Anatomy of the brachial plexus

Roots

The brachial plexus is most commonly formed by five roots originating from the ventral divisions of spinal nerves C5 through T1. The roots of the plexus are located in the cervical paravertebral space, between the anterior and middle scalene muscles. Besides understanding its origins, it is also important to understand the plexus in terms of the relative surface area occupied by its components at different levels of its trajectory. As shown in figure 1 each root of the plexus emerges from an intervertebral foramen. The C5 root appears between cervical vertebrae 4 and 5, while the T1 root emerges between thoracic vertebrae 1 and 2.

![Fig 1. Left supraclavicular area, cadaver dissection. The sternocleidomastoid and anterior scalene muscles have been removed. The subclavian artery and the vertebral artery appear painted in red. The suprascapular nerve is the branch seen coming off the upper trunk.](image)

The distance from C5 to T1 roots is large and irreducible, and it is equal to the height of four vertebrae. This fact helps to explain why during an interscalene block, usually performed at C5 or C6 level, dermatomes derived from C8-T1 are frequently missed. C8-T1 roots are simply too far from the site of injection. Another important and frequently ignored reason is the expansive, pulsatile effect of the subclavian artery over the C8 and T1 roots, preventing the local anesthetic from reaching them.

When the five roots combine together to form three trunks, not only there is a 40% reduction in the number of nerve structures (from 5 to 3), but also the trunks become physically contiguous. This is the point where the brachial plexus...
is reduced to its smallest surface area. This area of high concentration of nerve structures helps to explain the rapid onset and high success rate of the supraclavicular approach. This special circumstance is only seen in the brachial plexus and has not parallel in the lower extremity. The surface area of the plexus increases again when the trunks originate six divisions and even further when the plexus ends up by giving off terminal branches in the axilla.

**The scalene muscles**

The anterior scalene muscle originates in the anterior tubercles of the transverse processes of C3 to C6 and inserts on the scalene tubercle of the first rib. The middle scalene muscle originates in the posterior tubercles of the transverse processes of C2 to C7 and inserts on a large area of the upper surface of the first rib, behind the subclavian groove.

**Trunks to terminal branches**

The five roots converge toward each other to form three trunks - upper, middle and lower - stacked one on top of the other, as they traverse the triangular interscalene space formed between the anterior and middle scalene muscles. This space becomes wider in the anteroposterior plane as the muscles approach their insertion on the first rib.

While the roots of the plexus are long, the trunks are almost as short (1-2 cm) as they are wide, soon giving rise to a total of six divisions (three anterior and three posterior), as they reach the clavicle. The area of the trunks corresponds to the point where the brachial plexus is confined to its smallest surface area, three nerve structures carrying the entire sensory, motor and sympathetic innervation of the upper extremity, with the exception of a small area in the axilla and upper middle arm, which is innervated by the intercostobrachial nerve, a branch of the second intercostal nerve. This arrangement is mandated by the narrow passage between the clavicle and the first rib that the neurovascular bundle must negotiate to enter the axilla.

The brachial plexus enters the apex of the axilla lateral to the axillary artery, which is the continuation of the subclavian artery. At this point the divisions rearrange and mixed their fibers to form three cords, lateral, medial and posterior, named after their relative position to the axillary artery. The cords travel caudally in close proximity to the coracoid process, under the cover of the pectoralis minor muscle, which itself is covered by the pectoralis major muscle. At about the level of the lateral border of the pectoralis minor muscle the three cords give off their terminal branches. The posterior cord originates the axillary and radial nerves; the medial cord originates part of the median nerve, plus the ulnar, medial brachial and medial antebrachial cutaneous nerves. The lateral cord originates the rest of median nerve and musculocutaneous nerve. Very often the musculocutaneous nerve remains attached to the median nerve until reaching the proximal arm.
Distribution of the branches of the brachial plexus

Axillary nerve (C5-C6): gives an articular branch to the shoulder joint, motor innervation to the deltoid and teres minor muscles and sensory innervation to part of deltoid and scapular regions.

Radial nerve (C5-C6-C7-C8-T1): supplies the skin of the posterior and lateral arm down to the elbow, the posterior forearm down to the wrist, lateral part of the dorsum of the hand and the dorsal surface of the first three and one-half fingers proximal to the nail beds. It also provides motor innervation to the triceps, anconeus, part of the brachialis, brachioradialis, extensor carpi radialis and all the extensor muscles of the posterior compartment of the forearm. Its injury produces a characteristic “wrist drop”.

