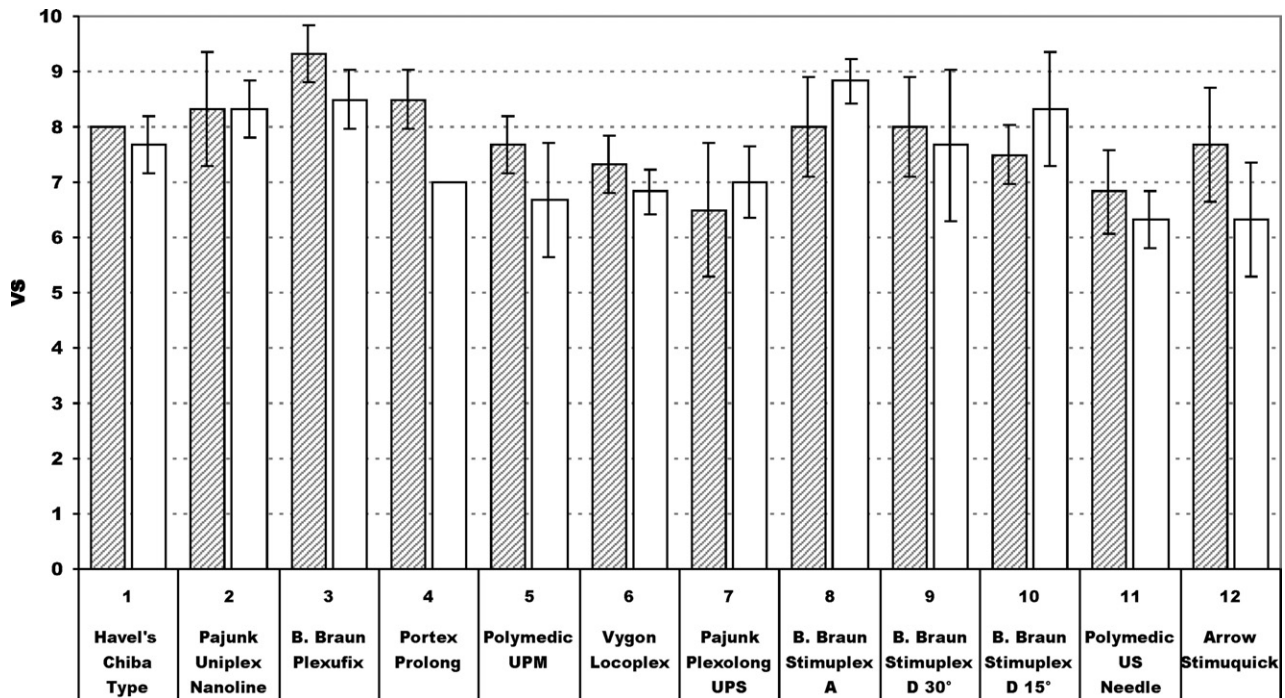


Fig 3. Visibility score (VS) of the criterion *detection and distinction from the surrounding media* of 12 tested needles within the water bath model differentiated between 2 angles. Each column represents data points of 2 investigators and 3 ultrasound systems. Gray columns: evaluation at 0 degrees; white columns: evaluation at 45 degrees. Results are given as mean and standard deviation (bars). Differences are nonsignificant. Manufacturer information for each product is given in [Table 1](#).

