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Real-time three-dimensional ultrasound for continuous interscalene brachial plexus blockade

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Abstract
Two-dimensional ultrasound guidance is used commonly for regional anesthetic techniques. This report describes the novel use of three-dimensional, ultrasound-guided, continuous interscalene regional analgesia, which was used in a 36-year-old woman undergoing left total elbow arthroplasty. Possible advantages of this novel technology over current two-dimensional methods include a larger area of available scan information that enables multiple planes of view without having to reposition the ultrasound probe, and three-dimensional visualization of local anesthetic deposition perineurally. Current technological limitations include an upper frequency of 7 MHz, which decreases the resolution of superficial scanning.

Key words Anesthesia, regional · Imaging technique, three-dimensional ultrasound · Interscalene block, technique · Regional anesthesia, complications

Two-dimensional (2-D) ultrasound (US) guidance is used commonly for regional anesthetic techniques, with an improved success rate over conventional techniques such as anatomic and nerve stimulation [1,2]. Current 2-D US technology captures a planar (flat) image in comparison to three-dimensional (3-D) US that acquires multiple planes of view without having to reposition the US probe. This report describes the novel use of 3-D, US-guided, placement of a continuous interscalene brachial plexus catheter, which was used for postoperative analgesia in a 36-year-old woman undergoing orthopedic surgery.

The patient had a history of long-term opioid consumption and was scheduled to have an interscalene block for pain management after a left total elbow arthroplasty. After application of standard American Society of Anesthesiologists (ASA) monitors and administration of supplemental oxygen via nasal cannula, the right interscalene groove was identified using surface landmarks. A 3-D US probe (Philips X 7-2; Philips Medical Systems, Andover, MA, USA) was then positioned on the clavicle (Fig. 1), and the brachial plexus nerves were identified. After skin preparation with chlorhexidine, the neck was draped, and a sterile sheath was applied to the US probe. The skin was anesthetized with 1% lidocaine after which sterile US gel was applied. A 17-gauge, insulated 50-mm needle (Arrow International, Reading, PA, USA) connected to a nerve stimulator (Stimuplex Dig RC; B. Braun Medical, Bethlehem, PA, USA; pulse duration, 0.3 ms; current, 1.5 mA; frequency, 2 Hz) was advanced caudally toward the brachial plexus under direct US observation of the needle shaft and tip. Real-time 3-D US visualizing the needle superior and medial to a brachial plexus nerve (Fig. 2) was obtained with real-time manipulation of the image. After an appropriate distal motor nerve response to 0.5 mA, a 19-gauge stimulating catheter (StimuCath; Arrow International) was advanced during continuous stimulation and 3-D US guidance 5 cm into the brachial plexus sheath. The injection of 30 ml of local anesthetic was observed in real time by the 3-D US and encompassed each nerve (Figs. 3, 4).

Complete block of the brachial plexus occurred, and the total elbow arthroplasty was uneventful. Postoperative analgesia was provided by continuous infusion of 0.2% ropivacaine at 6 ml an hour, with a demand dose of 4 ml every 30 min. On postoperative day 3, the local anesthetic infusion was discontinued.

The comparison between 2-D and 3-D US is analogous to the difference between plain X-ray and computer tomography. Unlike 2-D US, which captures a planar (flat) image, 3-D US technology acquires a wide band of information that enables multiple planes of view by manipulating the image without movement of the US probe.

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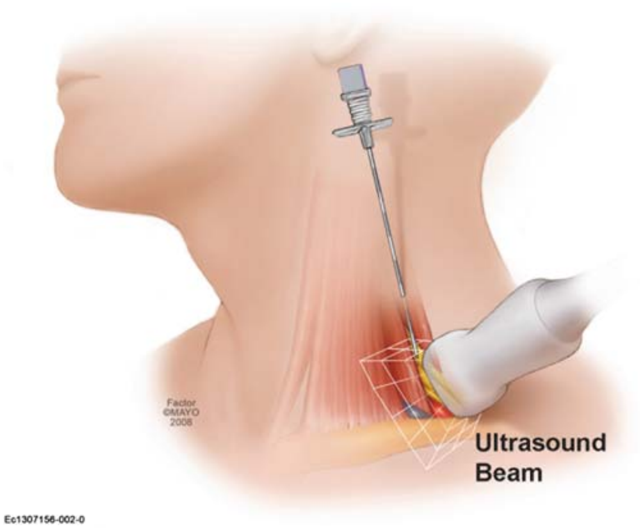

Fig. 1. Illustration of positioning of the X 7-2 matrix ultrasound probe (Philips Medical Systems) for an interscalene brachial plexus block

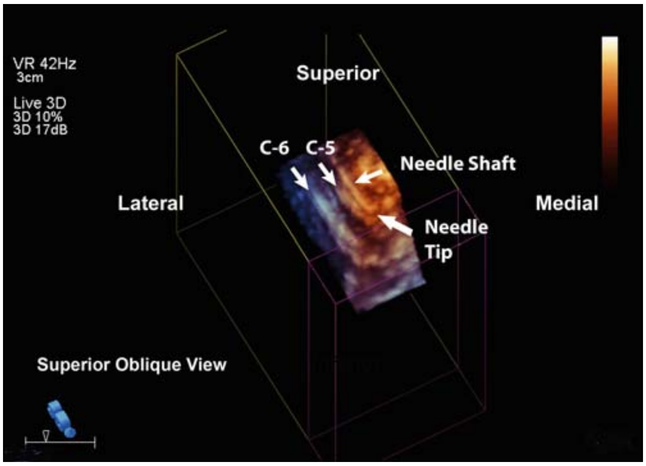

Fig. 2. Superior oblique view of the nerves of C-5 and C-6, and a 17-G Tuohy needle during placement of an interscalene brachial plexus block. *3D*, Three-dimensional; *VR*, volume rate