Median nerve (C5-C6-C7-C8-T1): gives off no cutaneous or motor branches in the axilla or the arm. In the forearm it provides motor innervation to the anterior compartment except the flexor carpi ulnaris and the medial half of the flexor digitorum profundus (ulnar nerve). In the hand provides motor innervation to the thenar eminence and the first two lumbricals. It provides the sensory innervation of the lateral half of the palm of the hand and dorsum of first three and one-half fingers including the nail beds.

Ulnar nerve (C8-T1): like the median nerve, the ulnar nerve does not give off branches in the axilla or the arm. Its motor component supplies the flexor carpi ulnaris and the medial half of the flexor digitorum profundus. In the hand it provides the motor supply to all the small muscles of the hand except the thenar eminence and first two lumbricals (median). Its sensory branches supply the medial third of the dorsum and palmar sides of the hand and dorsum of the 5th finger and dorsum of the medial side of 4th finger.

Medial brachial cutaneous nerve (T1): it is solely a sensory nerve. It supplies the skin of the medial side of the arm. It is joined here by the intercostobrachial nerve, branch of the second intercostal.

Medial antebrachial cutaneous nerve (T1): It is also a sensory nerve. It supplies the medial side of the anterior forearm.

Musculocutaneous nerve (C5-C6-C7): gives motor innervation to the choracobrachialis, biceps and brachialis muscles. At the elbow it becomes purely sensory innervating the lateral anterior aspect of the forearm to the wrist.

Pearls

- With the shoulder down the three trunks of the brachial plexus are located above the clavicle, therefore during a supraclavicular block the needle should never need to reach below the clavicle.
For the most part the first intercostal space is located below the clavicle (with the exception of the most posterior paravertebral part), therefore its penetration is unlikely during a properly performed supraclavicular block.

The needle should never cross medial to the parasagittal plane of the anterior scalene muscle because of risk of pneumothorax.

The pulsatile effect of the subclavian artery exerted mainly against C8-T1 roots and the lower trunk explains why the C8-T1 dermatome can be spared during a supraclavicular block. To avoid this problem the injection needs to be performed in the vicinity of the lower trunk, demonstrated by fingers twitch with a nerve stimulator or by injecting behind the subclavian artery when using ultrasound.

The SCM muscle inserts on the medial third of the clavicle, the trapezius muscle on the lateral third of it, leaving the middle third for the neurovascular bundle. These proportions are maintained regardless of patient’s size. Bigger muscle bulk through exercise does not influence the size of the muscle insertion area.

The brachial plexus crosses the clavicle at or near its midpoint. Because of the direction of the brachial plexus from medial to lateral as it descends, the higher in the supraclavicular area the more medial (closer to the SCM) the plexus is located.

**INTERSCALENE BLOCK**

**Indications**

Its main indication is anesthesia of the shoulder, lateral part of the clavicle and proximal part of the humerus.

**Point of contact of the needle with the brachial plexus**

The needle approaches the plexus at the level of the roots, high in the interscalene groove, approximately at the level of C5-C6 roots (most likely C5).

**Main characteristics**

This block is superficial and usually easy to perform. Characteristically it misses the C8-T1 dermatome, which includes ulnar nerve, medial antebrachial cutaneous nerve and medial brachial cutaneous nerve.

**Patient position and landmarks**

The patient is lightly sedated. Older, obese and recent trauma patients can be expected to be extremely sensitive to the depressant effects of benzodiazepines and/or narcotics. Titrate to effect.

The patient lies supine or on a 30-degree upright position. The ipsilateral shoulder is down and the head is turned slightly to the opposite side. The posterior (lateral) border of the sternocleidomastoid (SCM) muscle is identified as well as the upper border of the cricoid cartilage, as shown in figure 2.
A horizontal line is drawn from the cricothyroid membrane laterally to intersect the posterior border of the SCM. The index and middle fingers of the palpating hand are placed behind the SCM at this level pushing it slightly forward (medially), as shown in figure 3. This maneuver brings the palpating fingers behind the SCM and on top (anterior) to the anterior scalene muscle. The fingers are then rolled back until they fall into the interscalene groove, which at this proximal point in the neck is a real structure and easy to identify. This is the point of needle insertion.

