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ORIGINAL RESEARCH

A review of the anatomy and a step-by-step visual guide to performing an ultrasound-guided infraclavicular brachial plexus block

S Govender,[1,2] D Möhr,[2,3] ZN Tshabalala,[2] A van Schoor[2]

[1] *Department of Anatomy, School of Medicine, Sefako Makgatho Health Sciences University, South Africa*
[2] *Section of Clinical Anatomy, Department of Anatomy, School of Medicine, Faculty of Health Sciences, University of Pretoria, South Africa*
[3] *Private Practice, South Africa*
Corresponding author, email: *sabashnee.govender@smu.ac.za*

Background: The aim of this description is to provide step-by-step guidelines for performing an ultrasound-guided infraclavicular brachial plexus nerve block.
Methods: The brachial plexus in the infraclavicular fossa of sixty healthy volunteers was scanned in the horizontal/transverse plane. The relevant regional anatomy was studied to identify the muscular and vascular structures seen on the ultrasound screen.
Results: The entire process was documented and a standard, step-by-step guide to performing ultrasound-guided vertical infraclavicular brachial plexus blocks was developed.
Conclusion: The development of high-resolution ultrasound guidance has allowed for the direct visualisation of the brachial plexus when performing nerve blocks. Ultrasound-guided infraclavicular brachial plexus nerve blocks are becoming more popular. This description aimed to provide step-by-step guidelines on how to perform this block safely and efficiently.

Keywords: brachial plexus, nerve blocks, infraclavicular, ultrasound-guided

Introduction

The infraclavicular approach was first discovered in the early 1910s.[1] Later, in 1917, Bazy et al. further described the infraclavicular approach by inserting a needle below the clavicle, in an 'anaesthetic line' drawn between the anterior tubercle of the sixth cervical vertebra and the coracoid process.[2,3] In the following years, various authors substantiated this technique and confirmed Bazy's findings.[4,5] In 1973, Raj et al. introduced a new technique of inserting the needle at the midpoint of the clavicle, directing the tip laterally to prevent puncturing the chest wall.[6] The infraclavicular approach is performed in the infraclavicular fossa, where the axillary vessels and the cords of the brachial plexus (BP) lie deep to the pectoral muscles. This block is ideal for providing anaesthesia and analgesia for procedures of the distal arm to the hand. It may be performed as a single-shot injection or continuous catheter insertion.

The interscalene approach which is indicated for surgery of the shoulder region, clavicular area, upper arm and elbow joint is performed in the interscalene groove. Although this approach is simple to perform, a major disadvantage is the insufficient spread of anaesthetic to the inferior trunk of the BP. Therefore, this approach is not recommended for surgery of the forearm or hand.[7] Complications for this approach are similar to the supraclavicular approach, which are directly related to the volume of local anaesthetic used.[8]

Alternative approaches include the supraclavicular and axillary BP blocks. The supraclavicular approach is ideal for procedures of the shoulder joint proximally, to the hand distally. In this approach, the anaesthetic is introduced into the supraclavicular fossa targeting the trunks/divisions of the BP. Complications that may occur include hemi-diaphragmatic paresis, Horner's syndrome and pneumothorax.[9]

The axillary approach is performed at the level of the terminal branches of the BP and is indicated for procedures of the forearm and hand. This approach may require multiple injections. Although complications are specific to each terminal nerve, common ramifications include: Horner's syndrome, hemi-diaphragmatic paresis, pneumothorax and vascular injection.[8]

Indications

The infraclavicular block is indicated for surgery of the arm, specifically the distal arm, elbow, forearm and the hand.[9] Furthermore, it provides analgesia for post-surgical and traumatic pain, tourniquet pain, complex regional pain syndrome, post amputation pain, vascular diseases and tumour-related pain.[10] This approach is not recommended for procedures of the shoulder area, axilla or proximal medial arm. Absolute and relative contraindications must be considered prior to the procedure. These include infection at the site of the injection, allergic reaction to the local anaesthetic, pre-existing neurological deficits in the distribution of the block or previous surgery in the area of interest that may distort the anatomy of the BP.[11] Relative contraindications include coagulopathy and systemic infection.[10]

