

Laboratory Study

Needle Echogenicity in Ultrasound-Guided Lumbar Spine Injections: A Cadaveric Study

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Background: Echogenicity of regional anesthesia needles has been tested on different preclinical models; however, previous studies were done in an ideal experimental setting utilizing high-frequency insonation and superficially located targets. Because steep-angle deep injections are typically required for spinal and other chronic pain procedures, and low-frequency transducers are used, further feasibility study is warranted.

Objectives: To determine effectiveness of steep-angle deep injections, typically required for spinal and other chronic pain procedures.

Study Design: Experimental laboratory study.

Setting: Willed Body Program, University of Washington.

Methods: In-plane lumbar spine procedures with 50° and 70° angles were performed on a human cadaver. The images and video clips of a non-echogenic (Quincke-type) and echogenic (SonoPlex, StimuQuick, and EchoStim) needle placements were presented to 3 blinded assessors who rated the needle visibility on a 4-point scale.

The data was statistically analyzed to determine the differences in visibility between the needles with and without the digital image enhancement, and to compare the video clips to captured images.

Results: ANOVA analysis demonstrated that overall SonoPlex was significantly better ($P = 0.02$) than other needles. SonoPlex maintained its superiority in the subset of facet joint injections ($P = 0.02$), followed by Quincke-type, then the StimuQuik, and EchoStim needles. In deep procedures, EchoStim was comparable with SonoPlex ($P = 0.03$), and they both were better than the other 2 needles. The enhanced images received higher rates, with a 0.6 point mean improved rating ($P = 0$).

Limitations: This study is limited by choice of needles, number of experiments performed, and potential postmortem changes of echogenicity.

Conclusions: The SonoPlex needle appeared to have better echogenicity in this study. While non-echogenic Quincke-type needle visibility was adequate in superficial placements, it was limited in deep injections. An imaging enhancement is effective in improving needle visibility and should be used whenever possible.

Key words: Spinal injections, ultrasound, echogenic needle

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Currently ultrasound-guided procedures are commonly performed in regional anesthesia and musculoskeletal interventional practice. The ability to precisely direct a needle and track the needle tip is essential to ensure procedural

accuracy and safety. Ultrasound guidance has been increasingly utilized in pain management for procedures that have been traditionally performed under fluoroscopy, such as zygapophyseal joints (1,2), epidural injections (3), and sympathetic

blocks (4). This development is largely explained by the increased awareness to unnecessary radiation exposure (5), as well as by intrinsic desirable properties of ultrasonography that make possible to visualize soft tissue, nerves, and blood vessels, and to perform injections in the axial plane. The limitations of ultrasound are also well established, including the inability to detect intravascular injection, failure to capture images of structures acoustically sheltered by bone or air, and insufficient needle visibility, especially during deep injections with a sharp angle (6).

Several methods improving needle visibility have been introduced in the last 10 years, such as image enhancement software, biopsy guides, and the echogenic pattern of the needles themselves (7).

Studies relating to needle echogenicity in phantoms and water were done, but they cannot be generalized to clinical practice (8). More recent cadaveric studies painstakingly investigated echogenicity of different needles; however, only superficial injections under high-frequency insonation were performed (9,10). There have been no publications addressing needle visibility in spine injections. Furthermore, none of the published studies investigated the performance of a curvilinear low-frequency transducer that typically is used for deep injections.

This laboratory work was performed to address these questions by comparing the visibility of echogenic and non-echogenic needles in spinal procedures using a blinded rating system.

METHODS

An adult human cadaver was obtained from the University of Washington Willard Body program. Institutional Review Board approval was not required as personal information regarding the deceased individual, excluding biometric data, was not available to the investigators. The body was of woman 68 years old at death. The body mass index was estimated at being 25 kg/m².

The specimen was positioned prone, and a towel roll was placed under the abdomen to alleviate lumbar lordosis.

