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Ultrasound-Guided Off-Plan Lumbar Seated Erector Spinae Plane Blocks : Are There Advantages?

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Abstract
The erector spinae plane block (ESPB) has been widely used as a treatment strategy for a variety of acute and chronic painful conditions. ESPBs are typically performed under ultrasound guidance [USG] in an in-plane long axis approach, targeting the tip of the lumbar transverse process while the patient lies prone. Off-Plane Seated Injection Technique-ESPB [OPSIT-E] represents a useful alternative in situations where a standard prone spine injection would be technically challenged by circumstances which may include morbid obesity, orthopnoea, recent upper limbs surgeries, chest pain from recent pacemaker implant, and in a subjects were in-plane approaches may be complicated by skin lesions. A seated forward flexed off-plane injection position, may also flatten the lumbar lordosis, shift adipose tissue more anteriorly, lessening skin to target distance and facilitating bony landmark identification, in high BMI and hyperlordotic subjects. The relatively larger long axis curved transverse arc radius of the curvilinear probe [GE G1-5] in comparison to its transverse arc, also appears to offer improved central field of skin-transducer contact, earlier needle visualization, improved acute angle trajectory visualization of deep structures, which may be due to less crepuscular beam dispersion in comparison to transverse probe orientation. Even with a linear probe, the orthogonal technique facilitates a more perpendicular vector, lessening needle transit to target distance, which may in turn decrease procedure time, and improve patient comfort. The OPSITE, may also be easier to teach, learn, and master, as other studies have generally reported a higher rate of off-plane injection success among novice vascular interventionists.

Key words: Ultrasound, Erector Spinae Plane Block, Spine, Lumbar, Seated Spinal injection. Off-Plane, Orthogonal

Introduction

In 2018, the first application of lumbar ESPB for the postoperative analgesia of hip arthroplasty was published. [Tulgar & Senkurk 2018] Kose et al noted that the transverse process lumbar injection point is deeper and more lateral then in the thoracic spine, and more challenging to sonographically visualize and inject. [Kose et al 2018] This is due to the relative increased depth of structure but may also be partly due to the convex anterior lumbar curve which angulates structures. A forward flexed seated injection posture which flattens the lumbar lordosis may therefore facilitate sonographic imaging.

The lumbar ESPB targets the potential space between the paraspinals muscle fascial envelope (Spinalis, Longissimus Thoracis, IIiocostalis bundle) and the deeper lumbar transverse processes. Both thoracic & lumbar ESPBs are typically performed with an in-plane probe orientation, with dynamic monitoring fluid spread expansion between erector spinae fascia away and deeper thoracic transverse processes. Unique intercostal perforating channels then facilitate anaesthetic diffusion into the deep paraspinal space, yielding circumferential thoracic-abdominal wall sensory nerve blocks of the dorsal and ventral rami of the thoracic and abdominal spinal nerves. [[Magalhaes et al 2012] The transverse process acts as a bony anatomical barrier, which prevents inadvertent needle entry into deeper structures. An ESPB preserves bladder function and motor neuron function enabling early mobilization. Since motor function is unaltered, immediate postoperative neurological evaluation of spinal cord function is possible. USG caudal epidural is particularly safe in a transverse plane needle perpendicular approach to the epidural space [Inklebarger et al 2012], and is also used for back pain relief.

However, caudal epidurals are concluded by some authors to be more invasive than ESPB, and that the former can only be performed at specialized institutions (Japan). For these reasons, ESPB may be a relatively less invasive injection option. [Ma J et al 2021]

Methods

Patients were placed in a seated position. Subjects were forward flexed [FF] with elbows resting on thighs. Seated forward flexion helps to flatten the lumbar lordosis lessening the skin to transverse process target distance, while aligning the lumbar TPs and other relevant sonoanatomy more perpendicular to the US beams for image optimization. [Images below]