Nerve stimulator technique

The nerve stimulator is set to deliver a current of 0.8-0.9 mA, at a pulse frequency of 1 Hz and a pulse width of 0.1 ms (100 µs). A small skin wheal is raised with 1% lidocaine or 1% mepivacaine using a small gauge needle (ideally 27).

A 2” (5 cm) or 1” (2.5 cm), 22-gauge, short bevel, insulated needle can be used. The needle is introduced between the two palpating fingers in a medial direction that also has a small (20 to 30-degree) posterior and caudal inclination, as shown in figure 4.
Fig 4. Needle insertion. The needle is advanced medial, posterior and caudal.

A needle directed just medial has a bigger chance to enter the intervertebral foramen and produce intravascular injection (vertebral artery) or penetrate the subarachnoid and epidural spaces. This is a superficial block that should take place not deeper than the projection of the clavicular head of the SCM. With that in mind further penetration putting in risk the neuraxis are discouraged.

Any distal motor twitch as well as biceps, triceps or deltoid muscles are adequate. A twitch of the abdomen signals phrenic nerve stimulation and it is evidence that the needle is anterior to the anterior scalene. The needle should be withdrawn and redirected posteriorly. A motor twitch of the trapezius muscle indicates stimulation of the spinal accessory nerve and signals that the position of the needle is posterior to the brachial plexus and needs to be repositioned anteriorly.

The injection of the local anesthesia is started slowly with frequent aspirations. There is some confusion as to whether a shoulder twitch is acceptable. Anatomical and clinical evidence support accepting any twitches other than trapezius (please see: Silverstein W et al. Interscalene block with a nerve stimulator: A deltoid motor response is a satisfactory endpoint for successful block. Reg Anesth Pain Med 2000; 25:356-359 and accompanying editorial by William Urmey, same journal page 340-342).

Ultrasound technique

The area is best visualized by placing the probe obliquely across the anterior and middle scalene muscles at the level of C5-C6. The SCM is identified as well as the great vessels (common carotid and internal jugular). The internal jugular vein is easily collapsible by the probe, which helps with its identification. Behind and somewhat lateral to the SCM the anterior and middle scalene are usually easily visualized and the roots of the plexus appear in between them with a characteristic honeycomb appearance. The needle is advanced in plane with the probe, from lateral to medial, with a slight posterior and caudal deviation, similar to Winnie’s approach. The needle is brought under direct
visualization into the proximity of C6 root. The spread of local anesthetic should show the interscalene space expanding.

**Local anesthetic and volume**

For single shot techniques in adults, 30 mL of 1.5% mepivacaine plain provides 2-3 h of anesthesia. The addition of 1:400,000 epinephrine prolongs the anesthesia to about 3-4 h. The residual analgesia post anesthesia is variable in duration, although rarely persists for more than 2 h after block resolution. Ropivacaine 0.5% - 0.75% can be used in the same volume to provide 5-7 h of anesthesia. The addition of lyophilized tetracaine to 1.5% mepivacaine, for a final concentration of 0.2% tetracaine, accomplishes similar extended duration with shorter onset, although the onset is longer than for mepivacaine alone.

Also 20-30 mL of 0.2% ropivacaine can be used to provide postoperative analgesia for surgery performed under general anesthesia.

**Side effects and complications**

Systemic local anesthetic reaction can occur as with any block. More specific (and frequent) side effects related to interscalene block are: *Horner's syndrome* (ptosis, miosis and anhydrosis) due to stellate ganglion block and *hoarseness* due to recurrent laryngeal nerve involvement. Characteristically this block produces 100% of phrenic nerve block with diaphragmatic paralysis (Urmey W. et al. One hundred percent incidence of hemidiaphragmatic paresis associated with interscalene brachial plexus anesthesia as diagnosed by ultrasonography. Anesth Analg 1991; 72: 498-503). This can produce dyspnea and reductions in respiratory volumes of up to 30%. Pneumothorax is possible, but rare with this block.

