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Visibility of Ultrasound-guided Echogenic Needle and Its Potential in Clinical Delivery of Regional Anesthesia

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Objective: Ultrasound-guided regional anesthesia is recommended for nerve block due to its safety and reliability. Needle visualization is important when inserting needles into tissues in close proximity to target nerves. For safety reasons, the tip of the standard-type needle for application of nerve block is thinner than that of an interventional needle for insertion into intra-abdominal organs, and this makes it harder to determine its precise position. The purpose of this study was to evaluate the performance of an insulated echogenic needle under ultrasound guidance in phantoms and in the routine anesthetic management of patients undergoing elective surgery.
Methods: Needles with a 21-G diameter were inserted into Blue Phantom™ (Advanced Medical Technologies, LLC, WA) and chicken breast phantoms at angles of 15, 30, 45, 60, and 75 degrees relative to the surface. The needle was scanned by ultrasound using a TiTAN™ (SonoSite, WA, USA). Visualization was compared between an insulated needle with corner cube reflectors (CCR-type: Hakko, Japan) and an insulated standard needle (S-type: Hakko, Japan). Both types of needle were also used to deliver regional anesthesia in patients with an ASA classification of PS1–2 undergoing elective surgery.
Results: The tip of CCR appeared as 3 bright points under ultrasound, and was more hyperechoic than S. The CCR-type needle was clearly visible under ultrasound at insertion angles of 15, 30, and 45 degrees, and was consistently more hyperechoic than S. However, at steeper angles of > 60 degrees, visibility was poorer. In delivering clinical regional nerve block, CCR was usually more hyperechoic than S, allowing the nerve block points targeted to be accessed with greater ease.
Conclusions: The better visibility of the tip of CCR indicates that it is superior to S in the clinical delivery of peripheral nerve block.

Key words: Needle visibility, corner cube reflector, echogenic CCR-type needle, ultrasound-guided regional anesthesia

INTRODUCTION

Ultrasound allows the identification of a target and its collateral structures. This real-time information can then be used as a guide for the precise placement of needles. The site of insertion may be in close proximity to structures such as vessels, nerves, or the pleura, which means that visualization of the needle is essential [1].

In ultrasound-guided needle insertion, the physician uses real-time ultrasound images of the anatomical target to help choose the appropriate trajectory for the needle. Needle insertion itself may be required for a number of reasons such as biopsy, drug delivery, and surgical ablation. Percutaneous aspiration of fluid and aspiration biopsies offer a fast, safe, and inexpensive means of detecting and characterizing masses and bodies of fluid.

When the in-plane technique is used, the needle is visualized as it passes parallel to the long axis of the scanning head directly under the ultrasound beam [2]. The tip of the needle may be extremely difficult to visualize sonographically, however, especially with the in-plane approach [3]. This problem has been addressed, therefore, by the development of echogenic needles [4].

A number of methods have been used to enhance echogenicity for surgical or radiological purposes, including roughening, dimpling, and polymeric coating of the needle [5]. The corner cube reflector (CCR) was first applied to nerve block needles in Japan, becoming commercially available in 2006 [6].

The purpose of this study was to determine the clinical potential of echogenic needles by comparing the performance of an echogenic CCR-type needle with that of a standard needle (S) under ultrasound guidance in tissue phantoms and in the routine anesthetic management of patients undergoing elective surgery.

MATERIALS AND METHODS

Study needles

The following two types of needle commercially available for ultrasound-guided regional anesthesia (UGRA) in Japan were used:

1) A 21-G insulated CCR-type needle (Hakko, Japan). The corner cube reflectors (CCRs) are embossed at the distal end of the needle. The first is located at 2 mm from the end, with two more at 1-mm intervals, making a total of 3. There are a total of three lines of such CCRs spaced at 120-degrees apart around