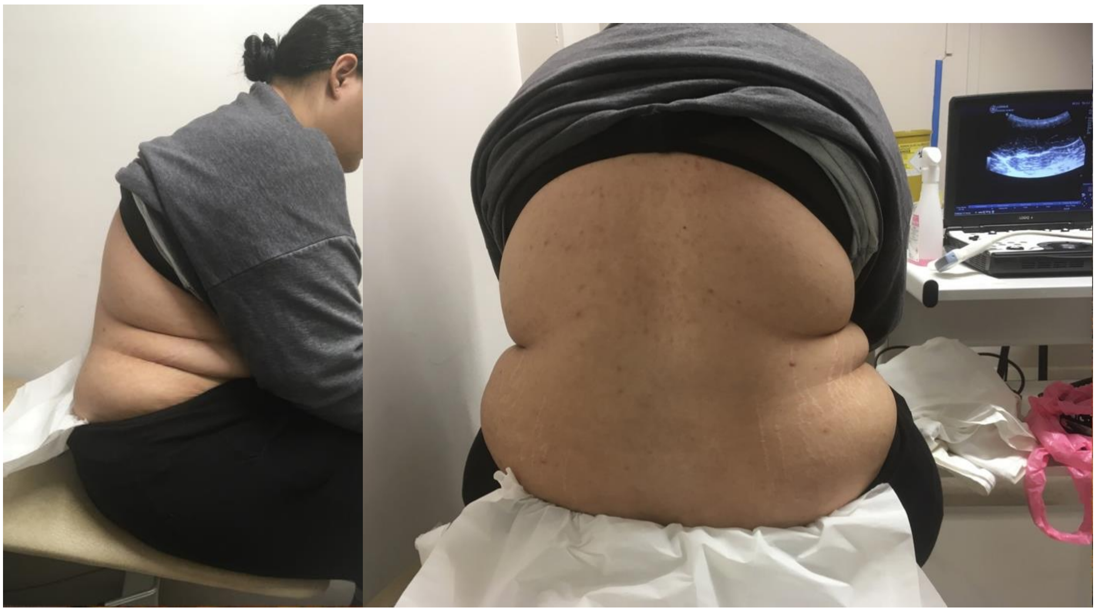


Image 1 & 2. Lumbar OPSITE positioning for a high BMI patient. The FF posture appears to flatten the lumbar curve improve anatomical landmark-probe alignment The forward-flexed seated position appears to also lessen the TP depth and angulation. Procedures were performed using Loqic GE C1-5 [footprint 69.3 x 17.2 mm] transducer with Loqic E or GE E9 machines. [image x]

The focus depth is adjusted to +/- 70 mm depth of the lumbar transverse process to be targeted. [image x]. US guided OPSITES were performed with the transducer positioned in a transverse plane directly centered over the tip of the target lumbar transverse process.

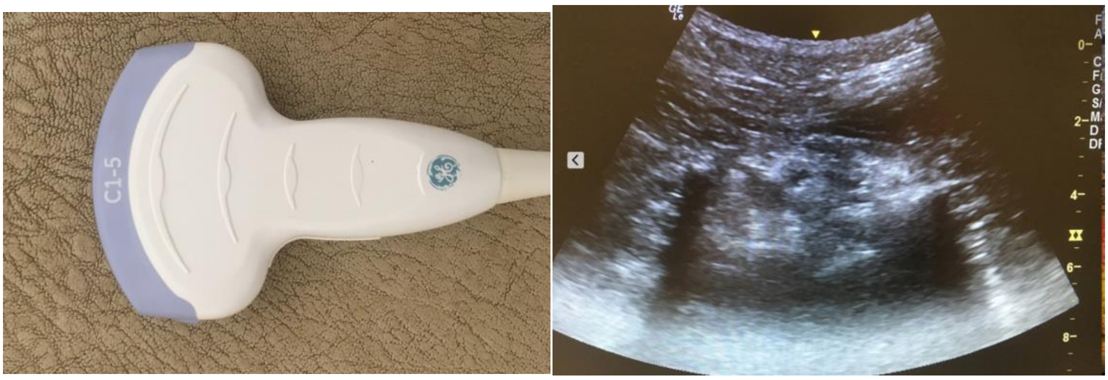


Image 3 & 4: GE C1-5 Curvilinear 1.4-5.7 MHz Probe, Seated position image R L5 TP process. Note that the SP, Lamina, TP are all visualized with the R TP tip depth at 60 mm in this example.

