Evolution of Supraclavicular Brachial Plexus Block

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Often considered the 'spinal anaesthesia of the upper extremity', the supraclavicular approach to the brachial plexus provides excellent anaesthesia of the upper limb with rapid onset[1]. Its use in history dates all the way back to the 1920s, but gradually fell out of favour due to high incidence of pneumothorax, improvement in general anaesthesia safety and safer alternative approaches. With the advent of ultrasound-guided techniques allowing real-time visualisation of anatomy, there has been renewed interest in the block due to increased safety and reduced complication rate.

ANATOMY

The brachial plexus supplies motor and sensory innervation to the upper limb. It is formed by the ventral rami of C5 to T1. They emerge, as roots, between the anterior and middle scalene muscles, then proceed to traverse the posterior triangle, forming three trunks, the upper, middle and lower. Posterior to the mid clavicle, each trunk then divides to form an anterior and posterior division. The divisions then combine to form the lateral, medial and posterior cords, which are named according to their relation to the second part of the axillary artery. Various peripheral nerves, including the terminal branches, emerge from these cords.

A brachial plexus block can be performed at multiple sites along its anatomical path. Common approaches include that at the interscalene, supraclavicular, infraclavicular and axillary levels (Figure 1)[2]. At the level of the supraclavicular fossa, the plexus is most compactly arranged, consisting of distal trunks and origins of divisions. Hence, the supraclavicular approach of the brachial plexus has been thought to provide anaesthesia to the entire upper extremity with a rapid onset and in the most consistent manner.

At the supraclavicular fossa, both the brachial plexus and subclavian artery lie above the first rib and the pleura. The brachial plexus is located lateral and posterior to the subclavian artery, while the subclavian vein and anterior scalene muscle are found medial to the subclavian artery. The pleura is usually situated within 1-2 cm medial from the brachial plexus.

INDICATIONS AND BENEFITS

The most common indication of the supraclavicular brachial plexus bock is upper extremity surgery[1]. As with all peripheral nerve blocks (PNBs), supraclavicular brachial plexus block offers an excellent anaesthetic alternative for upper limb surgery. It provides superior, long-lasting analgesia, and avoids potential side effects of a general anaesthesia including nausea, vomiting, dental trauma, sore throat, allergic reactions and intraoperative haemodynamics swings. PNBs indeed offer distinct benefits over general or neuraxial anaesthesia in certain clinical situations, especially high risk patients.

HISTORY

The first documented brachial plexus block was performed by William Steward Halsted in 1884, who directly exposed the brachial plexus in the neck with cocaine[3]. It was only in 1911 when Kulenkampff performed the first percutaneous supraclavicular brachial plexus block[4]. In collaboration with Persky[5], Kulenkampff's technique and experience with 1000 supraclavicular brachial plexus blocks was published in 1928.

However, Kulenkampff's technique of inserting the needle posteriorly, medially and caudally in the direction of T2 or T3 spinous process, carried an inherent risk of pneumothorax.[5] This, together with improvements in general anaesthesia safety, as well as the advent of reportedly safer alternatives including axillary approach by Accardo and Adriano (1949)[6], Eather and Burnham (1958)[7], later De Jong (1961)[8], supraclavicular approach gradually fell out of favour in the early 1960s.

Until the last two decades, with the introduction of real-time ultrasound guided techniques to reduce risk of inadvertent pleura puncture, the supraclavicular approach of the brachial plexus, with its rapid onset, high success rate and large area of anaesthesia coverage, has gradually regained popularity.[1, 2, 9, 10]

TECHNIQUES

A. Surface landmark with paraesthesia seeking

Classical approach (‘Kulenkampff technique’)

The classical Kulenkampff approach involves the patient to be in the sitting position, with the arm to be ‘blocked’ lying in the lap with the shoulder relaxed. If the sitting position is not possible, the patient will lie supine, with a pillow under his scapula and his head rotated opposite from the side to be blocked[4, 5].

The needle is inserted at a point middle of the clavicle, crossed by a line projected downward from the external jugular vein. It is advanced lateral to the subclavian artery and is directed posteriorly, medially and caudally to the upper border of the first rib (i.e. in the direction of the T2 or T3 spinous process). The classical approach involves inducing paraesthesia in the finger tips usually at a depth of 1-2cm. This indicates the needle's contact with the plexus. Local anaesthetic is then slowly injected, with paraesthesia increasing temporarily until the local anaesthetic's action causes the sensation to disappear.[4, 5].