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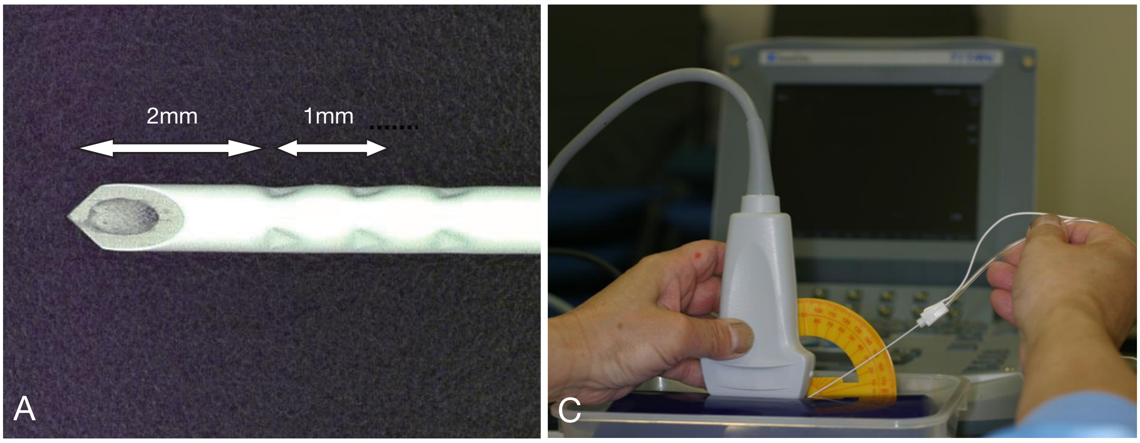

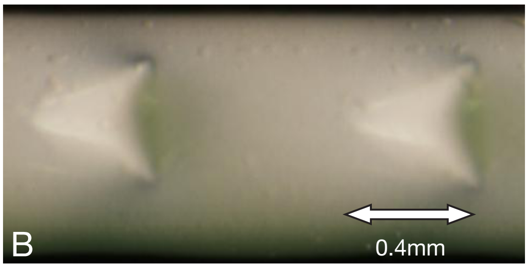

Fig. 1 Echogenic corner cube reflector-type needle
A, Echogenic corner cube reflectors (CCRs) embossed at distal end of needle. First is located at 2 mm from end, with two more at 1-mm intervals, making total of 3. There are 3 lines of such CCRs spaced at 120-degrees apart around circumference, making 9 CCRs in total. Needle tip has short 30-degree bevel.
B, Enlarged corner cube reflector CCR at distal end of needle.
C, Setup for in-plane insertion of CCR-type needle in Blue Phantom™ with linear array transducer.

the circumference, making 9 CCRs in total (Fig. 1-A, 1-B).

2) A 21-G insulated standard (S)-type needle (Hakko, Japan).

Ultrasound equipment

For ultrasound, the TiTAN™ (SonoSite Inc., Bothell, WA, USA) was used with a linear L38 (10-5 MHz) or convex C60 (5-2 MHz) transducer. Receiver gain and target-gain control of the ultrasound device were set at a constant to obtain the best image quality.

Phantom

The following two tissue phantoms were used as a hands-on training model:

1) The Blue Phantom™ (Advanced Medical Technologies, LLC, WA) synthetic gel model.

2) A chicken breast phantom, which has a background echogenicity close to that of human tissue [7].

Study protocol

Ultrasound was used for real-time guidance of needle insertion using the in-plane approach. The performance of each type of needle was assessed under the following conditions:

1) Under ultrasound-guidance in the tissue phantoms: The needles were inserted at angles of 15, 30, and 45 (with linear-type probe), and 60 and 75 (with convex-type probe) degrees relative to the phantom surface while using a protractor to determine imaging performance from shallow to steep (Fig. 1-C). Optimal in-plane needle images were then saved as an uncompressed file for printing and evaluation. We saved one typical image at a time at each angle. Prior traces were avoided when inserting the needles into the phantom.

2) Under ultrasound-guidance for the clinical application of a regional block: Patients with an American Society of Anesthesiologist- Physical Status Classification (ASA PS) 1-2 undergoing elective surgery were enrolled in the study. There were 11 patients in total, comprising 7 men and 4 women. General anesthesia was applied in 8 cases and subarachnoid block in 3. Written informed consent was obtained from all patients for participation in the study. Peripheral nerve block was applied at brachial plexus two (supraclavicular one and axillar approach one), obturator nerve one, and femoral nerve one.

RESULTS

In the Blue Phantom™, S and CCR consistently showed good tip and adequate shaft echogenicity. At a steeper angle, the tip of the CCR was clearly visible as 3 hyperechoic dots (Fig. 2 and 3).

In the chicken breast phantom, the tip of CCR was clearly visible at insertion angles of 15, 30, and 45 degrees, and was consistently more hyperechoic than S. However, at steeper angles of > 60 degrees, the tip of the CCR was barely visible, while that of S was only poorly visible (Fig. 4 and 5). With regional nerve block, the tip of the CCR needle was usually depicted as hyperechoic dots, enabling easier and safer accessibility to the nerve block points (Fig. 6), enabling the surgical procedure to be performed without any complications.