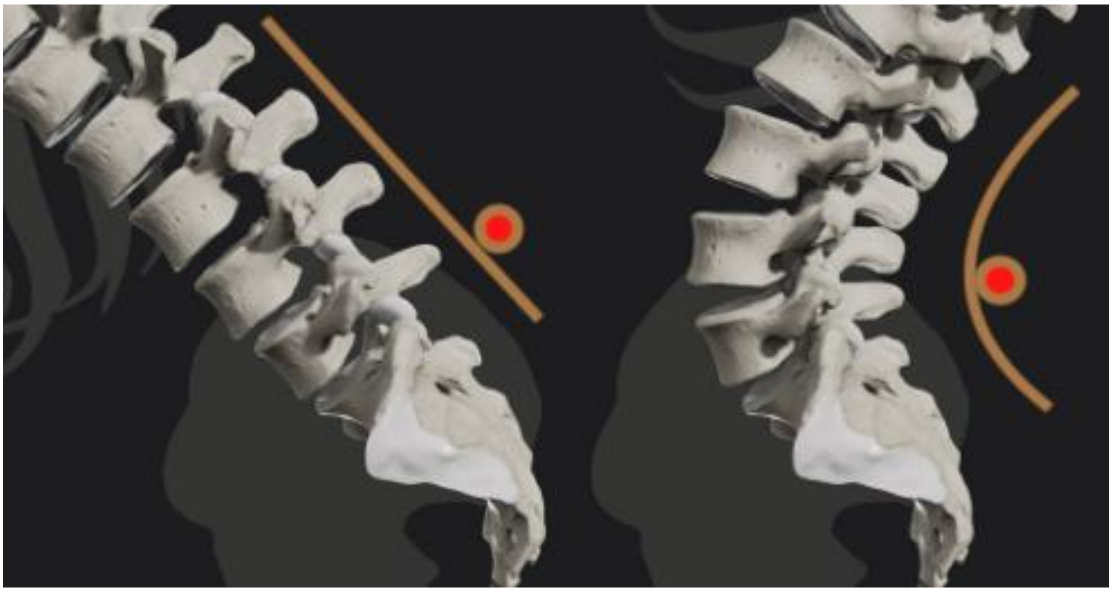


Image 5: Seated lumbar spine forward-flexed [FF] injection position, may augment probe to deep bony structure US beam alignment, while also decreasing the skin to TP needle travel distance.

Image 6: Long axis view. White dots L4-5 Spinous processes (SPs). Star marks the sacrum

STEP 1: The US probe was placed in centerline. The L4-L5 SPs and Sacrum are identified in long axis to determine level.

STEP 2 Image 7: The probe is then moved in-plane from midline laterally to locate the corresponding level TP tip. This image also shows a standard prone-position in-plane ESBP, the beveled edge down with the needle tip positioned just above the L3 TP tip. [Brown arrow]

STEP 3 Image 8 & 9: Off-Plane ESPB orientation midline bony landmark image: The probe in then rotated orthogonally to generate a transverse –[TV[plane image centered over the spinous process, and visualizing the facet joint, transverse process. Note: At the L4, L5 levels the posterior superior iliac spine and crest are also visualized [image] serving as a further confirmatory landmark. This is a TV plane view at the L4 level. Blue arrowheads: Tip of the TV process. White Arrow: Off-plane injection trajectory.