**Clinical pearls**

- Because of the position of the shoulder, so close to the head of the patient, the anesthesiologist must carefully evaluate the patient and surgeon before deciding to perform an interscalene block as the only anesthesia for the case. Rough movements by the surgeon could scare the patient.
- It must be remembered that most of these procedures are performed in positions other than supine (e.g., beach chair, prone, lateral), therefore management of the airway is a concern.
- Language barrier between patient and anesthesiologist is also a relative contraindication for interscalene block as the sole anesthetic.
- This is a very superficial block. Care should be taken not to introduce the needle more than 2 cm beyond the projection of the midpoint of the SCM muscle.
SUPRACLAVICULAR BLOCK

Indications
This block is ideally suited for any surgery on the upper extremity that does not involve the shoulder.

Point of contact of the needle with the brachial plexus
The needle approaches the plexus at the level of the trunks, and ideally the injection should take place in the vicinity of the lower trunk.

Main characteristics
This block is considered more difficult to learn than other upper extremity blocks and historically has been associated with a higher risk of pneumothorax. The literature cites pneumothorax rates between 0.5-6.1 percent. However with good anatomy and meticulous technique we have been able to practically eliminate this risk.

A supraclavicular block is usually associated with a short onset and high success rates. This is due to the compact arrangement of the plexus at this level. The location of such large amount of innervation in such reduced area does not have a parallel in the lower extremity, or anywhere else for that matter, qualifying the supraclavicular block as the most successful plexus block in the whole body. Indeed it has been called the “spinal of the upper extremity”.

Because of pneumothorax reports, the supraclavicular block started to lose its appeal and by the 1960’s the axillary block started to become popular. A rational approach should have dealt with the pneumothorax issue by finding reliable superficial landmarks for the dome of the pleura. An anatomical approach that starts by determining the pleura boundaries is the technique we perform and the reason for its safety and reliability. This allows us to take advantage of such extraordinary block while limiting its potential drawbacks. Our experience to late 2007 includes more than 3,500 supraclavicular techniques without any pneumothorax ever being demonstrated. A common question posed to us is whether we perform routine chest X-rays after a supraclavicular block. The fact is that we only do an X-ray when the clinical situation calls for it (e.g., an unusually difficult technique). The literature predominantly shows that when a pneumothorax has been found following a supraclavicular block, it has been after the patient developed clinical symptoms and not during routine chest x-ray post block. So our practice of performing selective chest X-rays, as needed, is comparable to the common practice in the rest of the country.

Some history of the supraclavicular technique
The supraclavicular block was introduced into clinical practice in Germany by Kulenkampff in 1911. A publication of his technique appeared later
in the English literature in 1928. Kulenkampff accurately described the plexus as being more compacted in the neighborhood of the subclavian artery, where he rightly believed that a single injection could provide adequate anesthesia of the entire upper extremity. Kulenkampff’s technique was simple and in many ways sound. Unfortunately his recommendation to introduce the needle toward the first rib, in the direction of the spinous process of T2 or T3, carried an inherited risk for pneumothorax.

Albeit with several modifications, the supraclavicular block remained a popular choice until the early 1960’s. Eventually, the combined effect of pneumothorax risk and the introduction of the axillary approach by Accardo and Adriani in 1949, and especially by Burnham in 1958, marked the beginning of the decline for one of the best regional anesthesia techniques ever described.

The axillary approach introduced a good technique with its share of shortcomings (e.g., smaller area of anesthesia than supraclavicular, tendency to produce “patchy” blocks and lower overall success rate), but definitely devoid of pneumothorax risk. The axillary block received a big push when in 1961 De Jong published an article in Anesthesiology praising it. The paper was based on cadaver dissections and included the now famous calculation of 42 mL as the volume needed to fill a cylinder 6 cm long, that according to De Jong “should be sufficient to completely bathe all branches of the brachial plexus”. Coincidentally (or not) the same journal carried a paper by Brand and Papper out of New York, comparing axillary and supraclavicular techniques. This article is the source of the 6.1% pneumothorax rate frequently quoted for supraclavicular block. In retrospect these two articles could be considered the point at which the tide definitely turned against the supraclavicular block making the axillary route the most common approach to the brachial plexus in the United States and the rest of the world. With some exceptions this is still true today.

Some authors also cite the perceived complexity of supraclavicular block as the reason for not performing it more often. However the advantages of a supraclavicular technique, namely its rapid onset, density, high success rate along with large area of anesthesia are too good to ignore. These good characteristics are, according to David Brown and colleagues, “unrivaled” by other techniques. In our practice the supraclavicular approach is the cornerstone of upper extremity regional anesthesia. Ultrasound has produced a resurgence in the interest to perform supraclavicular blocks once again.