DISCUSSION

The last two decades have seen ultrasound equipment grow both more compact and more affordable. As a result, we have seen the development of a new technology: point-of-care ultrasonography, which continues to be used by an increasing range of medical specialties [8].

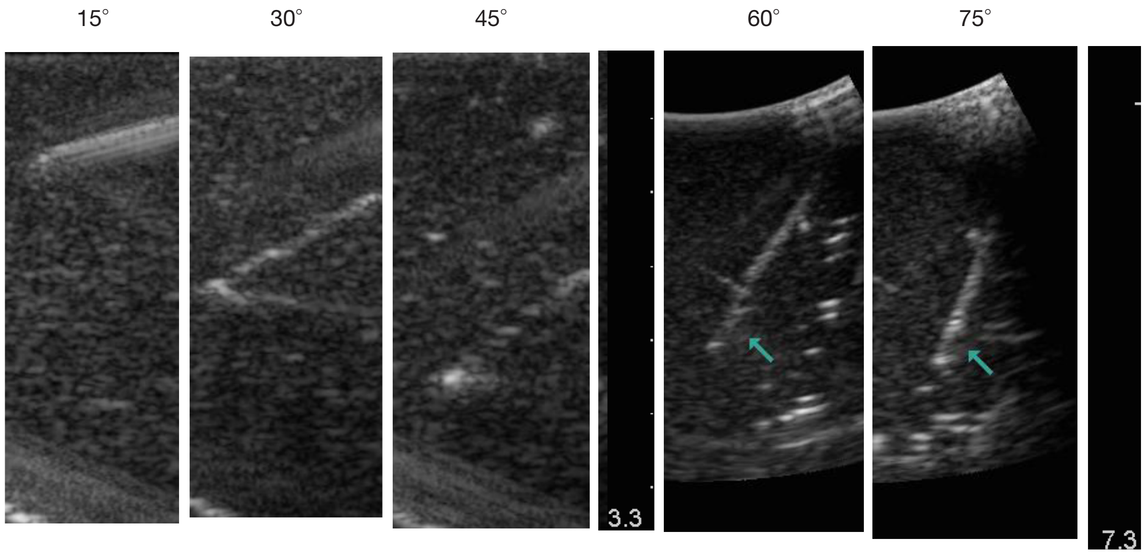

Fig. 2 Ultrasound images of standard needle (S) inserted at 15, 30, and 45 (with linear probe), and at 60 and 75 (with convex probe) degrees to surface of BP. S showed good tip and shaft echogenicity.
S, standard needle; BP, Blue Phantom™

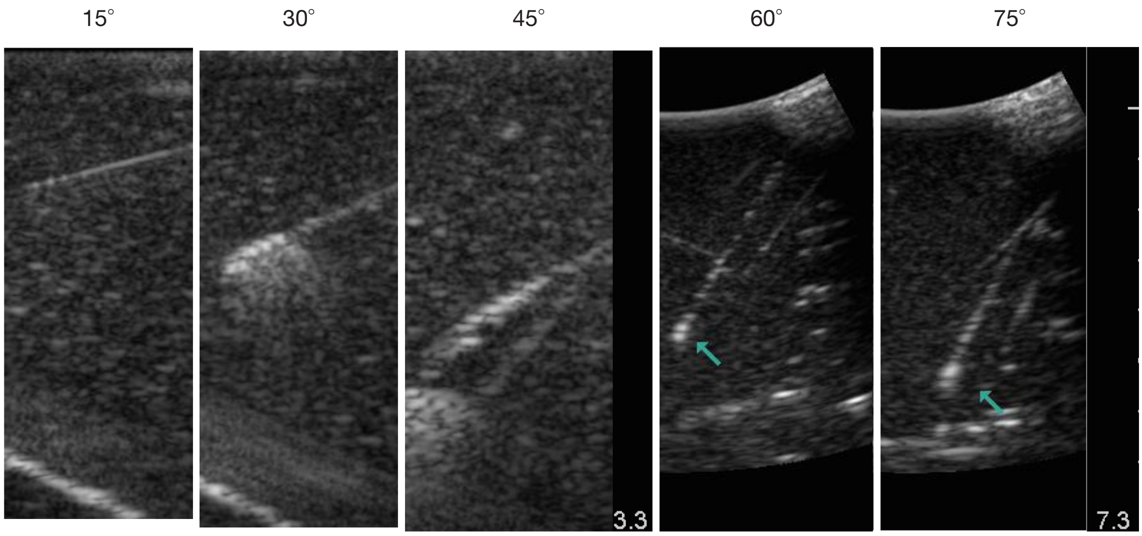

Fig. 3 Ultrasound images of CCR-type needle inserted at 15, 30, and 45 (with linear probe), and at 60 and 75 (with convex probe) degrees to surface of BP. Tip was clearly visible as 3 hyperechoic dots. CCRs maintained needle echogenicity, despite steeper trajectory.
BP, Blue Phantom™