Brachial plexus

The BP is a network of nerves formed by the union of the ventral rami of the fifth to eighth cervical spinal nerves (C5–C8), as well as the first thoracic spinal nerve (T1). Proximally, the BP consists of five roots (C5–T1) that converge to form the superior trunk (union of spinal root C5 and C6), middle trunk (spinal root C7) and the inferior trunk (union of spinal root C7 and T1). Each trunk

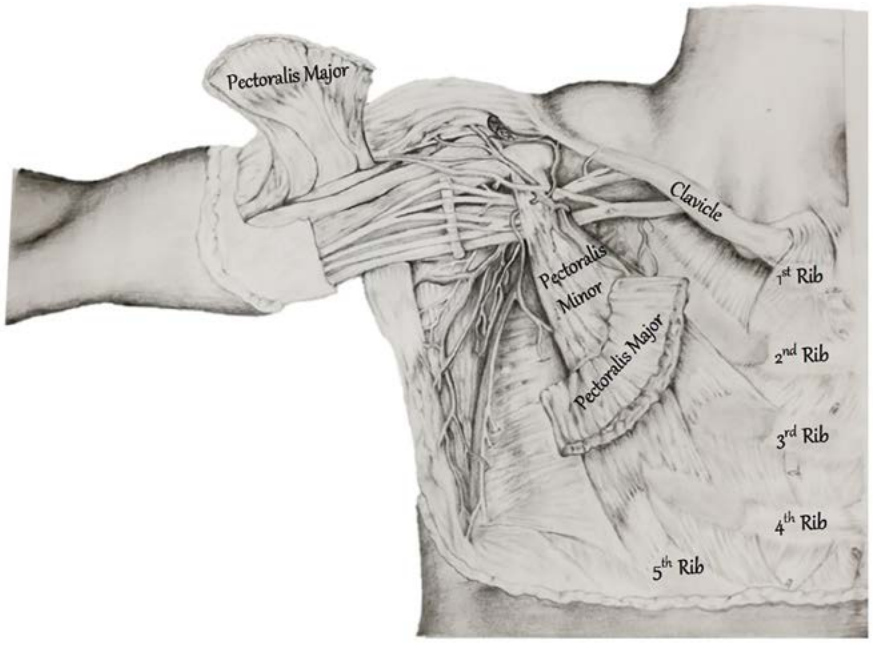

Figure 1: Image displaying the borders of the infraclavicular fossa. The clavicle is found superiorly, the pectoralis muscles anteriorly, the ribs medially and the humerus laterally.

will then divide into an anterior and posterior division that will subsequently combine to form the three cords (medial, lateral and posterior) of the BP. The BP then terminates as five major branches: the axillary, musculocutaneous, radial, median and ulnar nerves. At the level of the infraclavicular fossa, one may already encounter the three cords of the BP and perhaps even the terminal branches of the latter.

Anatomical considerations

The infraclavicular approach is performed in the infraclavicular fossa which is found inferior to the clavicle (Figure 1). The space is bordered anteriorly by the pectoralis major and minor muscles, medially by the ribs and laterally by the humerus. The clavicle and coracoid process – the most important landmarks – are located superiorly.[10] The BP is enclosed within a connective tissue sheath, which also contains the axillary artery and vein.

In the infraclavicular approach the cords of the BP, which are named according to their relationship to the axillary artery, and its branches are anaesthetised. The cords of the BP pass anterior to the first rib to continue posterior to the clavicle before entering the arm. The terminal nerves (and the branches) originating from the BP may have single or dual supply (sensory or motor innervation). Branches of the lateral cord include the lateral pectoral nerve, which provides motor innervation to the pectoralis major muscle, the musculocutaneous nerve provides motor innervation to the muscles in the anterior compartment of the arm as well as sensory innervation to the lateral side of the forearm and the lateral root of the lateral cord contributing to the median nerve (Figure 2).