Modified techniques

The medial orientation of the needle in the classical approach was associated with increased risk of pleural puncture and pneumothorax, reported 6% incidence[5]. Consequently, attempts to modify the classical technique were described to reduce this risk.

Several modified techniques were published in chronological order:

- MacIntosh & Mushin (1942)[11]
- Lamoureux & Bourgeois-Gavardin (1952)[12]
- Subclavian perivascular technique – Winnie & Collins (1964) [13]
- Parascalene technique – Vongvises & Panijayanond (1972) [14]
- Dupre & Danel technique (1982)[15]
- Brown's plump-bob technique (1988)[16]

There were great diversity of technique with minimal variations revealed that none of them was perfect and free from potential hazard. Below are some techniques worth mention.

Subclavian perivascular technique – Winnie & Collins[13]

This is a surface landmark with paraesthesia seeking technique. The needle is inserted at the base of interscalene groove, posterior to the subclavian artery, in the horizontal plane. The disadvantages of this technique are vascular puncture, hematoma, and pneumothorax (less than 1:1000 in experienced hand).

Dupre & Danel technique[15]

This is also a surface landmark with paraesthesia seeking technique. Surface landmarks: the external jugular vein, the sternocleidomastoid muscle, and the clavicular insertion of the trapezius muscle. The needle is inserted at the intersection point between external jugular vein and a line drawn from the top of supraclavicularis minor fossa to edge *of* external clavicular insertion of trapezius muscle. The advantage is that it did not require location of subclavian artery. No pneumothorax reported in 136 cases.

Brown's plump-bob technique[16]

This is initially a surface landmark with paraesthesia seeking technique which later incorporate the use of a nerve stimulator. This is performed with the patient supine on a horizontal table with the ipsilateral arm at the side and the head turned opposite the side to be blocked. The point of needle insertion is "immediately adjacent and superior to the clavicle at the lateral-most insertion of the sternocleidomastoid muscle onto the clavicle". The needle direction is anteroposterior—that is, perpendicular to the table—as if following the line of a suspended plumb-bob through the insertion site. Local anaesthetic is injected at a single site after adequate paresthesia or motor response by a nerve stimulator.

B. Surface landmark with nerve stimulator

Locating nerves by obtaining paraesthesia could indicate that the needle tip is intraneural. If local anaesthetic were to be injected despite the paraesthesia, this could potentially result in neural damage and complications. On the contrary, absence of paresthesia does not reliably exclude the possibility of needle-to-nerve contact nor does it prevent post-operative neural injury (PNI). Nevertheless, severe paresthesia that occurs with needle advancement or injection should prompt the cessation of either maneuver, and repositioning of the needle should be considered.[17].

In 1962, Greenblatt[18] was first to describe the use of a portable solid-state nerve stimulator with variable current output in nerve identification and location. Since then, peripheral nerve stimulation using a low intensity, short duration electrical stimulus to obtain a defined response to locate the nerve/plexus was used in the practice of PNBs. The goal of nerve stimulation is two-prong; firstly, to place the needle tip in close proximity to the target nerve/plexus so as to inject local anaesthetic in the vicinity of the nerve; secondly, for identifying intraneural needle tip placement (i.e. a motor response at ≤0.2 mA is obtained only with intraneural needle tip location). It has been reported that flexion of the third and fourth digits simultaneously, without or without other digits, is associated with the highest success rate of a supraclavicular brachial plexus block.[10]

The use of nerve stimulation became commonplace in clinical practice only in the mid- to late 1990s. Several studies were published using previously described modified surface landmark technique with a nerve stimulator. One of them, Franco et al[19] had performed 1001 subclavian perivascular brachial plexus blocks with a nerve stimulator with 997 blocks (97.2%) were completely successful, 16 blocks (1.6%) were incomplete and needed supplementation; 12 blocks (1.2%) failed and required general anaesthesia. Overall 98.8% success rate for regional anaesthesia in this study and no reported clinical pneumothorax or major complications.

Surface landmark with paraesthesia seeking or nerve stimulator are not only associated with a high incidence of pneumothorax, but also vascular puncture and unintended intravascular injection. The latter may lead to local anaesthetic systemic toxicity with resultant cardiovascular collapse. A study by Brown[20] in 1995 showed seizures associated with supraclavicular brachial plexus blocks to be as high as 79 in 10,000. These complications are due to the close proximity of the brachial plexus with the subclavian artery and pleura. Moreover, success of the block with the above techniques is largely dependent on our knowledge and understanding of the anatomy of the brachial plexus. However, it has been shown that there are large anatomical variations in over 50% of the population[10].