The advantages offered by UGRA mean that it has become widely accepted among anesthesiologists, and the likelihood is that it will soon become available for use at the point of care anywhere and at any time [9, 10]. Ultrasound offers a noninvasive means of obtaining information on both normal and abnormal anatomy. By means of ultrasound imaging techniques, the anesthesiologist is now able to accurately position the needle and determine the distribution of a local anesthetic in real time, which can improve the quality of nerve block, shorten its latency, and reduce the minimum volume required to secure its success [11–13].

Ultrasound also allows the needle trajectory to be monitored, adjacent structures to be avoided, injected solution to be observed, and real-time adjustments necessary for effective perineural spread of injectate to be made [14].

The in-plane approach generates a long-axis view of the needle, allowing full visualization of its shaft and tip, which requires alignment with the ultrasound beam. The in-plane approach does have one disadvantage, however: as the ultrasound beam is very narrow (as little as 1 mm at the focal zone of high-frequency transducers), it can be difficult to maintain needle-beam alignment as the needle is advanced [4, 14].

Failure to visualize the needle as it is being advanced and inadvertent movement of the probe without proper needle visualization are the most common errors encountered in training physicians in UGRA [15].

When a problem is encountered while taking the in-plane approach, it is necessary to visually determine the position of the needle and transducer in order to

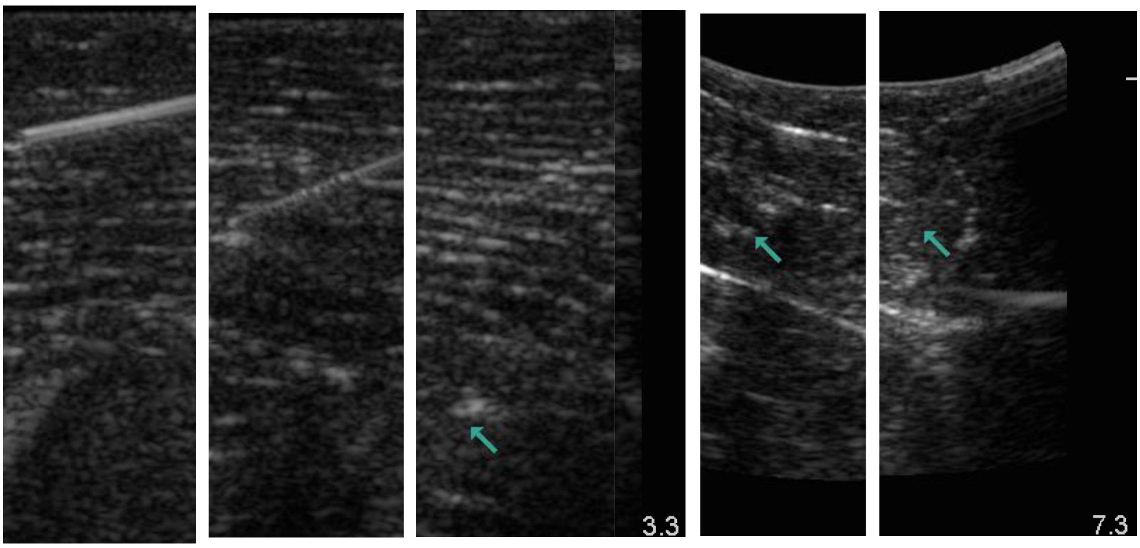

Fig. 4 In chicken breast phantom, ultrasound images of tip of S showed good echogenicity at shallow angle of < 30 degrees, but was only poorly visible at angles of > 45 degrees, and was invisible at steeper angles of > 60 degrees. S, standard needle