The medial cord gives rise to the medial pectoral nerve, which provides motor innervation to both the pectoralis major and minor muscles, as well as the medial root of the medial cord. This root will join the lateral root from the lateral cord to form the median nerve. The median nerve provides motor innervation to the anterior compartment of the forearm (with the exception of the one and a half muscles supplied by the ulnar nerve). It will also provide sensory innervation to the skin above the lateral two-thirds of the palm and fingers. The medial cutaneous nerve of the arm and forearm are also branches of the medial cord, and provide sensory innervation to the skin above the medial side of the arm and the medial side of the forearm extending to the distal part of the wrist, respectively (Figure 2). Finally, the ulnar nerve is the terminal branch of the medial cord and provides motor innervation to the intrinsic muscles of the hand, the flexor carpi ulnaris and the medial half of the flexor digitorum profundus muscles (anterior compartment of the forearm). The ulnar nerve also provides sensory innervation to the skin over the medial one and a half fingers of both the dorsum and palm of the hand.

Branches from the posterior cord include the upper and lower subscapular nerves, which collectively provide motor innervation to the subscapularis muscle and the latter also providing motor innervation to the teres major muscle (Figure 2). It also gives off the thoracodorsal nerve which provides motor innervation the latissimus dorsi muscle; the axillary nerve, which provides motor innervation to the deltoid and teres minor muscles, including sensory innervation to the skin above the deltoid and superior-posterior area of the arm; and the radial nerve, which provides motor innervation to all the extensor muscles of the posterior forearm and arm, including sensory innervation to the skin above the posterior aspect of the arm and forearm, as well as the lateral two thirds of the dorsum of the hand and fingers (Figure 2).

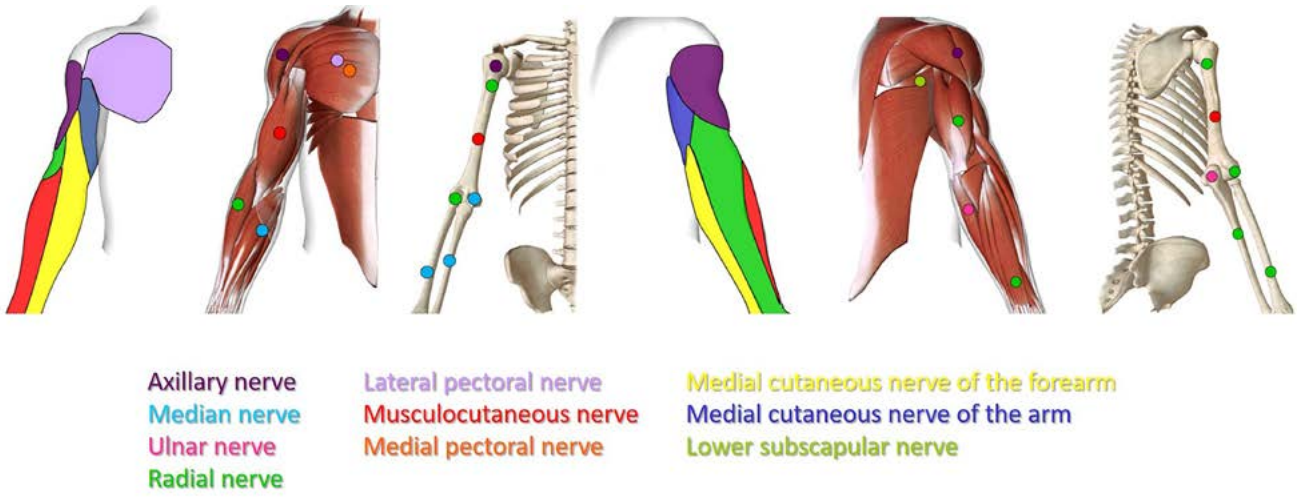

Figure 2: Image displaying the dermatomes, myotomes, and osteotomes of the upper limb

It is important to note that the skin of the axilla and the proximal medial arm are not anaesthetised during this approach as it is innervated by the intercostobrachial nerve (T2).