SonoSite S-Series ultrasound machine (SonoSite, Bothell, WA) with the C-60x curvilinear, low-frequency transducer 5-2 MHz was used. The study targets were identified by means of systematic scanning of the lumbar spine and paraspinal structures as described elsewhere (11).

The procedures were performed by a single operator (M.G.) with each of the 4 selected needles (Table 1), with and without the needle visualization protocol (MBe). The selection of needles was dictated by pragmatic considerations, i.e. these needles are routinely used in the hospital.

The experimental procedures were elected as a sample of ultrasound-guided pain interventions performed at a variety of depths and working angles. To minimize operator dependent procedural imperfections, a biopsy guide Infinity (Civco Medical Solutions, Kalona, IA) was used. The procedures included facet joint injections, which were performed twice with all needles, once at the L4-5 facet joint and once at the L5-S1 facet joint. These procedures were performed at a depth of 4 cm and approximately a 50° angle (Fig. 1). Subsequently, the transforaminal injections were performed at a depth of 6 cm and angle of 50°. Finally, the rami communicans injections were performed at an angle of 70° and depth of 8 cm (Fig. 2). Images and video clips of each procedure were organized in a PowerPoint presentation. In addition, introductory slides with a short refresher course of the sonoanatomy and teaching slides guiding how to conduct analysis were prepared. An investigator (S.A.), who was not involved in capturing the images, presented the slides to 3 board-certified interventional pain physicians, who rated the images for needle visibility on a 4-point scale (0 = cannot see the needle; 1 = poor echo-signal; 2 = satisfactory echo-signal; 3 = excellent echo-signal). The assessors were informed regarding the type of procedures per-

Table 1. *Needles used in the study.*

Number	Name	Gauge	Type	Manufacturer
1	BD Spinal Needle	22	Non-Echogenic	BD Medical, Franklin Lakes, NJ
2	EchoStim	21	Echogenic	Havel, Inc. Cincinnati, OH
3	StimuQuick Echo	21	Echogenic	Arrow International, Inc., Reading, PA
4	SonoPlex Stim	21	Echogenic	Pajunk Medizintechnologie, Geisingen, Germany

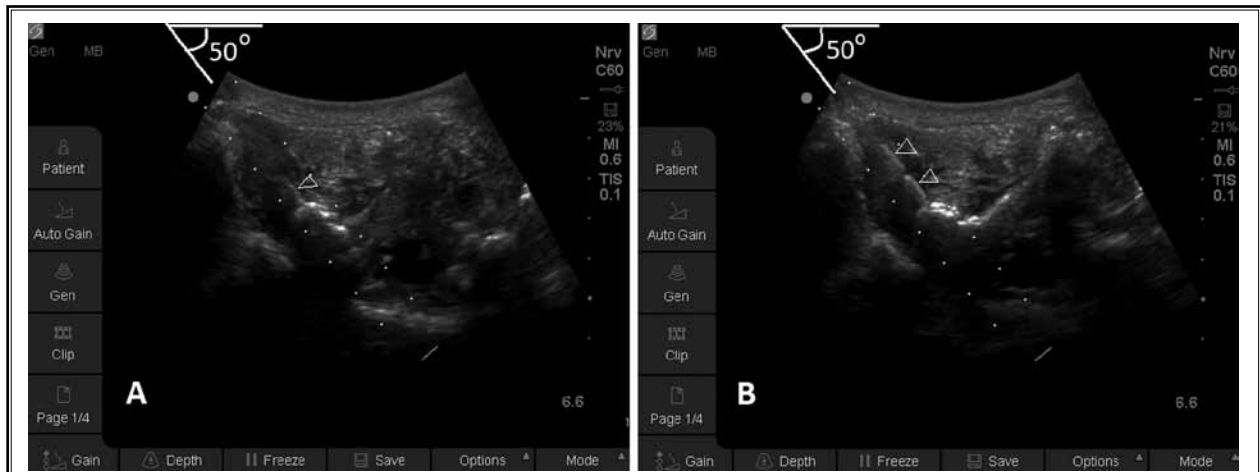


Fig. 1. L5/S1 facet joint injection. A. EchoStim needle (arrowhead). B. SonoPlex needle (arrowheads).