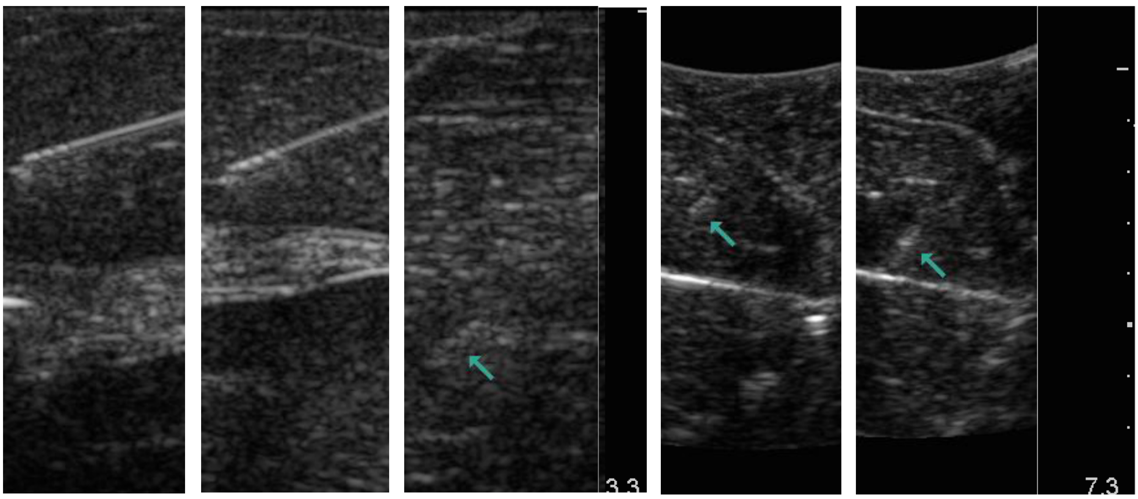

Fig. 5 In chicken breast phantom, ultrasound images of tip of CCR-type needle showed good echogenicity at shallow angle of < 45 degrees, but was only barely visible at steeper angles of > 60 degrees.

prevent gross misalignment. Any further movement of the transducer should be undertaken slowly and with caution, using the 3 basic movements (sliding, tilting, and rotating) described by Marhofer and Chan until the shaft and tip of the needle are brought back into view again [4].

Ultrasound-guided biopsy continues to grow in popularity. With finer-gauge needles, echogenic enhancement may confer an advantage in terms of visibility, which is essential for the safety and efficacy of UGRA [16].

When performing UGRA with the in-plane technique, clear visualization of the needle it easy when it is perpendicular to the beam. It is much more challenging, however, to perform this technique safely at steeper angles of 45 degrees or more in a clinical setting [17–19].

Many attempts have been made to improve the visibility of needles for application of anesthetic block, including roughening, dimpling, and polymeric coating [5]. However, clinical UGRA requires an angle of between 30 and 60 degrees, within which range the echogenicity of most types of needle is poor. Echogenic needles are engineered so as to steer the reflected ultrasound waves back towards the transducer [4]. This technology utilizes dimpling of the needle surface to obtain so-called "corner cube reflectors", which comprise indentations specifically oriented to function best at a steep angle of needle insertion. The principle is the same as that underlying bicycle reflectors and roadside guard rail reflectors, in which light is reflected towards its source, regardless of the angle at which it strikes the reflector itself (Fig. 7) [20].

Thus, echogenic needles offer improved shaft and tip visibility, regardless of the level of experience of the operator. Moreover, they compensate for suboptimal