Step-by-step procedure for an ultrasound-guided infraclavicular BP block

Step 1: Patient positioning

The patient should be asked to lie in a supine position, with the head turned to the contralateral side of where the block will be performed. Alternatively, the patient should be placed in a semi-lateral position where the patient lies on his/her side with the arm abducted or flexed at the elbow joint, keeping the relationship between the landmarks constant. The anaesthesiologist performing the block should be positioned at the head of the bed, with the patient, the block area and the ultrasound screen all in line, ensuring a clear view during the procedure (Figure 3). The probe should be held perpendicular to the skin.

Step 2: Preparation

While the patient is in the supine position, a sterile sheet should be placed over the thoracic area keeping only the area of interest – the infraclavicular fossa – exposed. A small amount of sterile ultrasound gel should be placed on the skin inferior to the clavicle, near to the coracoid process and on the ultrasound transducer (probe). For ultrasound-guided BP blocks, a high-frequency linear probe is preferred (ranging from 6–13 MHz). A 21G x 100 m echogenic SonoPlex needle may be recommended to inject the anaesthetic solution. Aseptic techniques should be adhered to during the entire procedure.[12]

Figure 3: An image of a patient lying in a supine position, with the head turned to the contralateral side of the block. This photo was included with the consent of Dr Möhr.

Step 3: Palpate and mark important landmarks

Landmarks for this approach include the clavicle and coracoid process (Figure 4). Prior to starting the procedure, the clavicle should be palpated using the index and middle fingers of the non-dominant hand and marked inferior to the lateral third of the clavicle. Alternatively mark a point, that is two finger breadths inferior and one finger breadth medial to the coracoid process. Both points marked are found lying within the infraclavicular fossa. The cords of the BP are found surrounding the subclavian artery/axillary artery.

Step 4: Probe placement

After palpating the clavicle and coracoid process, the linear probe is placed in the infraclavicular fossa, inferior to the clavicle and medial to the coracoid process. The placement of the probe is in

Figure 4: Anterior view of the bony landmarks – the clavicle and coracoid process – to palpate prior to the procedure.

a parasagittal plane, with the probe marker directed cephalad, to obtain an optimal short axis view of the vascular structures, cords of the BP and the pectoralis major and minor muscles.[13] It may be required to rotate the probe clockwise or counter clockwise to obtain an ideal ultrasound transverse image of the axillary artery.

Step 5: Summary of landmarks visualised on the ultrasound image

The axillary artery can be identified as a dark, round, pulsating hypoechoic structure at the bottom of the screen. Just medial/caudal to the axillary artery, the axillary vein can be seen as a smaller, oval, pulsating hypoechoic structure. These vessels can be further confirmed using the Doppler function on the ultrasound machine. Arteries and veins will appear in red and blue respectively, depending on the flow of the blood in relation to the probe. In an MRI study done by Sauter et al., the cords of the BP were found to be 2 cm from the centre of the axillary artery approximately within 2/3 of a circle. With reference to a clock face with the axillary artery at the centre, the cords are distributed between 3 to 11 o'clock.[14] This was confirmed with the findings of this study, as the hyperechoic cords of the BP were found radially surrounding the artery. The medial cord is found at a 2–3 o'clock position. The posterior cord is found at a 6 o'clock position with the lateral cord most commonly positioned at 10–11 o'clock.[15] It may be prudent to manipulate the cords of the BP as it is not always easy to identify and may present as an artifact instead. In certain cases, the BP may be found positioned between the artery and vein, instead of radially around the artery.[15] Superficial to the neurovascular structures (towards the top of the screen), the pectoralis major and minor muscles