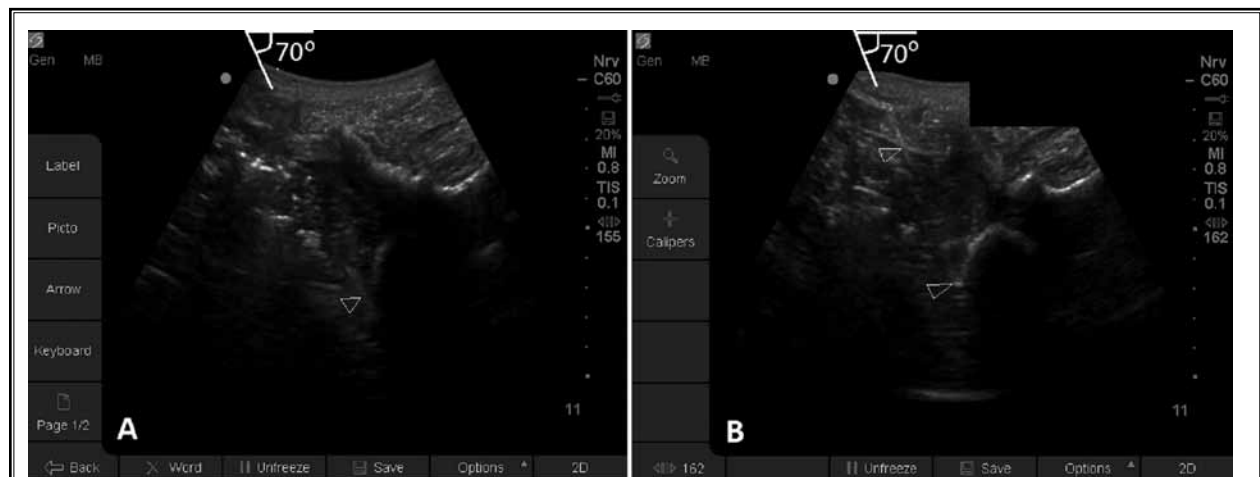


Fig. 2. L4 rami communicans injection. A. SonoPlex needle tip (arrowhead). B. EchoStim needle shaft and tip (arrowheads).

formed and received detailed instructions. They were not cognizant regarding the study objectives and the needle brands.

The ratings were then analyzed using standard statistical methods to determine the differences in visibility. The data were also analyzed to compare ratings with and without the use of digital image enhancement and to compare the video clips to the still images.

RESULTS

ANOVA analysis of the results by the needle type demonstrated that overall the SonoPlex received significantly better visibility ratings ($P = 0.02$). The non-echogenic Quincke-type and the EchoStim needles were

almost equivalent, and the StimuQuick had the worst visualization scores, with a mean score lower by 0.7 when compared to the SonoPlex mean score.

Separate sub-analyses of both superficial and deep injections were done. SonoPlex maintained its advantage in the subset of the facet joint injections ($P = 0.02$), followed by the Quincke-type, then the StimuQuick, and EchoStim. Analysis of the deep procedures found that the EchoStim was slightly better than the SonoPlex ($P = 0.03$), and that both needles had significantly higher visibility ratings than the other 2 (Fig. 3).

Finally, the different types of images were compared in terms of their visibility ratings. A paired t-test was used to compare the visibility ratings of proce-