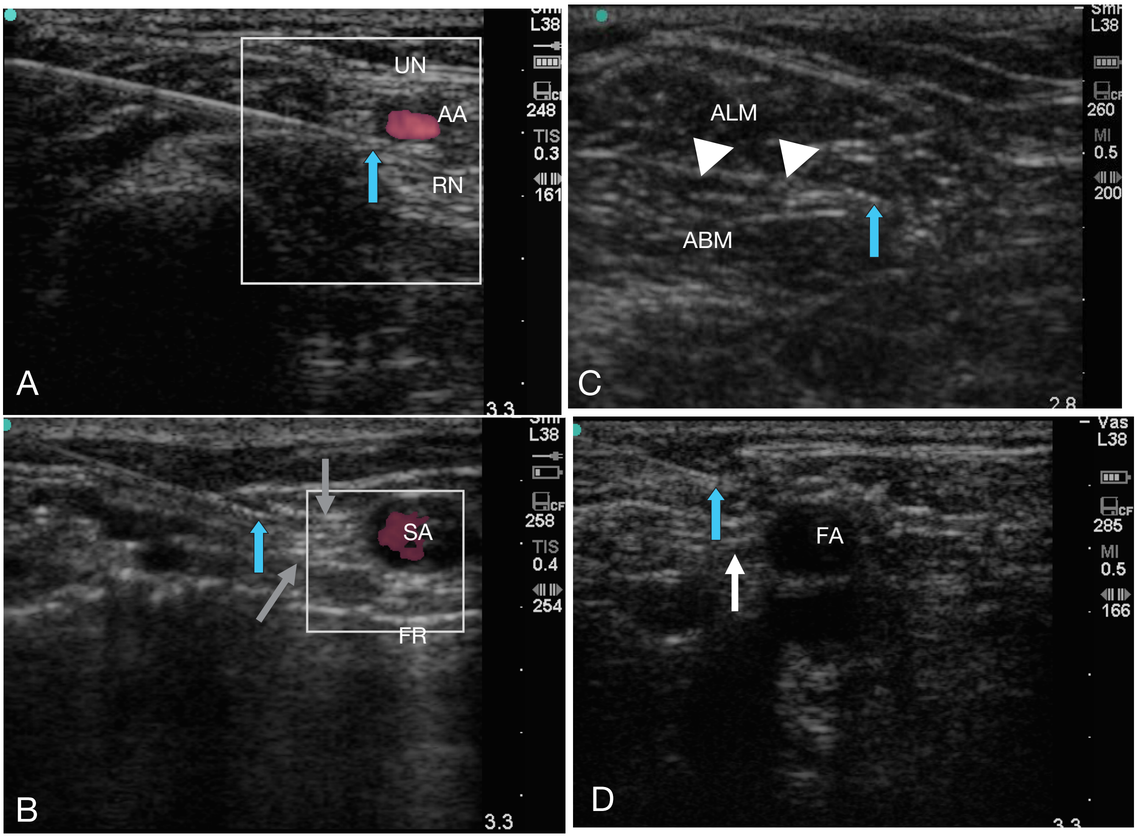

Fig. 6 Sample images of CCR-type needles used in clinical ultrasound-guided regional anesthesia (UGRA) before application of injectate.

A) Ultrasound image of axillary nerve block. Blue arrow: hyperechoic dots indicating tip of needle. AA, axillary artery; UN, ulnar nerve; RN, radial nerve.

B) Ultrasound image of brachial plexus (labelled by grey arrows) at supraclavicular level. Blue arrow: hyperechoic dots indicating tip of needle. SA, subclavian artery; FR, first rib.

C) Ultrasound image of adductor muscles. Thick fascial plane containing nerve separates muscles. ALM, adductor longus muscle; ABM, adductor brevis muscle. Fascia containing branch of obturator nerve (arrow head) and tip of needle (blue arrow).

D) Ultrasound image of femoral compartment. White arrow indicates femoral nerve and blue arrow tip of needle.

scanning, allow for a steeper insertion angle to be taken, and reduce technical difficulties, all of which means that they can be used with greater ease and confidence than would be possible with a conventional type of needle.

It is possible that the performance of echogenic needles may vary between phantoms and human tissue. Therefore, in the present study, in addition to application of echogenic and non-echogenic needles in synthetic gel and meat phantoms, they were also applied to patients undergoing UGRA.

The results of the present study indicate that CCR offers a better performance than S from a shallow to a steep angle of < 60 degrees (Table).

According to recommendations, axillary cervical plexus and femoral nerve block are considered basic, while supraclavicular cervical plexus and obturator nerve block are supposed to be of intermediate difficulty [21].

One study has suggested that the Sonoplex needle with a corner stone reflector (Pajunk, Geisingen, Germany) is currently the most widely used echogenic needle [22]. However, 50% of Pajunk echogenic needles tested showed poor visibility, even with the in-plane approach, for reasons that are as yet unclear. Therefore, standard procedures such as cautious insertion, hydro location testing with 0.5 to 1 ml of solution, and gentle manipulation of tissues remain the mainstay of clinical practice, rather than relying on needle observation alone [23].

In peripheral nerve block, success depends on precise localization of the nerve and delivery of the anesthetic close to the nerve. Until recently, the two most commonly used methods for nerve localization were paresthesia and electrical nerve stimulation. A current of 0.5 mA or less is considered acceptable for electrical nerve stimulation, after which an appropriate motor response is considered to indicate that the needle is close enough to the nerve for delivery of the drug [24].

Needle visibility, however, is only one factor in the safe delivery of nerve block [5]. Corner cube reflector needles are insulated, which allows peripheral nerve block to be delivered with a higher degree of safety than is possible with a non-insulated needle.