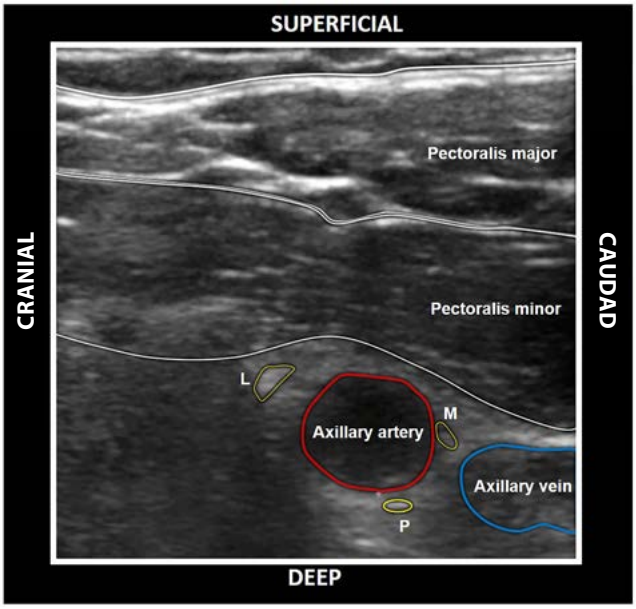

Figure 5: An ultrasound scan, showing the muscular and vascular structures in the infraclavicular fossa. Key: L – lateral cord, M – medial cord, P – posterior cord.

can be seen as two thick hypoechoic bands, that are bordered by intramuscular fascia which appear as hyperechoic lines surrounding the muscles (Figure 5).

Step 6: Needle insertion and course

The needle should be inserted at the superior pole of the probe, using the in-plane technique, advancing in a superficial to deep direction in the same plane as the ultrasound beam. If there is insufficient space between the probe and the clavicle, the needle should be inserted at the inferior pole of the probe, directed at a

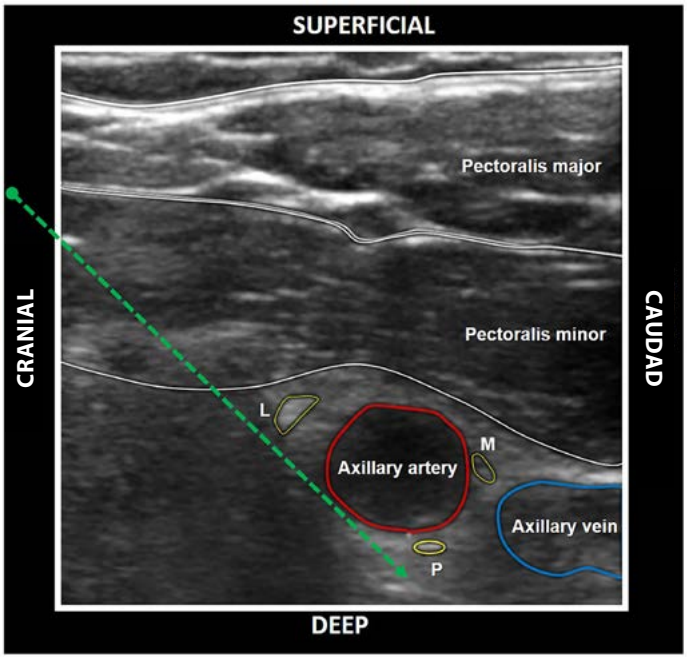

Figure 6: Image on the left – an ultrasound scan as it appears on the ultrasound screen during an ultrasound-guided infraclavicular BP block. Image on the right – in-plane needle insertion with the entire needle course visible on the ultrasound screen during an ultrasound-guided infraclavicular BP block.

superior angle. The needle should pierce both pectoralis muscles, which offer a small amount of resistance as the pectoralis minor muscle is enclosed within the clavipectoral fascia. The tip of the needle is directed towards the inferior border of the artery, where the posterior cord of the BP is found (Figure 6). The needle is then carefully withdrawn slightly, before being redirected towards the lateral and medial cords of the BP. The needle depth ranges from 1.6–3 cm.[15] The needle is then tested for negative aspiration before continuing with the procedure.