C. **Ultrasound-guided technique**

The use of ultrasound guidance in the practice of regional anaesthesia arguably began in the late 1980s[21], although ultrasound Doppler technology was used by La Grange[22] in 1978 to locate the subclavian artery, to indirectly facilitate needle positioning in a supraclavicular plexus block. This case series reported a high block success rate, with the absence of intravascular injections. Moorthy et. al.[23] in 1991 used Doppler technology to identify and mark the third part of the subclavian artery (above clavicle) and the first part of the axillary artery. A needle connected to the nerve stimulator is then inserted 2cm superior and posterior to the clavicle, and 1cm lateral and parallel to the identified subclavian artery. They named this technique, lateral paravascular approach with sixty one of the 82 cases (72%) of supraclavicular lateral paravascular block produced a good surgical anaesthesia.

Technology subsequently improved. Kapral et. al.[24] first described direct needle, plexus and local anaesthetic visualization using B-mode ultrasound in 1994. And ever since then, ultrasound-guided nerve blockade has gradually evolved into our daily practice and become the gold standard technique for regional anaesthesia[25].

Ultrasound compared to other nerve localization technique results in improvement in block quality, meaning faster onset time, better quality of surgical block, longer duration of block and high success rate, which definitely not inferior to other technique (Level 1B evidence)[26]. In fact, ultrasound allows visualization and identification of neural and adjacent anatomical structures; detection of anatomical variation[10]; visualize the spread of local anaesthetic and the needle tip, hence can optimally position the needle and avoid potential complications.

In 2003, Vincent Chan et. al.[27] first described combined ultrasound with nerve stimulator for supraclavicular approach in 40 patients. More publications pertaining to ultrasound guided supraclavicular brachial plexus block subsequently ensued.

With the patient lying supine and head rotated opposite from the side to be block, a linear high-frequency ultrasound probe is used to scan the the supraclavicular fossa in a coronal oblique plane, parallel and posterior to the clavicle. The neurovascular structures are identified – the pulsatile hypoechoic subclavian artery and the compact group of hypoechoic nerve structures (often referred to as a 'bundle of grapes') lateral and superficial to it. The probe is then angled until there is simultaneous visualization of both first rib and pleura. Both structures appear hyperechoic on the ultrasound image, with the former generating an anechoic shadow beneath it, while the latter a shimmering shadow (representing lung tissue) and a 'sliding' motion of the pleura with the patient's respiration in observed.[28]

Needle Insertion

With real-time ultrasound guidance, the needle is inserted in-plane with the beam in either a medial-to-lateral or lateral-to-medial direction. But in a sub-analysis of a prospective review of 510 cases, medial-to-lateral approach resulted in more incidence of vascular puncture, neurological deficit and Horner's syndrome though the differences were not statistically significant. No reported clinically evident pneumothorax in this study. Overall success rate after 1st attempt of block using either medial-to-lateral or lateral-to-medial needling direction was 94.6% [28].

End point of injection

The needle is advanced until the fascial sheath is penetrated (felt as a palpable 'pop') and the needle tip is visualised within the sheath compartment. Different end points have been described. One is to guide the needle towards the 'corner pocket' where the first rib lies inferiorly, the subclavian artery medially and the nerves superiorly. Depositing local anaesthetic at this point 'floats' the plexus superficially and results in more reliable blockade of the lower trunk/inferior divisions of the plexus, which has been shown to be cause of failed supraclavicular blocks[29]. Four years after its first description, Brull et al.[30] retold the achievement of corner pocket technique in more than 3000 blocks. This technique successfully blocked the ulnar nerve in at least 85% of patients within 30 mins of local anesthetic injection with only 1 symptomatic pneumothorax.

However, due to very close proximity to the first rib and the risk of pleural puncture, some authors describe administering two to three smaller aliquots of local anaesthetic at different locations within the plexus sheath as a safer alternative[1]. Tran et al.[31] conducted a randomized controlled trial in 2009 on 92 patients comparing single versus double injection. The double-injection ultrasound-guided supraclavicular block provides no significant advantages compared with its single injection counterpart.

Dual Guidance

Concurrent nerve stimulation with ultrasound guidance is believed to be safer[1] but there were case report of permanent nerve injury on dual guidance[32] and study[33] showed nerve stimulation as an adjunct to ultrasound guidance may have a limited role. For adequately imaged ultrasound guided supraclavicular nerve blocks, a positive motor response to nerve stimulation does not increase the success rate of the block. In addition, the high false-negative rate of nerve stimulator suggests that supraclavicular blocks under ultrasound guidance are usually effective, even in the absence of a motor response. However, 21% of the patients did not have satisfactory nerve imaging in the same study mentioned earlier[33]. Therefore, there is still role of dual guidance in peripheral nerve blocks especially in cases involve deep and difficult blocks whereby the sonoimages of needle and neural structures are poorly seen.