One study has recommended dual guidance as combining the benefits of ultrasound- and nerve stimulator-guided needle placement, maintaining that it allows the needle to be placed closer to the nerve

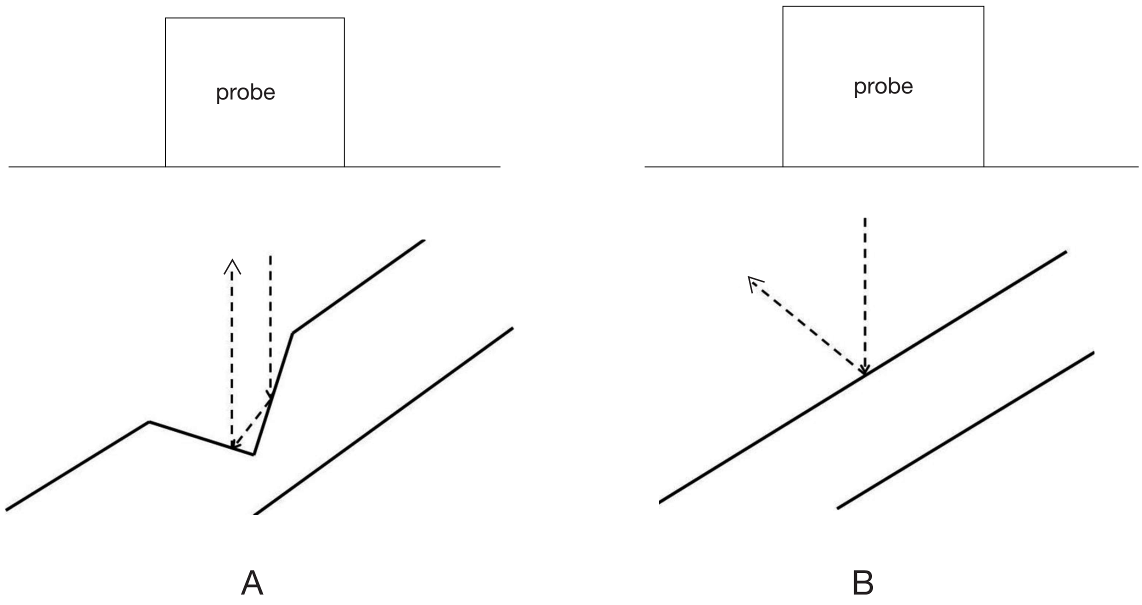

Fig. 7 Schematic diagram of ultrasound performance under in-plane approach
A: Insulated CCR-type needle
CCRs steered ultrasound waves back towards transducer.
When light struck CCR of needle, it was reflected back toward probe.
B: Insulated standard-type needle
Light was reflected off of needle surface away from probe.

Table Summary of needle visibility in chicken breast phantom

	CCR	standard
< 30 degrees	excellent	good
< 60 degrees	good	poorly

Needle visibility in chicken breast phantom with in-plane approach.
CCR, insulated CCR-type needle; standard, insulated standard-type needle.

and a subsequently lower incidence of hematoma formation due to needle trauma to be obtained [25].

At a steeper angle between needle and beam, we recommend using a CCR-type needle under ultrasound guidance for improved visibility together with peripheral nerve stimulation and tissue movement during advancement.

The results of the present study showed that the echogenic dimples of the CCR-type needle improved needle tip visibility in the tissue phantom at relatively low needle-beam angles (≦ 45 degrees). This indicates its potential as a safe and easy-to-use device for drug application in UGRA.

The CCR-type needle offers a number of advantages over the conventional S-type needle, including vastly improved visibility during ultrasound-guided advancement and greater ease of nerve localization for peripheral nerve stimulation, all of which makes the application of peripheral nerve block easier, safer, and more effective, even if the block is of an intermediate level of difficulty.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1) Chapman G A, Johnson D and Bodenham A R. Visualisation of needle position using ultrasonography Anaesthesia 2006; 61(2): 148–58.
2) Chan C, Lam F and Rohling R. A needle tracking device for ultrasound guided percutaneous procedures Ultrasound Med Biol 2005; 31(11): 1469–83.
3) Perrella R R, Kimme-Smith C, Tessler F N, Ragavendra N and Grant E G. A new electronically enhanced biopsy system: value in improving needle-tip visibility during sonographically guided interventional procedures AJR Am J Roentgenol 1992; 158(1): 195–8.
4) Chin K J, Perlas A, Chan V W and Brull R. Needle visualization in ultrasound-guided regional anesthesia: challenges and solu-

tions Reg Anesth Pain Med 2008; 33(6): 532–44.