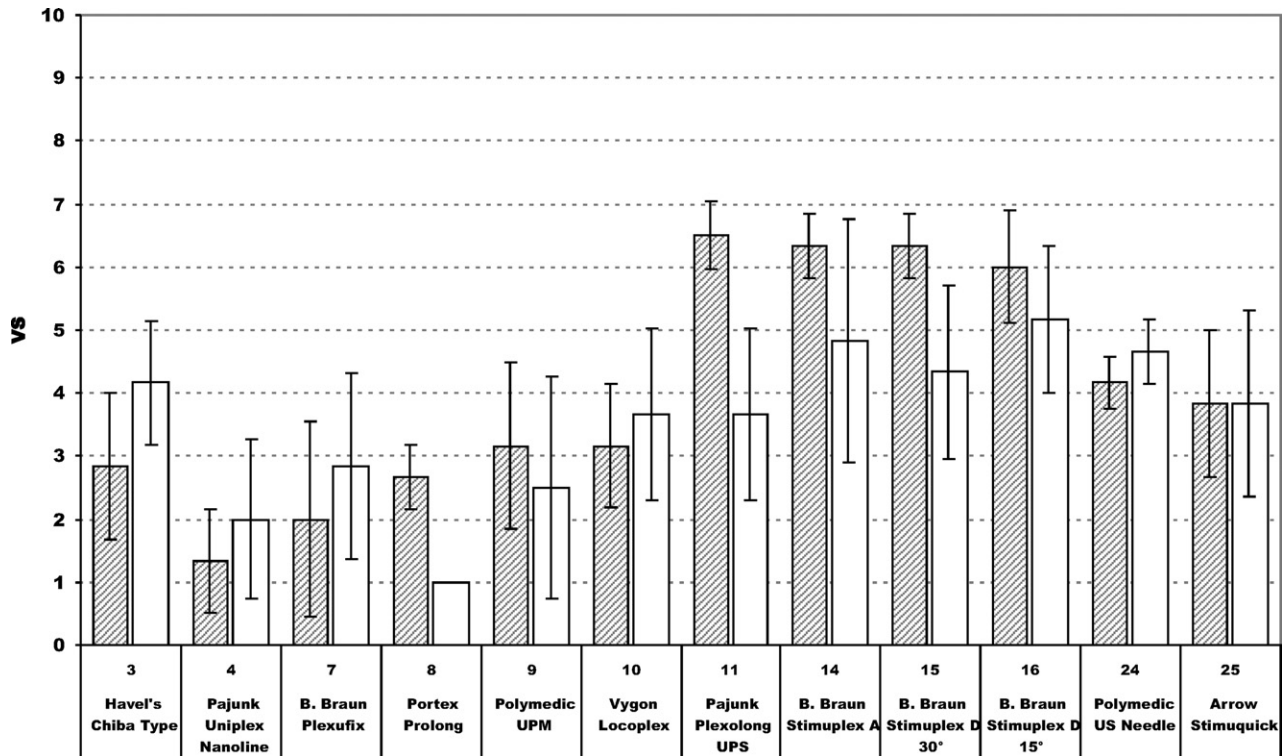


Fig 4. Visibility score (VS) of the criterion *artifact formation* of the tested needles of 2 different aspects of the needle within the animal model. Gray columns: longitudinal scan of the shaft; white columns: axial view of the tip. Results are given as mean and standard deviation (bars). Manufacturer information for each product is given in Table 1.

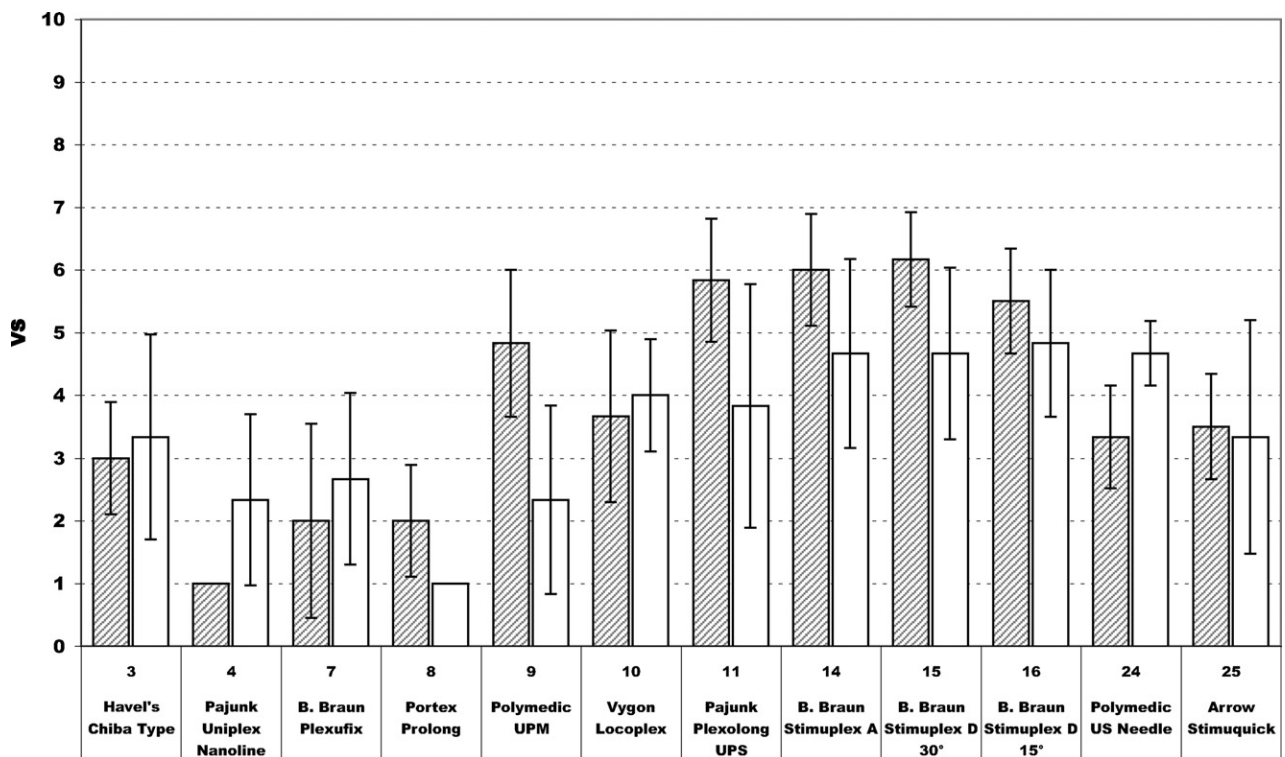


Fig 5. Visibility score (VS) of the criterion *degree of shadowing* of 2 scan aspects of the needle within the animal model. Gray columns: longitudinal scan of the shaft, white columns: axial view of the tip. Results are given as mean and standard deviation (bars). Manufacturer information for each product is given in Table 1.