If dual guidance is used, Bigeleisen et al[34] in his first human study comparing intraneural versus extraneural stimulation thresholds during ultrasound-guided supraclavicular block showed that there was clinical difference in stimulation thresholds between outside and inside the nerve. Ultrasound was able to clearly detect the location of the needle tip in only 69% of the cases. Stimulation current of less than or equal to 0.2mA reliable to detect intraneural position of the needle. Stimulation thresholds greater than 0.2 and less than or equal to 0.5mA could not rule out intraneural placement of the needle. Diabetic patients require higher stimulation thresholds both outside and inside the nerve to elicit a motor response.

Based on current evidence, the expert panels advise against purposefully seek needle to nerve contact or intentional intraneural injection[35].

Volume of local anaesthetic

It is believed with ultrasound technique, the spread of the local anaesthetic can be visualized hence reduce the volume required. Several studies reported variable local anaesthetic dosing and volume required for ultrasound guided supraclavicular block (USSCB). The mean required volume is still much lower if compared to non-ultrasound technique[13, 15, 16], which often used 30 to 40ml. The choice of local anaesthetic concentration is dependent on the surgical indication.

As an example, Tsui et al[36] described 94.2% success rate with USSCB in 104 patients undergoing hand surgery, using 20 to 30ml mixture of Lidocaine 1.5% and bupivacaine 0.125%. Perlas et al[28] reported 94.6% success among 47 different operators using a mean volume of 33ml for USSCB in 510 patients with Lidocaine 2% and Bupivacaine 0.5% plus epinephrine 5ug/ml. Bigeleisen et al[34] reported 100% success using 25ml admixture of Lidocaine 1% and Bupivacaine 0.25% plus epinephrine 3.33 mcg/ml. Brull et al.[30] used 15 – 25ml of local anaesthetic deposited at the corner pocket area for reliable surgical anaesthesia.

Current recommendation

Due to wide variety of practice in ultrasound guided brachial plexus block, a set of standardized approaches to upper extremity nerve blocks based on the current literature has been proposed.[37]

The current recommended technique for ultrasound guided supraclavicular block is needle injection in plane (most common), lateral to medial. Assess the depth of brachial plexus, insert needle in shallow angle and adjust accordingly. The ideal spread of local anaesthetic will be within brachial plexus fascial sheath, lateral to the subclavian artery but superficial to the first rib. Number of injections would be 2 to 3 follow the principle of bolus, observe, and reposition. Recommended volume of local anaesthetic 20 – 25ml. If nerve stimulator is used, look for motor response of forearm and hand.

COMPLICATIONS AND CONTRAINDICATIONS

The overall complications associated with supraclavicular brachial plexus block is low. These include vascular punctures, local anesthetic systemic toxicity as a result of fast absorption or unintended intravascular injection, neural damage, sympathetic ganglion blockade with Horner syndrome, recurrent laryngeal nerve blockade, and phrenic nerve palsy[28, 32]. The incidence of pneumothorax has reduced significantly since the advent of ultrasound- guided techniques[28]. No incident of pneumothorax in 510 cases received USSCB in study by Perlas et al[28]. Only 5 cases (1%) of symptomatic diaphragmatic paresis, 5 cases (1%) of Horner’s syndrome, 2 cases (0.4%) of vascular puncture and 2 cases (0.4%) had neurological deficit.

Phrenic nerve blockade with resultant hemidiaphragmatic paresis results in a reduction in functional residual capacity by 25%. Patients may present with dyspnea or chest pain, although most affected healthy individuals remain asymptomatic. Diagnosis is made with an upright chest radiography, in which a pneumothorax should be excluded. Rates of transient hemidiaphragmatic as high as 50% to 67% have been reported, and is reportedly reduced when a lower volume is used[38]. Patient selection is vital, and should be contraindicated in patients with significant respiratory disease or pre-existing contralateral hemidiaphragmatic paresis.

Real-time ultrasound techniques have also markedly reduced the rates of vascular puncture and unintended intravascular injections[28] .Vessels in the vicinity include the subclavian artery, dorsal scapular artery transverse cervical artery and their venous counterparts. Slight elevation of the head of the bed allows for better drainage and less prominence of the neck veins, the use of colour Doppler before needle placement, aspirating before injection and real-time visualization of local anaesthetic spread during injection are methods used to reduce vascular puncture and intravascular injections[28].