Step 7: Injecting local anaesthetic solution

A small amount of saline solution (0.5 ml) rather than local anaesthetic is injected into the fossa to confirm the proximity of the needle tip. Visualisation of the needle may present with problems due to the steep angle of insertion. However, a technique to aid with visualisation is to tilt the tip of the needle superficially. The anaesthetic is administered in small aliquots postero-lateral to the axillary artery, before being slightly withdrawn and redirected to the medial and lateral cords (Figure 7). The concentration of anaesthetic depends on the purpose of the block – anaesthetic or analgesic procedures. Both procedures require the same volume, however, the concentrations differ.[16] For surgical procedures, 20 ml of 0.5% of bupivacaine is recommended whereas, for longer postoperative analgesic procedures, 20 ml of 0.25% or 0.125% of bupivacaine is recommended. Alternatives such as 0.2% of ropivacaine or 0.25% of levobupivacaine may be considered.[17] Furthermore, epinephrine can be administered as an adjuvant as it may reduce the absorption rate and therefore, the probability of system toxicity.

Step 8: Visualising the spread of the local anaesthetic solution

The anaesthetic solution should spread in a uniform U-shaped pattern around the axillary artery or cephalad to caudal to cover the lateral and medial cords (Figure 8). The spread is a hypoechoic fluid and appears black on the ultrasound scan, making the cords

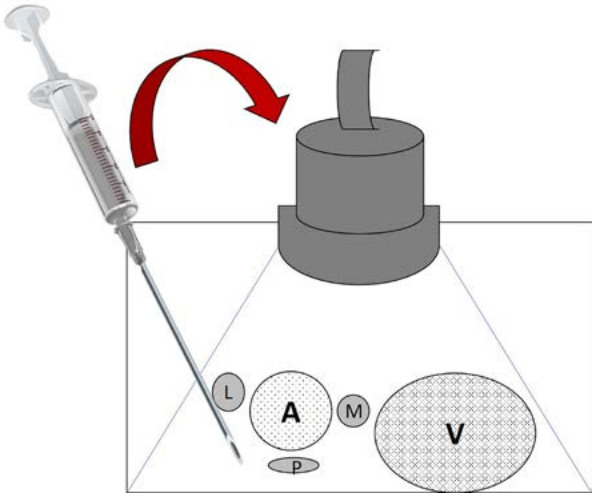

Figure 7: Diagram of the needle insertion, postero-lateral to the axially artery. Key: A – axillary artery, V – axillary vein, P – posterior cord of the BP, L – lateral cord of the BP, M – medial cord of the BP.