STEP 4: Once all relevant midline anatomical landmarks listed in Step 3 have been identified, The probe is then moved from the midline laterally to position the centre of the probe over the tip of the target transverse process. The skin is the marked & cleaned. [image]

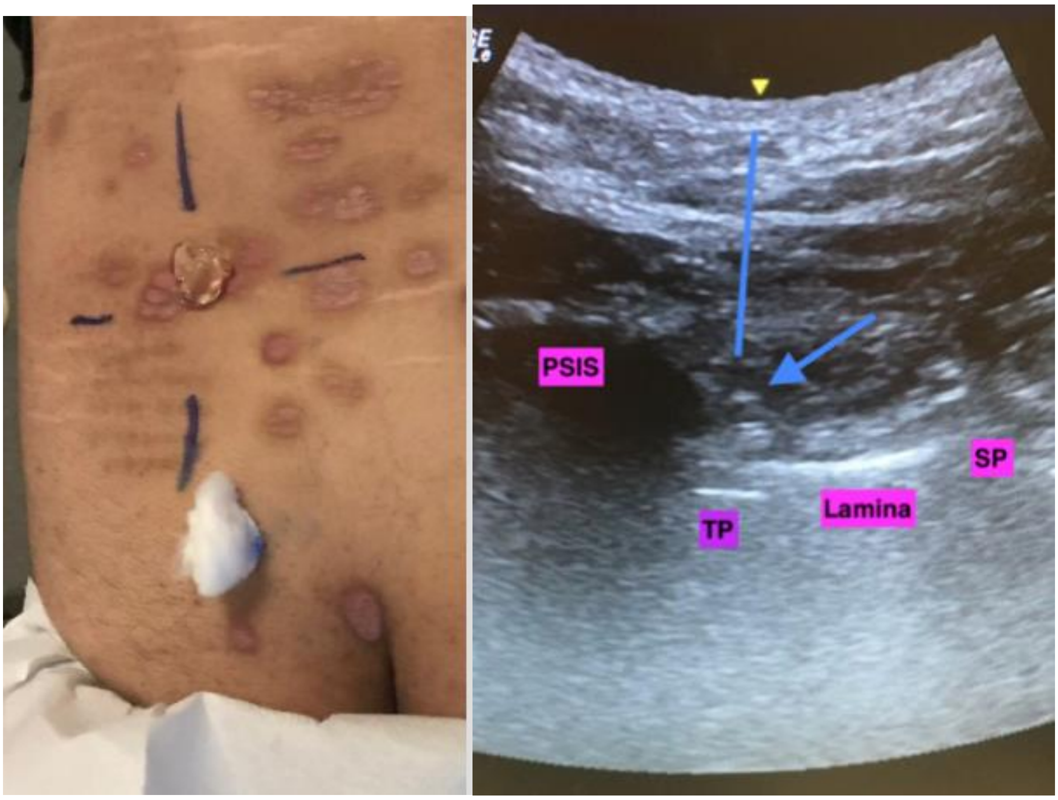


Image 10 & 11: Skin marking for a L L5 TV ESPB in a patient with Nummular Psoriasis The OPSIT-E in this case, had advantage over in-plane technique, as the needle could be introduced precisely, in a small area of skin clear of lesions, with the point of needle skin entry in this case introduced 30mm below the center of the probe. US Image: Line is the needle trajectory. Arrow points to needle tip [beveled edge lateral] at 50 mm depth

STEP 5: While maintaining probe position over the tip of the Transervse Process [TP], the needle is introduced +/- 1 cm [finger breath] either above or below the probe, aiming for the center of the probe. Once the needle-tip is identified, the needle is methodically advanced to the tip of the TV process and then injection performed. If the needle-shaft and tip are not well-visualized tracking may be facilitated by monitoring for tenting of the tissues as it passes through the fascial planes or by injecting small volumes of fluid to locate and brighten the needle tip. The needle may also be withdrawn slightly and steered in an arc trajectory around the PSIS/Iliac crest [if required], when injecting at the L4, L5 levels.

In all cases, procedure accuracy was confirmed by sonographic bony landmarks and real-time needle trajectory and needle tip monitoring. Informed consent was obtained prior to each procedure. All procedures were performed by one expert practitioner (JI), with many years of spine interventional practice and US diagnostic and image- guided injection experience. The criteria for accurate needle placement was by direct needle-tip tracking, fascial plane tenting and/or volumetric fluid expansion.

