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The Novel Use of Biplane Imaging for Ultrasound-Guided Regional Anesthesia

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- Letter to the Editor -

Ultrasound-guided regional anesthesia (USGRA) is most commonly performed with B-mode (2D) imaging using high-frequency linear array and low-frequency curved array transducers. Biplane imaging (BI) is available in phased array and high-frequency curved array (endocavity) transducers to evaluate cardiac and fetal anatomy, as well as for needle-guidance in transrectal procedures. BI capabilities were recently incorporated into high-frequency linear transducers making this technology available to be utilized in USGRA. During a peripheral nerve block (PNB), real-time BI eliminates the need to rotate the transducer to obtain both short and long-axis views of nerves, vessels, bones, muscles or fascial planes. In addition, the needle is displayed in-plane and out-of-plane and local anesthetic spread can be visualized in two orthogonal planes simultaneously. BI in USGRA has the potential to decrease procedure time, number of attempts and needle passes, improve block success and quality, and maximize safety by mitigating the risk of unintended intraneural, intrapleural, and intravascular injection. We report the novel use of BI for USGRA of the thorax, abdomen, upper and lower extremity.

This technical report is exempt from internal review board approval as it is devoid of patient identifiable information as per institutional policies. Deidentified images were obtained from the regional anesthesia image bank. The highest quality images from each major region of the body were selected. Upper extremity biplane USGRA images seen in Figs. 1A-1C include interscalene, infraclavicular and axillary brachial plexus blocks. Images of truncal fascial plane blocks are presented in Figs. 1D-1F which include the superficial parasternal block, deep serratus plane block and rectus
sheath block. Figs. 1G and 1H highlight paravertebral block and the erector spinae plane block. Lower extremity biplane USGRA of the femoral, saphenous and sciatic nerves are depicted in figures 1I-1K.

The Butterfly IQ+ (Butterfly Network, Inc., Guilford, CT) ultrasound attached to either an iPhone 11 (iPhone 11 Pro-Butterfly iQ app) or a 5th generation iPad mini (iPad Butterfly iQ app) was utilized to perform biplane USGRA. The standard B-mode image (reference plane) is displayed at the bottom of the screen while the orthogonal plane that correlates to the cursor (perpendicular plane) is shown at the top of the screen. The transducer was positioned to be simultaneously perpendicular to the object of interest in the short-axis and parallel in the long-axis to ensure optimal BI. A 20–22 gauge blunt-tip, 50–100 mm echogenic block needle (B Braun Ultraplex 360, USA) or 18-gauge SonoTAP Tuohy needle (PAJUNK GmbH Medizintechnologie, Germany) were advanced using the reference plane in an in-plane technique to the target location for each block. The biplane cursor was either placed over the needle tip to see it in short-axis, on the neurovascular structures to image the entire nerve or artery in long-axis, and/or bone, muscle, or fascial planes of interest to obtain an orthogonal view. The biplanar spread of local anesthetic was observed upon injection.

BI can be activated at any time; however, due to the reduced screen size and image quality, we recommend timing the application of BI on a case-by-case basis. For superficial blocks, where needle visualization is less challenging, BI can be activated as soon as the optimal monoplane image is obtained in B-mode. For deeper blocks where needle localization is more difficult to confirm sonographically, we recommend advancing the needle in B-mode and activate BI once the needle tip is in the desired location. This approach will improve the accuracy and visualization of local anesthetic injectate as it dissects orthogonally through the tissue planes.

BI for superficial ultrasound-guided (USG) procedures has been reported with low-frequency and high-frequency matrix transducers for vascular access. One study concluded that enhanced
visualization of structures and needles led to improved performance and feasibility. Anesthesiologists performing internal jugular vein (IJV) cannulation with short-axis, BI using a low-frequency matrix transducer had fewer attempts to puncture, needle redirections, a lower incidence of posterior wall puncture when compared to B-mode and successful puncture of IJV on the first attempt in 90% vs. 50% [1]. The low-frequency transducer used in this study to image large, superficial vascular structures is acceptable for IJV cannulation, however, would provide suboptimal visualization of small superficial structures like nerve roots for USGRA [2]. Convissar et al. [3] described a case in which a semiconductor-based ultrasound with a high-frequency setting (vascular) was used to perform radial artery cannulation with BI. To date, this case is the first report of BI needle-guidance with high-frequency ultrasound. BI for USGRA has not been reported. Figs. 1A-1K are images of USG PNB and fascial plane blocks with the novel application of using a high-frequency ultrasound transducer.