CONCLUSION

Ever since the introduction of ultrasound guidance in regional anaesthesia, there has been a resurgence of interest in the supraclavicular approach to the brachial plexus. The ability to image the surrounding anatomy and needle placement has significantly reduced the incidence of pneumothorax as well as vascular puncture. Moreover, ultrasound guidance has allowed smaller volumes of local anaesthetic to produce an equally rapid and dense upper extremity blockade. Ultrasound guided supraclavicular brachial plexus block is the most popular regional technique of choice for upper extremity surgery.

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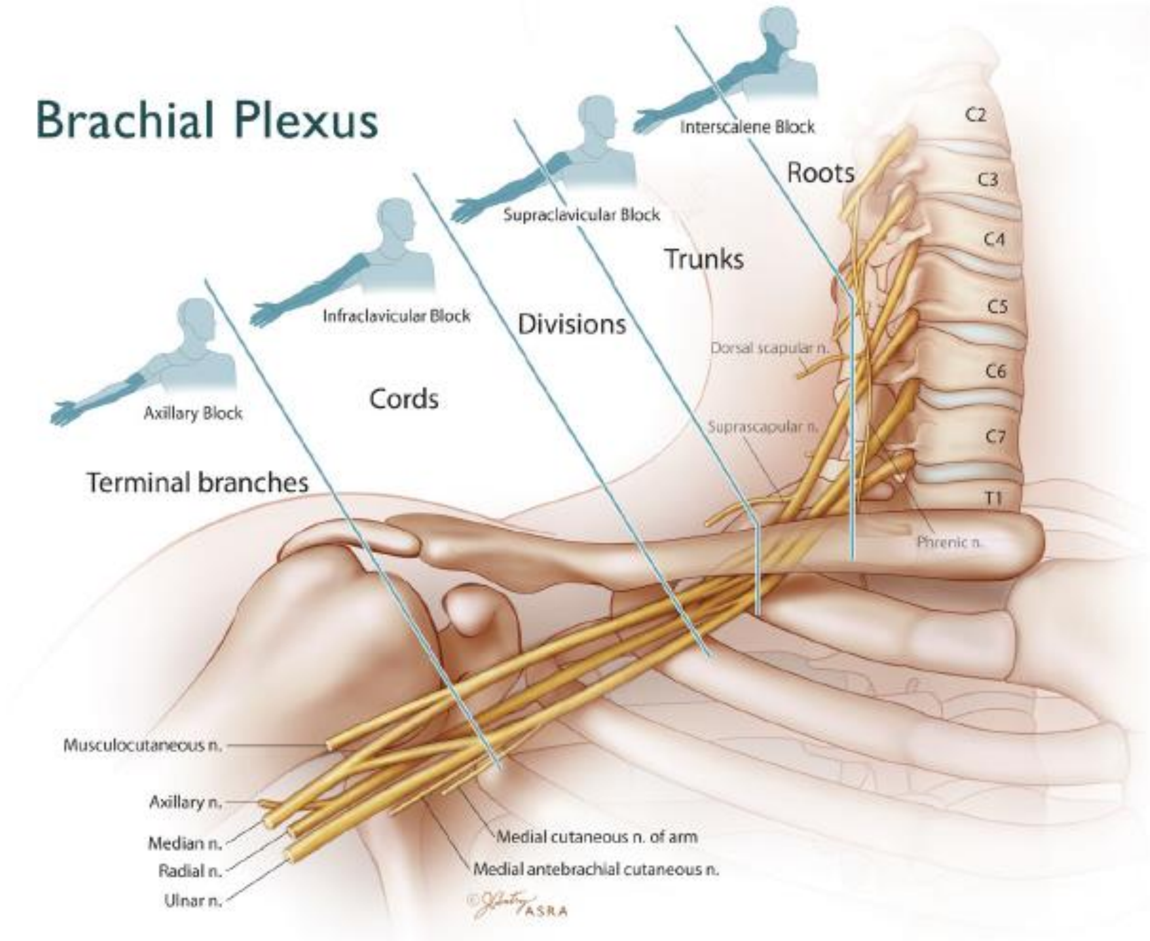

Figure 1: Brachial plexus. Various approaches define individual brachial plexus blocks and their expected distribution of cutaneous anesthesia. Illustration by Jennifer Gentry. *American Society of Regional Anesthesia and Pain Medicine. (with permission from Wolter-Kluwer)