Discussion

Studies have demonstrated differences in the relevant anatomy of thoracic and lumbar blocks. [Fusco et al 2017] The anatomy of the thoracic and lumbar nerves also differs. Thoracic spinal nerves continue as the dorsal ramus and ventral ramus (intercostal nerves) after leaving the epidural foramen, while in the lumbosacral region, the ventral ramus merges to form the lumbar and sacral plexuses. Another difference is the thoracic region dorsal ramus divides into lateral and medial branches, while the lumbosacral ramus separate into medial, intermediate, and lateral branches. Additionally the lumbar dorsal ramus of the lumbosacral nerves merge within themselves to form the cluneal nerves which are responsible for the sensory innervation of the waist and buttocks. The sensory anatomy of the lower abdomen and lower extremities is therefore more complex than the thoracoabdominal region. Subsequently, craniocaudal spread of ESPB is more limited in the lumbar region when compared to the thoracic region, and 5 ml of local anaesthetic is recommended at each TP lumbar level [Tulgar S et 2020] Lumbar ESP injections customarily performed at the L4 level and injectant spread for this technique has been documented in multiple studies. [Harbell 2020][Tulgar et al 2018][Chung et al 2018] [38] [39] [De Lara Gonzales et al 2019] Chung et al administered ESPB using a 20 mL mixture for pain management in lower extremity complex regional pain syndrome. Balaban et al performed ESPB with 30 mL mixture for postoperative analgesia in total knee arthroplasty. Fluoroscopic imaging demonstrated spread to L2-S1 levels in both lumbar ESBP cases. [Chung et al][Balaban et al 2018]. In a study, a higher volume single injection (40ml), was used to demonstrate the spread of LA between L1-S4. [Celik et al 2019] De Lara González et al reported their findings in 6 cadavers after bilateral lumbar ESPB (total:12 blocks) was performed using a 20 mL LA mixture. In all applications, the spread of the LA mixture was observed between L2-4 in the craniocaudal plane. In nine applications, the spread included L5 caudally and in one application L1 cranially. The first question regarding lumbar ESPB is whether LA spreads to the anterior of the transverse process. In nine injections this anterior spread was observed, with spread to the medial border of the psoas muscle in seven and spread to the L3 and L4 spinal nerves in two injections. [De Lara Gonzalez et al 2018] Harbell et al performed nine lumbar ESPB on five cadavers using 20mL at the L4 transverse process level and reported staining of the multifidus and longissimus muscles following six injections. In only one injection the spread was reported to have been observed posterior to the lumborum muscle. No spread to the anterior of the transverse process was reported. [Harbell et al 2020] Reports from cadaveric anatomic studies are essential for understanding the mechanism of action of plane blocks. However, due to their nature, cadaveric studies have a significant limitation. Even when fresh cadavers are used, tissue tension decreases due to the loss of vitality. Therefore, the spread of injectate in cadavers most probably does not accurately represent the spread that would occur under normal conditions. [Tulgar et al 2020]. Other literature has demonstrated methods of both in plane and out of plane USG-ESPB techniques. [Schartz et al 2019] Customary lumbar ESP blocks with fluid, allow for continued visualization of fascial plane separation and fluid expansion under ultrasound guidance. Small amounts of air injected under ultrasound guidance, have been used to monitor needle tip position for other types of injections. [Hunter et al 2000]. If in doubt, a small amount of normal saline (2-5 ml) may also be injected first to confirm needle tip placement and inter fascial plane expansion. ESPB contraindications include infection at the site of injection in the paraspinal region and patient refusal However, ESPBs carry a very low risk of complications, as sonoanatomy is easily recognizable and there are no structures in close proximity at risk of needle injury. [Ahiskagliogu 2018, Beek 2019]