**Patient position and landmarks**

The patient lies supine with the head of the bed elevated 30 degrees (fig 5). The ipsilateral shoulder is down and the head is turned to the opposite side. The arm to be blocked is flexed at the elbow and, if possible, the wrist is supinated to easily detect a twitch of the fingers. We use the same position for ultrasound-guided technique.
The patient lies supine with the head of the bed elevated 30 degrees. The head of the patient is turned, the shoulder is down and the arm is flexed at the elbow and supinated at the wrist.

The point at which the clavicular head of the SCM muscle inserts in the clavicle is then identified as shown in fig 6. A parasagittal (parallel to the midline) plane that crosses this point determines an “unsafe” zone medial to it, where the risk of pneumothorax is high and a lateral zone that is safer.

Because the trunks are short and run in a very steep direction caudally towards the clavicle, there is a narrow “window of opportunity” to perform the block above the clavicle. It must be performed at enough distance from the insertion of the clavicular head to be away from the pleura, and close enough to this point to still reach the trunks, before they disappear behind the clavicle. We call this distance “the safety margin”. In adults we calculate this distance to be about 1 inch (2.5 cm), which corresponds to the width of the author’s thumb. This distance is marked on the skin over the clavicle for orientation, as shown in figure 7.
This is only an orientation point because the actual point of needle entrance is determined by palpation of the most lateral elements of the plexus in the supraclavicular area around the orientation point. At this level the brachial plexus is usually easily palpable, either as a groove or some type of cord. This is usually called “interscalene groove”, but the interscalene groove only exists high in the C5-C6 level.

The palpating finger is placed parallel to the clavicle and the point of needle entrance is marked with a downward pointing arrow, as shown in figure 8 (upper lateral arrow). Over the clavicle an upward pointing arrow is also drawn, as shown in figure 8 (lower lateral arrow). Both arrows together show the direction of the needle, parallel to the midline. The lower lateral arrow also marks the caudal limit for penetration of the needle (as far caudal as we are willing to go), keeping it supraclavicular and away from the first intercostal space.

Nerve stimulator technique

The needle is inserted first anteroposterior (toward the table) with a 30 degree caudal orientation as shown in figure 9, for a distance of a few mm up to 1.5 cm, depending on the amount of subcutaneous tissue. Usually a twitch of the upper trunk (shoulder) is found as evidence that the needle is approaching the plane of the plexus.
The direction of the needle is then changed from anteroposterior to caudal, to be advanced parallel to the midline (and parallel to the most lateral pleural boundary), as shown in figure 10.

The reference to the midline is easy to ascertain and avoids the use of other landmarks (e.g., nipple), which have enormous patient-to-patient location variability.

The needle is advanced caudally with a slight posterior angle. Because the trunks are physically contiguous a twitch of the upper trunk (shoulder) is followed by middle trunk (pectoralis, triceps, supination, pronation) and finally lower trunk (wrist and fingers). The goal of the technique is to stimulate the fingers. Wrist flexion and extension are acceptable responses, but supination or pronation or other more proximal twitches are not.

If advancing the needle, after finding a proximal trunk, makes the twitch disappear it means that the angle of the needle is not matching the orientation of the trunks, and that the tip of the needle is wandering away from the trunks. The needle is slowly withdrawn until the original twitch is once again visible, and then redirected either posteriorly (most of the times) or anteriorly, but always parallel to the midline.

It is very important not to advance the needle more than 2 cm in the caudal direction if no twitch is visible. In this case the situation is reassessed starting with the nerve stimulator and its connections. As long as a twitch from the brachial plexus is being elicited the needle can be safely advanced caudally without regard to depth.
Ultrasound technique

We also use the semi sitting position. A linear, high frequency probe, as for the interscalene block, is used. We usually start scanning high in the neck at above C6 to identify SCM, scalene muscles and great vessels. The probe is then advanced caudally and placed just above the clavicle and almost parallel to it. The angle (tilting) is adjusted to get a good cross section of the subclavian artery and the scalene muscles. The plexus, either trunks or divisions, are visualized behind and proximal to the artery in a characteristic honeycomb arrangement.