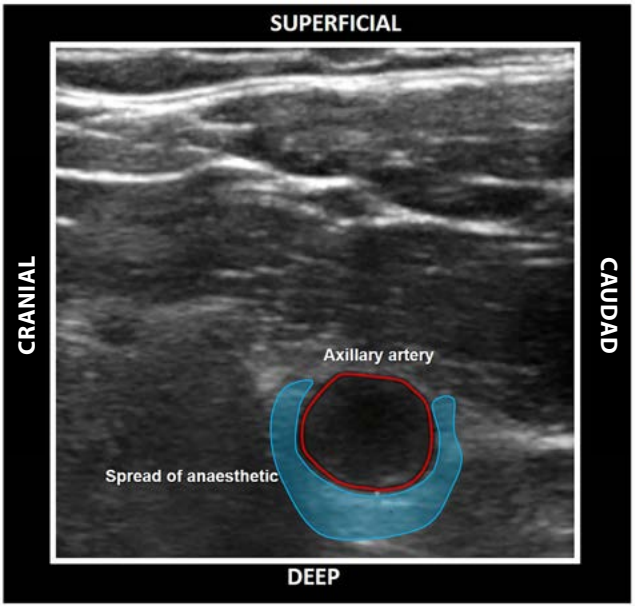

Figure 8: Spread of local anaesthetic solution (hypoechoic area high around the artery) around the BP, concealing it from view on the ultrasound machine.

easier to identify. Should the local anaesthetic spread be judged as inadequate, needle repositioning may be warranted.

Although the infraclavicular approach is the least preferred approach due to the unclear bony landmarks and the intricacy of the needle placement, it is still one of the most successful approaches.[18] Several authors have reported on their success rates for the ultrasound-guided infraclavicular BP block, while comparing various parameters. Using multiple injections for each BP cord, Sandhu et al. achieved successful surgical anaesthesia in 99.3% of the sample,[19] whereas only 86% to 89% of successful surgical anaesthesia was achieved in other studies, using a single shot injection.[20,21] Dingerman et al. further stated that there was no benefit in combining electrical nerve stimulation with ultrasound guidance, as the success rates did not vary.[21]

Advantages and disadvantages of ultrasound-guided infraclavicular BP blocks

The advantages of the ultrasound-guided infraclavicular approach include: the direct visualisation of the neuronal and surrounding anatomical structures; accurate needle placement due to the on-screen visualisation; monitored spread of local anaesthetic as it is seen in real time; as well as the ability to compensate for any anatomical variations that may occur and an overall reduction in the risks of complication.[22] Unlike other approaches, there is no need to position the patient's arm in a specific manner – which may be beneficial to patients with serious trauma to the upper extremity.[23,24]

Due to the trajectory of the needle away from the chest cavity in a standard vertical infraclavicular approach, the potential risk of pneumothorax is less likely (an incidence rate between 0.5–0.7%) as compared to the interscalene or supraclavicular BP blocks. This approach is associated with relatively high rates of phrenic nerve palsy (up to 50%), and moderate rates of intravascular puncture

(10%).[25] Other complications include muscle pain, haematoma and systemic toxicity as a result of excessive local anaesthetic. The rate of complications is also related to the experience of the anaesthetist. Like any approach, good technique and a vast knowledge of the human anatomy are essential to performing a successful nerve block, despite the guidance of ultrasound.

Conclusion

The introduction of ultrasound guidance into the medical field has had a major impact on anaesthesiologists around the world, sparking an interest in ultrasound-guided nerve blocks. Although nerve stimulators remain a useful technique, ultrasound guidance has dramatically improved nerve localisation, offering various advantages. For any ultrasound-guided nerve block, a thorough knowledge of the regional anatomy, basic principles of ultrasound application and regular technique practice are vital to ensure safe effective nerve blocks. Ultrasound-guided upper extremity blocks provide more effective intraoperative and postoperative analgesia. Although the infraclavicular BP nerve blocks are faster to perform, the onset, however, is slower compared to other approaches. Combined with the use of nerve stimulators this approach proves to be highly successful and safe.[25]

The aim of this description is to provide the reader with the basic relevant regional anatomy for a vertical infraclavicular nerve block and to further equip them with the basic understanding of how to perform an ultrasound-guided infraclavicular BP nerve block. This review also aims to assist researchers in further understanding the technique and process of performing this block and to assist students with grasping the idea of a vertical infraclavicular BP nerve block, academically.

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ORCID

S Govender https: //orcid.org/0000-0001-6738-9071
D Mohr https://orcid.org/0000-0002-1396-7427
A van Schoor https://orcid.org/0000-0001-9813-0441

Conflict of interest

The authors declare no conflict of interest.

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