Conveniently, anthropomorphic measurements have noted and average adult index finger width 20 mm. [Johnson PW et al 2007] MRI measurements of the mean landmark depth of the L1-5 adult lumbar transverse processes is 69.35 in females and 69.41 in males. [Kawchuk GN et al 2011]

Understanding if landmark depth changes with a subject's body mass index (BMI) may help clinicians attribute importance to their palpation findings. In this study, 105 consecutive subjects were referred for lumbar magnetic resonance imaging (MRI) in a hospital setting. Four blinded examiners measured T1-weighted MRI images to quantify the depth of spinous and transverse processes [SP/TP] in the lumbar spine. For each process, a linear mixed-effects model was carried out by gender with depth as the outcome and BMI as a covariate. The average BMI for males (n = 57) was 27.52 kg/m(2) and 27.02 kg/m(2) for females. The mean landmark depth was 22.77 mm, 23.00 mm, 27.40 mm, 33.40 mm, 36.65 mm for spinous processes L1-L5 respectively and 69.35 mm and 69.41 mm for the left and right L4 transverse processes. The inter-evaluator, intra-class correlation coefficient averaged 0.98 for all depth measurements.

Trainees and consultants fail to use ultrasound to its full potential during interventional procedures. A lack of understanding of how to position the needle tip is a major obstacle. Needle visualisation is essential when inserting needles into tissues, which may be in close proximity to structures such as vessels, nerves. [Maury E et al 2001]

In the transverse approach, some papers recommended that the needle trajectory be nearly parallel to that of the US transducer, which yield a poorer needle visualisation in comparison to a long longitudinal approach. However, in a near vertical only a short segment of the needle echogenically displayed with shaft-tip distinguished by rocking the transducer back and forth or by withdrawing the needle slightly and re-aligning into a vertical plane. [Chapman GA et al 1996]

Though the above parallel needle to orientation recommended above may be suitable for linear probe targeting of more superficial structures, off-plane curvilinear probe [CVP] needle tip tracking to TP appears to be more suitable for OPSITE. A GE 4 CD CV probe with a traverse diameter of 18 mm was used, and as the adult human index finger breath is on average 20 mm, selecting a needle entry point either 1 index finger breadth above or below the transducer [18 CVP width + 20 mm index finger width], while entering at a 60 degree angle and aiming at the centre of the TP, facilitates needle tip tracking along the hypotenuse [slope], thereby optimizing visualization of the needle tip at the cirtical average lumbar TP depth at 70 mm below the skin surface.

As the meant landmark depth of the L1-5 Transverse processes are on average 70 mm in males & females. [Kawchuk GN et al 2011, Image 6.58 cm], hypotenuse 66.8 [70 degrees] needle angulation trajectory in off-plane CVP injection technique, the lumbar transverse process may be readily reached with a 90 mm spinal needle while offering a surplus 10 mm shaft of steerage leeway, which would not be available in an in-plane procedure. As the curvilinear probe has a lessened radius with increased arc convexity, [image xx] the crepuscular beam angles are greater. Off-plane injection takes advantage of central skin contact, affording earlier needle visualisation. As the needle trajectory is more aligned and parallel to the central vertical beams, successful needle tip tracking at greater depth may be achieved.

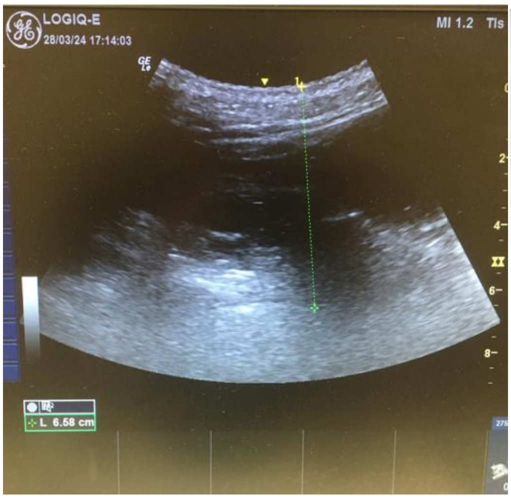


Image 12 & 13: Skin to L4 TP tip distance of 6.58 in a high BMI patient. Focus again adjusted to TP depth. Image 2: C1-5 GE transverse arc. GE C1-5 Curved Array Transducer has a frequency of 1.4 – 5.7 MHz, a footprint of 17.2 x 69.3 mm