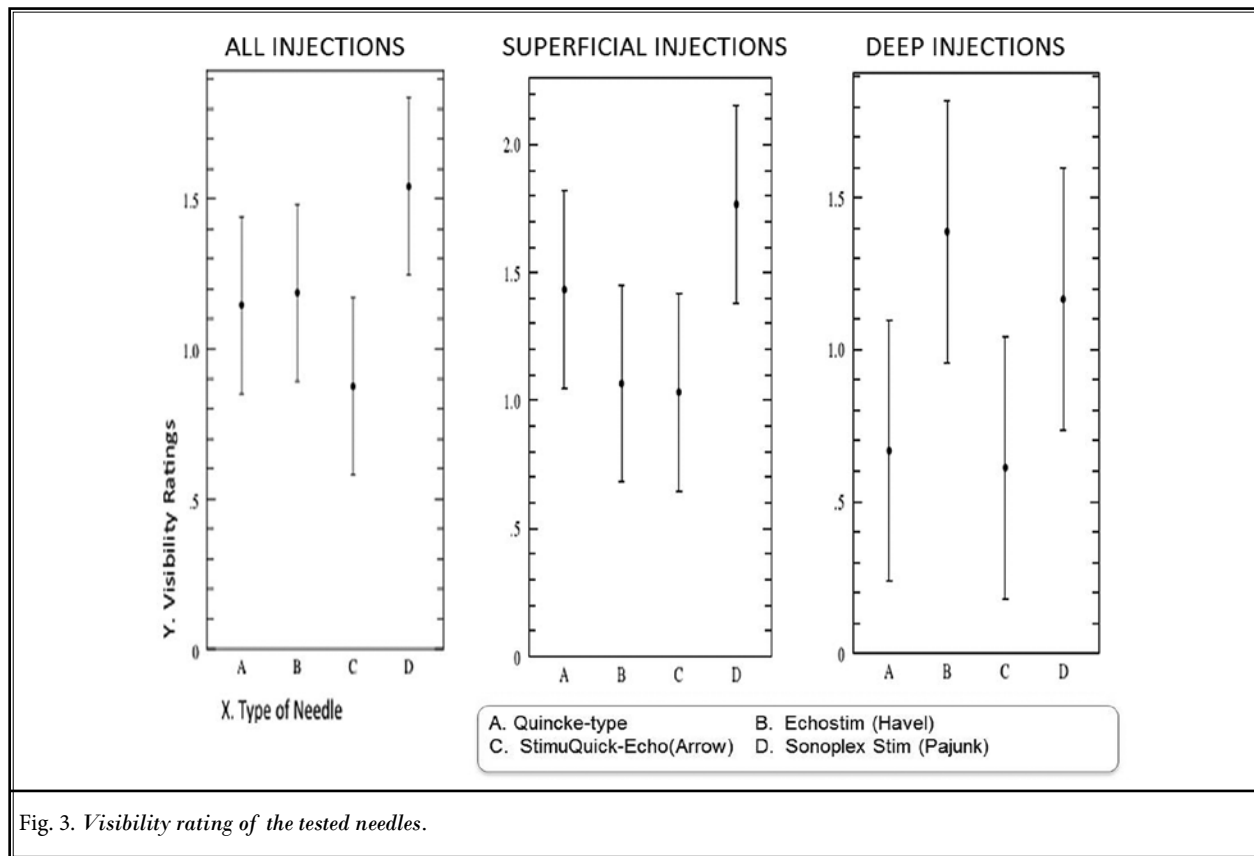


Fig. 3. Visibility rating of the tested needles.

dures with and without MBe enhancement, and the enhanced images were unquestionably better with 0.6 point higher mean visibility score ($P = 0.001$).

Two assessors unsolicitedly commented that the video clips were easier to interpret than the still images. Specifically the needle tip was more noticeable during dynamic progress, and it was almost invisible on the captured images. To test if this impression was reflected in a greater variation of assessment scores, the ratings for the still images were compared to the ratings of the corresponding video clips. The standard deviation of the still images was actually greater (0.982 vs. 0.875).

Discussion

The present study addressed 2 knowledge deficiencies areas, i.e. visibility of different needles under different protocols in spinal ultrasound-guided injections and the performance of a low-frequency curvilinear transducer. This study demonstrated that of the 4 needles studied, the SonoPlex needle had overall higher visibility ratings. The findings were quite different between the shallow and deeper procedures.