Injectate spread following PNB is studied by cadaveric dissection following injections with dye or radiologic contrast. However, these studies have been criticized as postmortem alterations of tissue integrity could affect patterns of injectate spread and may not accurately represent spread of local anesthetic in real-life clinical situations. While performing USGRA on patients, arterial pulsations, muscle contraction, respirations, and differences in tissue resistance can influence local anesthetic spread [4]. Although BI technology is not currently available in most commonly used ultrasound systems for USGRA, enhanced imaging may improve understanding of sonoanatomy and local anesthetic spread. In 2019, a high-frequency matrix linear array piezoelectric transducer was introduced into the market for vascular applications (Philips XL 14-3 mMatrix, Netherlands). In 2020, BI for high-frequency handheld ultrasound became commercially available. Rapid technological advances in ultrasound coupled with the potential for enhanced superficial imaging might lead to a future where matrix, 3 and 4-dimensional imaging for USGRA is the norm.
BI is a new feature in high-frequency matrix ultrasound transducers that can improve needle localization and enhance visualization of local anesthetic spread in USGRA. We report the novel application of BI in USGRA. More studies are needed to assess the utility of BI in USGRA and evaluate its impact on the safety and delivery of regional anesthesia.
References


Figure legends

**Fig. 1A. Interscalene Brachial Plexus Block**

In the nerve setting, the ultrasound transducer is placed over the lateral neck in a transverse orientation. In the reference plane, the orientation marker (B) is lateral, and the nerve roots that form the brachial plexus, anterior and middle scalene muscles, vertebral artery, and the lateral edge of the sternocleidomastoid muscle are displayed in the short-axis while the 7th cervical transverse process is seen in long-axis. The needle trajectory is in-plane lateral to medial. The biplane cursor is over the 5th and 6th cervical nerve roots. In the perpendicular plane, the butterfly icon is caudal. The needle trajectory out-of-plane, and the tip can be seen between the 5th and 6th cervical nerve roots, seen in the

**Fig. 1B. Intraclavicular Brachial Plexus Block**

In the nerve setting, the ultrasound transducer is placed over the lateral chest in a sagittal orientation. In the reference plane, the orientation marker (B) is cranial with the brachial plexus and axillary artery displayed in short-axis. The needle trajectory is in-plane - the biplane cursor directly over the axillary artery. In the perpendicular plane, the butterfly icon is lateral. The needle trajectory out-of-plane. The
axillary artery and the mediolateral spread of local anesthetic are visualized in the long axis. PMM: Pectoralis major muscle, PmM: Pectoralis minor muscle, AxA: Axillary artery, PC: Posterior cord, AxV: Axillary vein, MC: Medial cord, LC: Lateral cord.

Fig. 1C. Axillary Brachial Plexus Block

In the nerve setting, the ultrasound transducer is placed over the axilla in a sagittal orientation. In the reference plane, the orientation marker (B) is superior, and the branches of the brachial plexus and axillary artery, and vein are displayed in the short-axis. The needle trajectory is in-plane from superior to inferior. The needle reverberation artifact makes it challenging to identify the median and
musculocutaneous nerves in this image. The biplane cursor directly over the axillary artery. In the perpendicular plane, the butterfly icon is lateral. The needle trajectory out-of-plane. The axillary artery and the mediolateral spread of local anesthetic within the connective tissue surrounding the brachial plexus are visualized in the long axis. AT: Adipose tissue, AxA: Axillary artery, CT: Conjoint tendon, TM: Triceps muscle, BBM: Biceps brachii muscle, CBM: Coracobrachialis muscle, McN: Musculocutaneous nerve, MN: Medial nerve, RN: Radial nerve, UN: Ulnar nerve.

Fig. 1D. Superficial Parasternal Block
In the musculoskeletal setting, the ultrasound transducer is placed over the 4th costal cartilage in a sagittal orientation. In the reference plane, the orientation marker (B) is caudal, and the 4th and 5th costal cartilages are displayed in the short-axis while the internal mammary vein is seen in long-axis. The needle trajectory is in-plane in a craniocaudal direction. The biplane cursor directly over the 4th intercostal space. In the perpendicular plane, the butterfly icon is lateral. The needle trajectory out-of-plane with the shaft of the needle is seen traversing the PMM. The internal mammary vessels are seen in the short-axis and the mediolateral spread of local anesthetic between the PMM and ICM. PMM: Pectoralis major muscle, ICM: Intercostal muscles, IMV: Internal mammary vein, IMA: Internal mammary artery, CC5: 5th costal cartilage, CC4: 4th costal cartilage, TTM: Transverse thoracic muscle.
Fig. 1E. Deep Serratus Plane Block