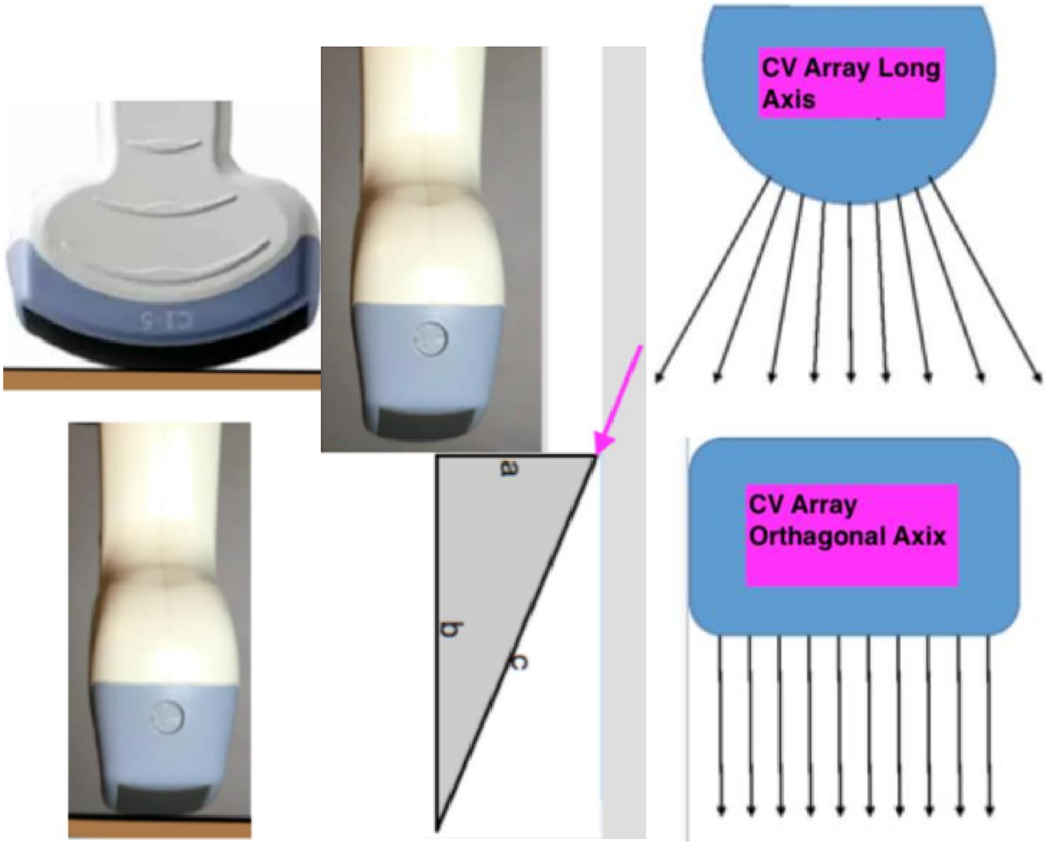
The needle tip is seen as a highly echogenic (white) spot. [Blavis M et al 2003]. Anechoic injection fluid may also brighten the needle tip in off-plane injection. [blue arrowhead image]

Image 14: Off-plane bright needle-tip echo reflection at depth [blue arrow]

However, it has been noted that even inexperienced ultrasound interventionists, obtain vascular access much faster using a short axis (transverse) approach than using a long axis (longitudinal) approach. [Caspers JM et al 1997, Hendrick WR et al 1995]