The needle is directed in plane from lateral to medial under the probe. The needle should be inserted at 1-2 cm away from the probe to avoid a steep angle of insertion that would make its visualization harder. The needle is directed toward the lower trunk, behind the subclavian artery. The anesthetic solution should be seen surrounding the plexus.

Local anesthetic and volume

For single shot techniques in adults, 30 mL to 40 mL of 1.5% mepivacaine plain will provide 2-3 h of anesthesia. The addition of 1:400,000 epinephrine prolongs the anesthesia to about 3-4 h. The residual analgesia post anesthesia is variable in duration, although it rarely persists for more than 2 h after block resolution. Ropivacaine 0.5%-0.75% can be used in the same volume to provide 4-7 h of anesthesia. The addition of lyophilized tetracaine to 1.5% mepivacaine, for a final concentration of 0.2% tetracaine, accomplishes similar extended duration with shorter onset, although the onset is longer than for mepivacaine alone.

Also 20-30 mL of 0.2% ropivacaine can be used to provide postoperative analgesia for surgery performed under general anesthesia.

Complications

Besides the common complications accompanying any block, the supraclavicular technique can also be followed by Homer’s syndrome, hoarseness and phrenic nerve palsy, but less frequently than after interscalene block. Neal et al in 1998 studied diaphragmatic paralysis in 8 volunteers after supraclavicular block using ultrasound (replicating what Urmey et al did in 1991 to demonstrate 100% of diaphragmatic paralysis after interscalene block). They found an incidence of 50% of diaphragmatic paralysis. No subject experienced changes in pulmonary function tests (PFT) values or subjective symptoms of respiratory difficulty. This is our experience too.
Clinical pearls

- This is not a block for a practitioner that rarely performs peripheral nerve blocks. The person interested in learning to perform it should first become familiar with the anatomy of the supraclavicular area including the location of the dome of the pleura. Using ultrasound makes the visualization of the pleura easier, but still requires the operator to be familiar with the anatomy of the area.
- When using a nerve stimulator technique, the block should not be attempted unless the insertion of the sternocleidomastoid in the clavicle is clearly established. In fact, this is a must especially for a person not experienced with the technique. With time it becomes easier to ascertain the boundaries of the SCM.
- It helps to know that the neurovascular bundle crosses the clavicle under the midpoint of it, so this should be kept in mind as a reliable reference.
- Due to the steep direction of the plexus from the neck to the axilla, the higher in the neck (the further away from the clavicle) the more medial the plexus is. By the same token, the further below the clavicle the more lateral to its midpoint the plexus is.
- The needle should never be inserted more than 2 cm caudal if no twitch is elicited. This warning applies to every patient regardless of weight.
- The injection should always be slow, alternated with frequent aspirations. This technique provides time to recognize accidental intravascular injection in those cases where blood is not aspirated. I also believe it helps to keep the needle from moving backwards as a result of high speed flow at the tip of the needle.

INFRACLAVICULAR BLOCK

Indications
This block is more suited for surgery distal to the elbow.

Point of contact of the needle with the brachial plexus
The needle approaches the plexus at the level of the cords in the proximity of the terminal branches.

Main characteristics
The infraclavicular block is really an axillary block in which the needle enters the axilla through its anterior wall (pectoralis muscles), instead of through its base. This fact is usually unrecognized and infraclavicular block is presented as a block completely different than axillary. It is a good place to place a catheter since it is less mobile than neck and axilla. It also hurts more because it is a deep block that requires the needle to go through muscle. Patients should be adequately sedated.
It is widely recommended to obtain a distal twitch in the hand or wrist and to avoid a biceps twitch (musculocutaneous nerve or lateral cord) or pronation of the forearm (lateral cord). This is based on clinical experience. A biceps twitch could be the result of musculocutaneous nerve stimulation, outside the sheath, or from lateral cord stimulation inside the sheath, and as such it is unreliable. It is theoretically possible that a twitch from the posterior cord (elbow, wrist and or finger extension) could be best, because the posterior cord is located at about the same distance from the other two, and subjected to more pressure from surrounding structures, although it is more difficult to get to it. Ultrasound, with visualization of the axillary artery, makes the injection posterior to it easy.