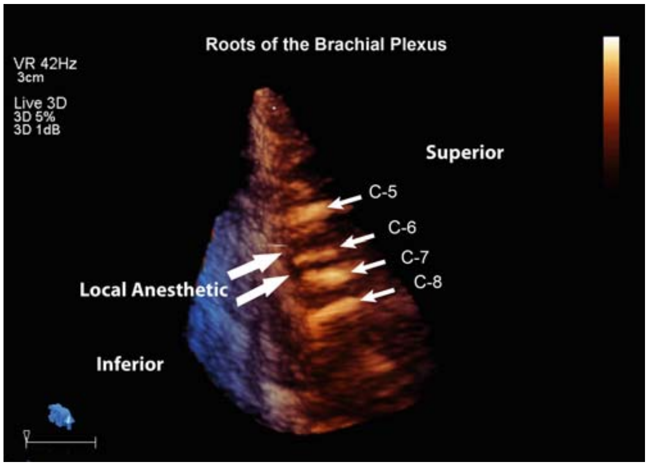

Fig. 3. Roots of the brachial plexus after injection of 30 ml of local anesthetic

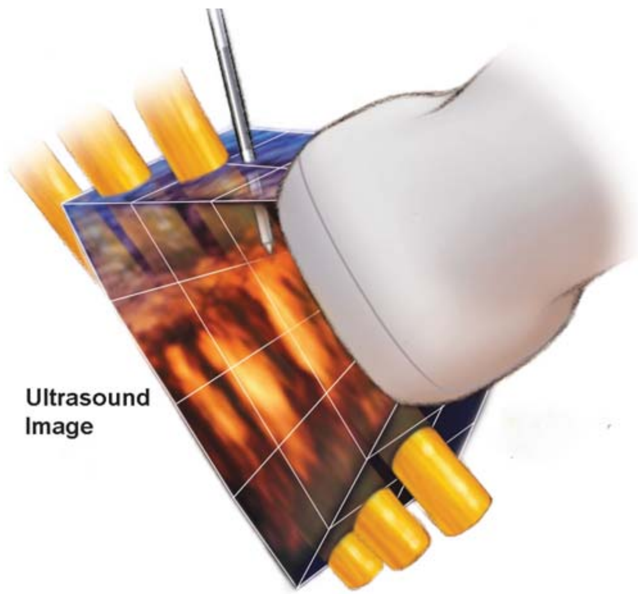

Fig. 4. Artist's illustration of the beam generated by the X 7-2 matrix ultrasound probe (Philips Medical Systems) incorporated with the actual three-dimensional ultrasound image of the interscalene brachial plexus

Real-time 3-D US has been used to observe local anesthetic distribution during the placement of a popliteal sciatic nerve block, and images were obtained with the X 3-1 matrix array probe (Philips Medical Systems) [3,4]. The frequency range of the X 3-1 probe is from 1 to 3 MHz, but it offers poor resolution. Recently, real-time 3-D US has been used to identify aberrant popliteal sciatic nerve bifurcation while using the new-generation matrix array probe (X 7-2), which has a frequency of 1–7 MHz. This wider frequency range capability, compared with that of the older, 1- to 3-MHz range, improves the resolution of the images and aids in the identification of nerves. Current methods for acquiring 3-D in real-time (i.e., four-dimensional [4-D]) US images include the use of mechanical probes and matrix technology. Mechanical probe technology usually acquires data sets that contain a large number of 2-D planes (B-mode images) by sweeping a B-mode transducer within the housing of the US probe. The processing power of the modern computer facilitates real-time acquisition of B-mode images, which are then displayed as 3-D data sets in real time. The matrix array transducer, which contains more than 2400 piezoelectric elements, both transmits and receives data. Signal processing within the transducer head funnels this information into 128 channels of a standard US system. The X 7-2 matrix probe was initially designed for 3-D US of the pediatric heart and computer tomography. The X 7-2 probe on the iU22 ultrasound system (Philips Medical Systems) captures the standard 2-D US view and, with the push of a button, real-time 3-D imaging is visualized, allowing the practitioner to compare the same anatomic structures in 2-D and 3-D (sonoanatomy). On 3-D US, nerves appear as hyperechoic cord structures when viewed on long axis, which can then be confirmed by appropriate motor response to nerve stimulation. Further development of 3-D US probes with even higher frequency capabilities is needed to further enhance image quality and linear probe designs, which would aid in needle tracking during the performance of nerve block.

Advantages of 4-D US are that the probe can be held stationary, the large band of US data (Fig. 4) can be manipulated, and real-time observation of the needle can be seen in multiple planes; this may enhance localization of the needle in relationship to the nerves. Unintentional probe movement during the performance of a block has been identified as a serious error in the hands of novices [5]. In the present interscalene application of 3-D US-assisted block, catheter placement was facilitated by directing the nerve block needle caudally to the brachial plexus sheath and placing and fixing the US probe on the clavicle. With this approach, the needle is directed away from important vascular structures that lie medially.

In teaching environments, the possibility of potentially severe complications underscores the importance of appropriate training in US techniques being provided to trainees by experienced mentors [5–7]. The theoretical advantages of real-time 3-D US require scientific confirmation. Limitations of current 3-D US technology include an upper frequency of 7 MHz, which hampers high-quality resolution of the images. Higher-frequency probes are under development and, once available, will further enhance 3-D US-guided regional anesthesia.

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