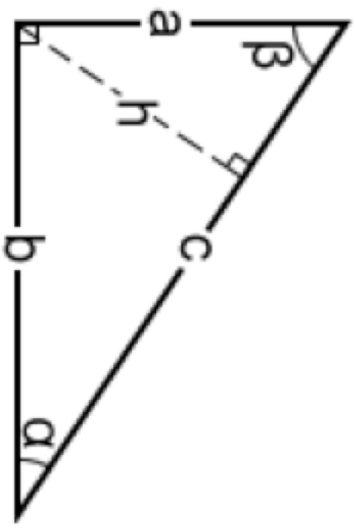
Determining Opsit Needle Entry Position

GE C1-5 Curved Array Transducer has a frequency of 1.4 – 5.7 MHz, a footprint of 17.2 x 69.3 mm, one-half the transverse footprint distance is 8.6 mm. As the average adult index finger width 20 mm. [Johnson PW et al 2007], then the average distance between the centre of the probe and one finger breath is 30 cm. As the depth of the average adult lumbar TP on average is 70 mm the optimal needle-tip entry point from the edge of the probe can be calculated [image]



Images 15 & 16: The relatively gentler arc of an orthogonal axis orientation, offers good skin surface contact area, and a needle entry point closer to the lateral border of the probe. This in turn facilitates a more acute angle injection trajectory with earlier needle visualization. Lessened US beam divergence may also facilitate needle tip tracking at depth.

- **Given a=30 mm [1/2 probe diameter of 8.6 mm plus the average 20 mm adult index fingerbreath**
- **b=70 mm [average adult depth of a lumbar TP]**
- **c = 7.61577 [average distance of needle travel to target the L1-5 TP when:**
- **∠α = 23.199°**
- **∠β = 66.801° : 70 degrees [purple arrow] is the recommended average needle angle to target the L1-5 TP in an off-plane approach.**



Starting 1.5-2 cm away from the superior-inferior edge of the curvilinear probe and angling towards the centre of the probe while advancing the needle through soft tissues, optimizing needle tip tracking and trajectory at depth. If the needle track-tip is not clearly visualized withdrawing the needle slightly, and or arcing the needle to curve to the target is recommended. This may also help to steer the needle around the PSIS. Tracking may further be guided by observing tissue tenting as the needle-tip progresses through tissue

layers, and also be injecting small amounts of fluid. Once the needle tip position and shaft trajectory are confirmed, the needle is then steered to the tip of the transverse process

Discussion

Due to the newness of the procedure it is controversial and RCTs are urgently needed. [Qui Y et al 2020] However, recent meta-analysis has demonstrated that ESPB are effective in decreasing postoperative pain intensity and postoperative opioid consumption in spine surgery. [Ma J et al 2021] Case reports have also concluded that lumbar USG-ESPB are technically simple and safe procedures for failed back surgery pain management. [Takahashi H et al 2018].

A cadaver lumbar ESPB with dye noted cephalocaudal spread from L3 to L5 in all specimens with extension to L2 in four specimens. Medial-lateral spread was documented from the multifidus muscle to the lateral edge of the thoracolumbar fascia. There was extensive dye in and around the erector spinae musculature and spread to the dorsal rami in all specimens. There was no dye spread anteriorly into the dorsal root ganglion, ventral rami, or paravertebral space. The conclusion was that lumbar ESP injection has limited craniocaudal spread compared with injection in the thoracic region. It has consistent spread to dorsal rami, but no anterior spread to ventral rami or paravertebral space. [Harbell MW et al 2020]

However, some case reports have begun to demonstrate the role of ESP blocks in the management of DLBP. [Schwartz et al 2019]

Conclusions

OPSITE in certain circumstances may offer some advantages as an alternative to standard prone in-plane ESPB technique. The seated forward flexed injection position may flatten the lumbar lordosis-hyperlordosis for improved target visualation, and decrease needle transit distance. The more perpendicular needle position in OPSITE may also facilitate injections when skin lesions are present [images 10-11]. The seated FF position, also helps to decrease accentuated lumbar lateral flexion Cobb angles, which might otherwise challenge typical lumbar ESPB in scoliotic patients.

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