Many infraclavicular techniques have been described. A simple technique is the coracoid approach first described by Whiffler in the British Journal of Anaesthesia in 1981 and later redefined by MRI studies performed in 40 volunteers by Wilson, Brown et al, and published in Regional Anesthesia in 1998.

**Patient position and landmarks**

The patient lies supine with the ipsilateral shoulder down. The coracoid process is found by palpation and marked on the skin. The coracoids can be found at around 2 cm below the clavicle, at the level of the deltopectoral sulcus (junction between the middle third with the lateral third of the clavicle). A C-arm can be useful if available. The point of needle entrance is marked 2 cm caudal and 2 cm medial to the coracoid process as shown in fig 11.

![Fig 11. Needle entrance point.](image)

**Nerve stimulator technique**

The nerve stimulator is set to deliver a current of 0.9-1.0 mA at a frequency of 1 Hz and 0.1 ms of pulse duration. It is frequently necessary to use a 4” (10 cm) needle to be able to reach the plexus.

The needle attached to the nerve stimulator is advanced in the anteroposterior direction, perpendicular to the skin, as shown in figure 12.
Before entering in contact with the plexus the needle passes through the pectoralis major and pectoralis minor muscles producing a visible local twitch. The brachial plexus is found deep to them. If no response from the plexus is obtained the needle is redirected caudal (most of the time) or cephalad, but maintaining the same parasagittal plane without medial or lateral deviation.

**Ultrasound technique**

Because the brachial plexus at this level is deep, being located under pectoralis major and minor muscles, a lower frequency linear probe is usually used, in the range of 4-7 MHz. The probe is aligned almost perpendicular to the junction between the middle and lateral thirds of the clavicle in the proximity of the coracoid process. This way a cross section of the plexus and axillary vessels is obtained. The tilt is adjusted until a clear view in cross section is obtained. The needle can be advanced in plane with the probe from proximal to distal or vice versa. The best target, if a single injection is desired, is the posterior cord behind the artery. Separate injections of the cords can be done as needed.

**Local anesthetic and volume**

This block requires a higher volume for better results, although ultrasound techniques do not. Usually 40 mL of 1.5% plain mepivacaine will provide 2-3 h of anesthesia. The addition of 1:400,000 epinephrine prolongs the anesthesia to about 3-4 h. The residual analgesia post anesthesia is variable in duration although rarely persists for more than 2 h after block resolution. Ropivacaine 0.5% can be used in the same volume to provide 4-6 h of anesthesia. The addition of lyophilized tetracaine to 1.5% mepivacaine, for a final concentration of 0.2% tetracaine, accomplishes similar extended duration with shorter onset, although the onset is longer than for mepivacaine alone.

Also 30 to 40 mL of 0.2% ropivacaine can be used to provide postoperative analgesia for surgery performed under general anesthesia.
Complications

Pneumothorax can occur due to injury of the pleura through an intercostal space. Muscle pain and hematomas, which can be large in size, are not uncommon.

Clinical pearls

- This is a good place to put a catheter because it is easier to fix it.
- Use adequate sedation, as this block is more uncomfortable for patients.
- The block should not be attempted medial to the junction between the lateral third and middle third of the clavicle, because of increased risk of pneumothorax.

AXILLARY BLOCK

Indications

It is best suited for surgery distal to the elbow.

Point of contact of the needle with the brachial plexus

The needle approaches the plexus at the level of its terminal branches.

Main characteristics

The axillary block is not properly a plexus block, but rather a block of the terminal branches of the brachial plexus. The distance between the different branches plus the expanding wave of the axillary artery pulse are obstacles that the local anesthetic must overcome to adequately reach the nerves. A single injection technique is an option, but a second and even a third injection has shown to increase the success rate. If a single injection is to be attempted, the epicenter of the injection if possible, has to coincide with the specific nerve responsible for the sensory innervation of the surgical area. For example, to deal with an extensor tendon injury of the thumb (radial nerve) the injection should occur around the radial nerve. The same is true for lesions located in the ulnar and median territories. If the surgical area involves more than one terminal nerve, the single injection technique should be performed in the proximity of the radial level, because I believe the solution diffuses more easily from back to front that vice versa. This may be because of more resistance in the back of the plexus (muscles and scapula) than in front (subcutaneous tissue). The anatomy lab also shows that better diffusion could be obtained by placing a pillow under the elbow with the shoulder abducted slightly less than 90 degrees.