The non-echogenic Quincke-type needle was rated the close second to SonoPlex when it was inserted superficially, but its visibility was inadequate in the deep procedures. In deep tissue planes and adjacent to the bone, the SonoPlex and EchoStim needles, both echogenic, received the highest scores. In a steep angle (70°) and deep position the bright echogenic tip of EchoStim was rated as having the best visibility. A low-frequency transducer demonstrated satisfactory performance allowing visualization of the proximal needle shaft on the still images and adequate tracking of the needle tip on the dynamic cine. In addition, it appeared that the software imaging enhancement (MBe) was significantly contributing to improved needle visibility regardless of the procedural angle and the needle brand.

There have been several publications addressing echogenicity of different regional anesthesia needles using laboratory modeling. These models include phantoms (12-15), water baths, and animal tissues (16). All these techniques have method-specific limitations and drawbacks. Water bath is the most primitive model,

giving only rough estimation of needle echogenic properties. Phantoms neither have the same echogenic characteristics as real tissues, nor do they replicate real anatomy, and can entrap air along the needle path during intervention. Most likely, phantoms are only suitable for training of psychomotor skills. A recently published study utilized cadaveric material embalmed with the Thiel process, using a specific biocidal preservation technique to maintain satisfactory sonographic tissue appearance (10). This study also utilized standardized angulations by means of a machined plastic guide, which was cut at 4 predetermined angles.

The Thiel-method embalmed human specimen is an excellent and long-lasting model. However, image degradation still occurs in the deep tissue plane, and the Thiel method is unavailable in the USA.

An unembalmed cadaveric model appears to be a perfect medium for testing needle visibility in the spine and deep tissue injections. This model has been previously used; however, only superficial (4 cm) injections were performed and a high-frequency linear transducer was utilized (9,17).

The deficiencies of previous publications (i.e., superficial needle placements and use of linear high-frequency transducers) were addressed in the present study. Generally the results were corroborative with numerous previous publications' findings where the SonoPlex needles received highest scores of visibility even when were used for deep tissue plane injections under low-frequency conditions (9,10,15,18).

Ultrasound-guided spine injections are challenging because of a unique combination of concomitant difficulties, such as deep tissue plane, fixed anatomical target, steep procedural angle, and bone artifacts. Nevertheless, the procedures are technically feasible and are logistically less cumbersome than the same ones performed under fluoroscopy (19).

The present work also implemented a novel method of assessment. The still images and video clips were organized into a PowerPoint presentation that also included detailed instructions and the rating system. Blinded assessors experienced in ultrasound-guided

procedures had unlimited time to review the images and to respond in an unbiased way.

Limitations

The main limitation of the study is the number of experiments performed. Limited number of injections and assessors may explain a wide confidence interval (Fig. 3). We also elected not to evaluate all commercially available needles, but only those that are routinely used in the hospital daily practice. Therefore it is possible that another brand may have performed better than SonoPlex. Considering the results of previous publications, this scenario is implausible. Another limitation is possible postmortem changes of echogenic properties of paraspinal structures.

The choice of the rami communicans injection is worth a separate explanation. This is not a regularly performed spine procedure, although potentially it may be useful in managing discogenic pain. However, given the relatively low body weight of 25 kg/m² of the specimen another definitive target for deep injections could not be identified. In a clinical scenario, this particular setting of deep injections with a steep angle may be required for common paravertebral procedures.

CONCLUSIONS

The SonoPlex needle appeared to have better visibility overall in this study. While non-echogenic Quincke-type needle visibility was adequate in superficial placements, it was unacceptable for case of deep injections. If economic factors impede the routine case of use of echogenic needles, reserving them for deeper targets may be medically and financially indicated. An imaging enhancement is effective in improving needle visibility and should be used whenever possible.