5) Hopkins R E and 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(6): 499–502.
6) Takayama W, Yasumura R, Kaneko T, Kobayashi Y, Kamada T, Yoshikawa T and Aoyama Y. [Novel echogenic needle for ultrasound-guided peripheral nerve block "Hakko type CCR"] Masui 2009; 58(4): 503–7.
7) Hocking G, Hebard S and Mitchell C H. A review of the benefits and pitfalls of phantoms in ultrasound-guided regional anesthesia Reg Anesth Pain Med 2011; 36(2): 162–70.
8) Collins G B, Fanou E M, Young J and Bhogal P. A comparison of free-hand vs laser-guided long-axis ultrasound techniques in novice users Br J Radiol 2013; 86(1029): 20130026.
9) Bloc S, Ecoffey C and Dhonneur G. Controlling needle tip progression during ultrasound-guided regional anesthesia using the hydrolocalization technique Reg Anesth Pain Med 2008; 33(4): 382–3.
10) Marhofer P and Chan V W. Ultrasound-guided regional anesthesia: current concepts and future trends Anesth Analg 2007; 104(5): 1265–9, tables of contents.
11) Casati A, Danelli G, Baciarello M, Corradi M, Leone S, Di Cianni S and Fanelli G. A prospective, randomized comparison between ultrasound and nerve stimulation guidance for multiple injection axillary brachial plexus block Anesthesiology 2007; 106(5): 992–6.
12) Grau T. Ultrasonography in the current practice of regional anaesthesia Best Pract Res Clin Anaesthesiol 2005; 19(2): 175–200.
13) Marhofer P, Greher M and Kapral S. Ultrasound guidance in regional anaesthesia Br J Anaesth 2005; 94(1): 7–17.
14) Sites B D, Chan V W, Neal J M, Weller R, Grau T, Koscielniak-Nielsen Z J and Ivani G. The American Society of Regional Anesthesia and Pain Medicine and the European Society of Regional Anaesthesia and Pain Therapy joint committee recommendations for education and training in ultrasound-guided regional anesthesia Reg Anesth Pain Med 2010; 35(2 Suppl): S74–80.
15) Halaszynski T M, Kurup V and Souzdalnitski D. Needle visualization in ultrasound-guided regional anesthesia: technological challenges and educational solutions Reg Anesth Pain Med 2009; 34(5): 527–8.
16) Kilicaslan A, Topal A, Tavlan A, Erol A and Otelcioglu S. Differences in tip visibility and nerve block parameters between two echogenic needles during a simulation study with inexperienced anesthesia trainees J Anesth 2013.
17) Maecken T, Zenz M and Grau T. Ultrasound characteristics of needles for regional anesthesia Reg Anesth Pain Med 2007; 32(5): 440–7.
18) Schafhalter-Zoppoth I, McCulloch C E and Gray A T. Ultrasound visibility of needles used for regional nerve block: an in vitro study Reg Anesth Pain Med 2004; 29(5): 480–8.
19) Takatani J, Takeshima N, Okuda K, Uchino T and Noguchi T. Ultrasound visibility of regional anesthesia catheters: an *in vitro* study Korean J Anesthesiol 2012; 63(1): 59–64.
20) Hebard S and Hocking G. Echogenic technology can improve needle visibility during ultrasound-guided regional anesthesia Reg Anesth Pain Med 2011; 36(2): 185–9.
21) Griffin J and Nicholls B. Ultrasound in regional anaesthesia Anaesthesia 2010; 65 Suppl 1(1–12.
22) Hocking G and Mitchell C H. Optimizing the safety and practice of ultrasound-guided regional anesthesia: the role of echogenic technology Curr Opin Anaesthesiol 2012; 25(5): 603–9.
23) Guo S, Schwab A, McLeod G, Corner G, Cochran S, Eisma R and Soames R. Echogenic regional anaesthesia needles: a comparison study in Thiel cadavers Ultrasound Med Biol 2012; 38(4): 702–7.
24) Perlas A, Niazi A, McCartney C, Chan V, Xu D and Abbas S. The sensitivity of motor response to nerve stimulation and paresthesia for nerve localization as evaluated by ultrasound Reg Anesth Pain Med 2006; 31(5): 445–50.
25) Vassiliou T, Eider J, Nimphius W, Wiesmann T, de Andres J, Muller H H, Wulf H and Steinfeldt T. Dual guidance improves needle tip placement for peripheral nerve blocks in a porcine model Acta Anaesthesiol Scand 2012; 56(9): 1156–62.