A point usually stressed in the literature is to perform the block as proximal in the axilla as possible. This can be uncomfortable to the patient and challenging to the anesthesiologist. The only perceived advantage would be to increase the chances of blocking the musculocutaneous nerve before it leaves the plexus. This is never certain. A better strategy is to block this nerve first before
performing the block of the rest of terminal branches. Although some variability exists, usually the median nerve is superficial (anterior) to the artery following its same direction, the ulnar nerve (and medial brachial/antebrachial cutaneous) are medial and somewhat posterior to the artery, the musculocutaneous nerve is lateral to the artery (and eventually under the biceps muscle) and the radial nerve is posterior to the artery.

**Patient position and landmarks**

I do not like the transarterial technique so we will only discuss nerve stimulator and ultrasound techniques. The patient is supine, the arm is abducted to about 80 degrees and the elbow is elevated 30 degrees by using a small pillow or folded blanket.

The biceps muscle is identified by visualization and/or palpation, under which a cord like structure signals the presence of the coracobrachialis muscle. Immediately posterior to it the pulse of the axillary artery can be found. A marker is used to identify the proximal trajectory of the artery in the upper arm/axilla junction, as shown in figure 13.

![Fig 13](image)

**Nerve stimulator technique**

A 2’, 22-gauge insulated needle usually suffices. The block of the musculocutaneous nerve is accomplished first. The operator identifies and holds the patient’s biceps muscle with one hand and directs the needle with the other in a direction perpendicular to the main axis of the arm into the substance of the coracobrachialis muscle as shown in fig 14.
At some point under the biceps a motor twitch of the elbow in flexion is elicited. The current is reduced to 0.5 mA and 5 mL of local anesthetic solution is slowly given. The needle is then withdrawn and the nerve stimulator is set again to 0.8-0.9 mA. Using the mark of the axillary artery on the skin as a reference, the needle is directed either tangential to it (median), medial to it (ulnar and medial brachial/antebrachial) or posterior to it (radial), as shown in figure 15.

**Ultrasound technique**

The brachial plexus once again is superficial here so a linear, high frequency (10-15 MHz) probe is used. The arm is abducted and a pillow is placed under the elbow, as described for the nerve stimulator technique. The probe is placed across the neurovascular bundle to get a cross section image of it. The median nerve is usually seen superficial (anterior) to the artery. The ulnar nerve is medial and somewhat posterior, the radial nerve is posterior. Distally in the axilla the radial nerve starts shifting more lateral, but it still remains posterior to the artery. The musculocutaneous is lateral to the artery at all times and it can be seen entering the coracobrachialis muscle. If a single injection is planned it should be made in the proximity of the radial nerve. Individual injections of terminal nerves can be done as needed.

**Local anesthetic and volume**

The terminal nerves in the axilla are more separated than at more proximal locations. The terminal branches of the plexus are enclosed in a fibrous sheath which is filled with loose connective tissue without any defined organization or septa, as we have recently demonstrated (Franco et al. Gross...
anatomy of the brachial plexus sheath in human cadavers. Reg Anesth Pain Med, 2008; 33: 64-69). This connective tissue in itself is an obstacle to the free diffusion of local anesthetic within the sheath. Planes of cleavage surrounding nerves and vessels help promote longitudinal spread of local anesthetics as opposed to circumferential spread. For these reasons an axillary block should be performed using a higher anesthetic volume than at other more proximal locations, 50 mL injected slowly using the usual precautions is the volume most used. A multi injection technique is a justifiable alternative. Ultrasound techniques help to decrease the total volume of local anesthetic used.

Complications

Pneumothorax is virtually impossible to get from this location. Hematomas from vascular puncture are more common and can be associated with nerve damage.

 Pearls

- This is a block mainly indicated for surgery on the distal forearm, wrist and hand.
- It is not a good choice for elbow surgery.
- Tourniquet pain is an issue and not necessarily due to intercostobrachial nerve, but mainly due to insufficient proximal anesthesia of the whole arm.
- The main injection should aim for the nerve most responsible for the sensory innervation of the surgical site.
References

5. Greenblatt Gm, Denson GS. Needle nerve stimulator-locator: nerve blocks with a new instrument for locating nerves. Anesth Analg 1962; 41: 599-602