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REFERENCES

1. Galiano K, Obwegeser AA, Walch C, Schatzer R, Ploner F, Gruber H. Ultrasound-guided versus computed tomography-controlled facet joint injections in the lumbar spine: A prospective randomized clinical trial. *Reg Anesth Pain Med* 2007; 32:317-322.
2. Gofeld M, Bristow SJ, Chiu S. Ultrasound-guided injection of lumbar zygapophysial joints: An anatomic study with fluoroscopy validation. *Reg Anesth Pain Med* 2012; 37:228-231.
3. Chin KJ, Perlas A, Chan V, Brown-Shreves D, Koshkin A, Vaishnav, V. Ultrasound imaging facilitates spinal anesthesia in adults with difficult surface anatomic landmarks. *Anesthesiology* 2011; 115:94-101.
4. Gofeld M, Bhatia A, Abbas S, Ganapathy S, Johnson M. Three-dimensional ultrasonography of the cervical sym-

- thetic trunk and validation of a new ultrasound-guided technique. *Reg Anesth Pain Med* 2009; 34:475-479.
5. Center for Devices and Radiological Health U.S. Food and Drug Administration. Available at: www.fda.gov/downloads/RadiationDoseReduction/UCM200087.pdf. Accessed November 6, 2012.
 6. Peng PW, Narouze S. Ultrasound-guided interventional procedures in pain medicine: a review of anatomy, sonoanatomy, and procedures: Part I: Nonaxial structures. *Reg Anesth Pain Med* 2009; 34:458-474.
 7. Chin KJ, Perlas A, Chan VW, Brull R. Needle visualization in ultrasound-guided regional anesthesia: Challenges and solutions. *Reg Anesth Pain Med* 2008; 33:532-544.
 8. Hocking G, Hebard S, Mitchell CH. A review of the benefits and pitfalls of phantoms in ultrasound-guided regional anesthesia. *Reg Anesth Pain Med* 2011; 36:162-170.
 9. Hebard S, Hocking G, Murray K. Two-dimensional mapping to assess direction and magnitude of needle tip error in ultrasound-guided regional anaesthesia. *Anaesth Intensive Care* 2011; 39:1076-1081.
 10. Guo S, Schwab A, McLeod G, et al. Echogenic regional anaesthesia needles: A comparison study in Thiel cadavers. *Ultrasound Med Biol* 2012; 38:702-707.
 11. Chin KJ, Karmakar MK, Peng P. Ultrasonography of the adult thoracic and lumbar spine for central neuraxial blockade. *Anesthesiology* 2011; 114:1459-1485.
 12. Hopkins RE, Bradley M. In-vitro visualization of biopsy needles with ultrasound: A comparative study of standard and echogenic needles using an ultrasound phantom. *Clin Radiol* 2001; 56:499-502.
 13. Schaffhalter-Zoppoth I, McCulloch CE, Gray AT. Ultrasound visibility of needles used for regional nerve block: An in vitro study. *Reg Anesth Pain Med* 2004; 29:480-488.
 14. Deam RK, Kluger R, Barrington MJ, McCutcheon CA. Investigation of a new echogenic needle for use with ultrasound peripheral nerve blocks. *Anaesth Intensive Care* 2007; 35:582-586.
 15. Sviggum HP, Ahn K, Dilger JA, Smith HM. Needle echogenicity in sonographically guided regional anesthesia: Blinded comparison of 4 enhanced needles and validation of visual criteria for evaluation. *J Ultrasound Med* 2013; 32:143-148.
 16. Maecken T, Zenz M, Grau T. Ultrasound characteristics of needles for regional anesthesia. *Reg Anesth Pain Med* 2007; 32:440-447.
 17. Edgcombe H, Hocking G. Sonographic identification of needle tip by specialists and novices: a blinded comparison of 5 regional block needles in fresh human cadavers. *Reg Anesth Pain Med* 2010; 35:207-211.
 18. Hebard S, Hocking G. Echogenic technology can improve needle visibility during ultrasound-guided regional anesthesia. *Reg Anesth Pain Med* 2011; 36:185-189.
 19. Gofeld M, Montgomery K. Ultrasonography in spine interventions. *Pain Management* 2012; 2:373-382.