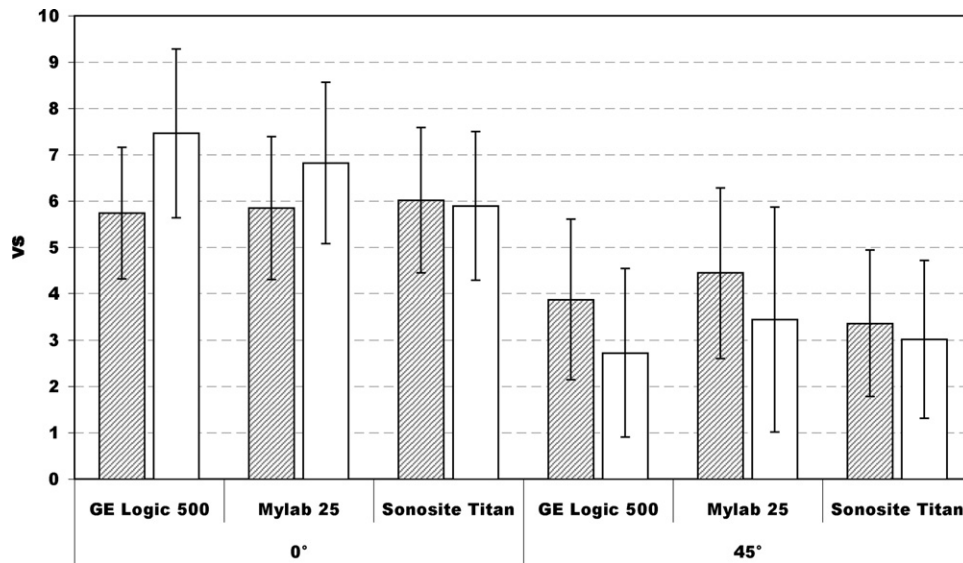


Fig 6. Visibility score (VS) of the criterion *consistency of the needle surface* as a surrogate parameter for the quality of the depiction of the ultrasound system. Differentiation between water bath model (gray columns), animal model (white columns), and 2 angles. Each column represents data points of the 2 investigators and all needles. Results are given as mean and standard deviation (bars). Ultrasound systems: Logic® 500, GE Healthcare®, Solingen, Germany; MyLab® 25, Esaote® Biomedica GmbH, Halbergmoos, Germany; Titan®, SonoSite® GmbH, Erlangen, Germany.

However, good needle depiction is usually expected in hypoechoic tissue (similar to water) or when the ultrasound plane is perpendicular to the needle. Our data and data from other groups show that needle visibility is reduced at steeper insertion angles.³ Unfortunately, not every target can be reached with optimal ultrasonic depiction of the needle and there is general complaint about decreased needle visibility with ultrasound at small (steep) angles.⁴⁻⁶

Because needle visibility (in particular its tip) is highly dependent on the physician's ability to coordinate the ultrasound plane and needle position in parallel, physicians should additionally consider the ultrasonic characteristics of different needles for regional anesthesia for specific procedures. In our opinion, of special interest for clinical use is the criterion "difference and detection of the needle from the surrounding area." Recommendations for specific needles are based on these criteria and are as follows. *Choice of needles (best 3):* Of the tested needles only 3 (in our opinion) are acceptable for US-guided RA (VS of 7 or higher) when puncture angles other than 0 degrees are necessary: Pajunk Plexolong UPS, B. Braun Stimuplex A and B, Braun Stimuplex D with 15-degree bevel. Because needle visibility and the ability to differentiate needle from tissue is crucial for safe and successful US-guided RA, we suggest that 6 needles are not suitable for puncture procedures at an angle of 45 degrees (VS of 5 or lower): Pajunk Uniplex Nanoline, B. Braun Plexifix, Portex Prolong, Poly-

medic UPM, Vygon Locoplex, and Arrow Stimuquick. However, when performing RA with an US plane perpendicular to the needle 11 of 12 needles were sufficient for ultrasonic depiction.

This study was not designed to answer the question of why needles of different manufacturers have a different ultrasonic appearance. However, the dictum "every light has its shadow" becomes true for needles with strong artifact formation, because these were associated with a high degree of shadowing. Many phantoms have been used (gelatine, turkey breast, wet sponge, liquids, etc.) to address the requirements of needle testing and there are several techniques to quantify and qualify needle visibility (including ours). A universally accepted model and technique does not exist. Visibility in the water bath was superior, where overall needle visibility and detection and distinction from the surrounding media was significantly reduced in a model mimicking human tissue. We, like other authors,⁷ feel that the interpretation of US scans of needles in a water bath provides limited clinical information. So, the question of how needles can be optimized is a challenging one: manufacturers will have to consider test media and different insertion angles in addition to special characteristics of the needles' materials.

In summary, needles for RA have different ultrasonic appearances. None of the tested needles was optimal for every aspect of ultrasonic depiction and only a few needles were acceptable for puncture procedures at an angle of 45 degrees. Because good

needle visibility is such a crucial component for safe ultrasonic procedures, the authors strongly recommend manufacturers improve their needles for use under ultrasound guidance.

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