In the nerve setting, the ultrasound transducer is placed over the posterior axillary line in a sagittal orientation. In the reference plane, the orientation marker (B) is cranial, and the 5th rib is displayed in the short-axis. The needle trajectory is in-plane. The biplane cursor directly over the 5th rib. In the perpendicular plane, the butterfly icon is anterior. The needle trajectory out-of-plane with the needle tip visible deep to the serratus anterior muscle. The 5th rib, as well as the anteroposterior spread of local anesthetic, is visualized in long-axis. AT: Adipose tissue, LDM: Latissimus dorsi muscle, SAM: Serratus anterior muscle.
**Fig. 1F. Rectus Sheath Block**

In the nerve setting, the ultrasound transducer is placed over the mid-abdomen sagittal orientation. In the reference plane, the orientation marker (B) is medial, and the rectus abdominis muscle is displayed in the short-axis. The needle trajectory is in-plane. The biplane cursor directly over the tip of the needle. In the perpendicular plane, the butterfly icon is cranial. The craniocaudal spread of local anesthetic is visualized, and the tip of the needle in a short-axis. RAM: Rectus Abdominis Muscle, RS: Rectus Sheath.
**Fig. 1G. High Thoracic Paravertebral Block**

In the musculoskeletal setting, the ultrasound transducer is placed over the 4th transverse process in a transverse orientation. In the reference plane, the orientation marker (B) is medial, and the 4th transverse process is displayed in the long-axis. The needle trajectory is in-plane. The biplane cursor directly over the paravertebral space. In the perpendicular plane, the butterfly icon is caudal. The 5th transverse process and the craniocaudal spread of local anesthetic are visualized in the short-axis. TM: Trapezius muscle, RM: Rhomboid muscle, ESM: Erector spinae muscle, ICM: Intercostal muscle, 5TP: 5th Transverse process, 4TP 4th Transverse process.
**Fig. 1H. Low Thoracic Erector Spinae Plane Block**

The ultrasound transducer is placed over the 10th transverse process in a sagittal orientation with an approximately 20-degree clockwise rotation in the nerve setting. In the reference plane, the orientation marker (B) is caudal, and the transverse process is displayed in the short-axis. The needle trajectory is in-plane. The biplane cursor directly over the transverse process. In the perpendicular plane, the butterfly icon is lateral. The transverse process, as well as the mediolateral spread of local anesthetic, is

Fig. 1I. Femoral Nerve Block

In the nerve setting, the ultrasound transducer is placed over the inguinal ligament in a transverse orientation to identify the femoral nerve, artery, and vein. The ultrasound is moved laterally to allow a more parallel needle trajectory for improved visualization. In the reference plane, the orientation marker (B) is lateral, and the femoral nerve is displayed in the short-axis. The needle is seen in-plane. The mediolateral spread of local anesthetic is noted in this plane. The biplane cursor is over the femoral
nerve. In the perpendicular plane, the butterfly icon is cranial. The femoral nerve and craniocaudal spread of local anesthetic are visualized in long-axis. FL: Fascia lata, FI: Fascia iliaca, FN: Femoral nerve, IM: Iliacus muscle.

Fig. 1J. Distal Femoral Triangle Block
In the musculoskeletal setting, the ultrasound transducer is placed over the medial thigh in a transverse orientation. In the reference plane, the orientation marker (B) is medial, and the superficial femoral artery, saphenous nerve, and nerve to vastus medialis are displayed in the short-axis. The circumferential spread of local anesthetic around the superficial femoral artery is noted in this plane. The biplane cursor is over the SFA. In the perpendicular plane, the butterfly icon is inferior. The SFA
and craniocaudal spread of local anesthetic are visualized in long-axis. AT: Adipose tissue, SM: Sartorius muscle, SFA: Superficial femoral artery, VM: Vastus medialis muscle, AL: Adductor longus muscle, NVM: Nerve to vastus medialis, SN: Saphenous nerve.

**Fig. 1K. Popliteal Sciatic Nerve Block**

In the musculoskeletal setting, the ultrasound transducer is placed over the bifurcation of the sciatic nerve into the tibial and common peroneal nerves in a transverse orientation. In the reference plane, the orientation marker (B) is lateral, and the tibial nerve and common peroneal nerve are displayed in the short-axis after a popliteal sciatic block. The circumferential spread of local anesthetic is noted in this plane. The biplane cursor is over the tibial nerve and popliteal artery. In the perpendicular plane, the
butterfly icon is inferior. Superiorly the sciatic nerve is visualized in long-axis. Inferiorly, the tibial nerve and the popliteal artery and craniocaudal spread of local anesthetic are visualized in long-axis. BFM: Biceps femoris muscle. SmM: Semimembranosus muscle, SN: sciatic nerve, TN: Tibial nerve, PA: Popliteal artery, CP: Common peroneal nerve, PV: Popliteal vein, AT: Adipose tissue.