

The Infraclavicular Brachial Plexus Block

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The infraclavicular brachial plexus block is still an underused technique for regional anesthesia of the upper limb, but represents a reliable and safe approach for surgery of the hand, the forearm, the elbow, and the antecubital fossa, also involving the musculocutaneous nerve. This report intends to describe, as well as the anatomical evidence, an infraclavicular technique modified by Grossi, in which the arm is adducted or in a rest position. Vertical direction of the needle and electrical nerve stimulator with insulated needle is required. An historical review of infraclavicular blocks and their relation with other approaches are reported. Evident advantages are represented by compliance of the patient, tourniquet tolerance, usefulness of this approach to place a catheter, an alternative to the axillary approach in presence of joint stiffness or ankylosis, fractures of the limb, local infection or scars, and previous axillary lymphadenectomy. The possible complications are related to pleural or vascular puncture. No impairment of the respiratory function or involvement of the phrenic nerve is reported.

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Infraclavicular brachial plexus block (BPB) is an underused technique for regional anesthesia of the upper limb, but is an effective alternative to the axillary block when this is not suitable for specific purposes. This review describes a new technique as well as relevant anatomy of the brachial plexus and illustrates the safety and indications of this approach to the brachial plexus. Compliance of the patient, facility in catheter placement, and advantages over the axillary approach are discussed. The possible complications related to pleural or vascular puncture and the influence on respiratory function are also outlined. A lower incidence of pneumothorax and no impairment of respiratory function are reported.

Historical Consideration

In this review we describe a modified (by Grossi) infraclavicular approach to BPB, which can produce excellent anesthesia of the whole arm up to the proximal third of the humerus, is safer than the supraclavicular approach, and more complete than the axillary approach.

Its advantages include the ability to perform the block with the patient's arm in a resting position, minimization of the risk of pneumothorax, ease of securing a brachial plexus catheter

and fixing it to the chest wall, and the inclusion of the musculocutaneous nerve using a single injection.

The infraclavicular approach to the BPB is today an underused technique but it has been described already in the beginning of this century. In the technique described by Bazy,¹ the needle was directed medially from the midpoint of the clavicle to the Chassaignac's tubercle. It was a compromise between Hirschel's axillary and Kulenkampff's supraclavicular approaches,^{2,3} attempting to deposit the anesthetic solution in the same place, that is just above the first rib along the line of anesthesia at the level of the trunks of the plexus. Afterwards, many techniques with lightly different landmarks and points of introduction were then described by Balog,⁴ Babitzky,⁵ Kim,⁶ and others,⁷ with an axillary or a clavicular direction of the needle. All these techniques have some advantages and many disadvantages over the supraclavicular or axillary approach. Clinically, the danger of pneumothorax remained unchanged, limiting the infraclavicular approach in popularity for several years.

In 1973 Raj⁸ described a new approach to the brachial plexus in the infraclavicular region. In this technique the patient lies supine, his head is turned away from the arm to be blocked and his arm is abducted to 90°. The landmarks are the whole length of the clavicle, the subclavian artery pulsation under the clavicle (this landmark usually is at the midpoint of the clavicle), the brachial artery in the arm, the C6 tubercle on the same side, and the line from the C6 tubercle to the brachial artery in the arm, passing through the midpoint of the clavicle. An 89 mm 22-gauge (G) unsheathed spinal needle connected to an electrical nerve stimulator (ENS)⁹ is introduced through the skin 2.5-cm under the midpoint of the clavicle (or where the subclavian artery pulsation is palpated before disappearing under the clavicle) and is directed laterally toward the brachial artery. The needle is advanced at an angle of 45° to the skin and when its tip is in the close proximity to nerve fibers of the brachial plexus we can observe arm movements, electrically provoked. An injection of 30 to 40 mL of local anesthetic solution followed. Raj's technique differs from previous infraclavicular techniques with regard to needle introduction, which is more medial and directed laterally from the point of entry so that the needle is always outside of the thoracic cavity. Thus there is no real danger of pneumothorax. Otherwise, there are also some disadvantages. First of all, the needle is advanced blindly with respect to the vessels and the possibility of vascular puncture is certainly greater with this technique than with other approaches. Secondly, because a long needle is required to penetrate both the pectoralis major and minor muscles and because multiple attempts are frequently necessary, the patient acceptance of this procedure could be less; in obese patients the needle could be too short and it is common to puncture the neurovascular sheath anteriorly and posteriorly with a possible significant loss of the local anesthetic

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injected inside the bundle. The arm is abducted to 90°, as in the axillary approach, excluding all the cases in which it is not possible to do it. Finally, due to the needle being directed laterally, the spread of the injected solution is directed laterally. If the tip of the needle is lateral to the coracoid process, the majority of the injected solution may therefore miss the musculocutaneous and axillary nerves and this technique may simulate an axillary block that is performed higher in the axillary perivascular compartment.

In 1977 Sims¹⁰ suggested new landmarks in the effort to overcome some of the disadvantages of Raj's technique, making the infraclavicular BPB easier (also in obese patients) and using a shorter needle. The landmarks are the inferior border of the clavicle and the coracoid process of the scapula. The index finger should be placed in the groove between these two structures; advancing medially and inferiorly, it will fall into a depression within the superior portion of the major pectoralis muscle (inferiorly and medially), the coracoid process of the scapula (laterally), and the clavicle (superiorly). A 40-mm needle is introduced at this point and advanced inferiorly, laterally, and posteriorly toward the apex of the axilla. Usually, the plexus is located 2 to 3 cm beneath the skin.

In 1981, Whiffler¹¹ proposed the coracoid block in which the injection site is not far from that proposed by Sims, but the technique of injection is completely different. The patient lies supine with the head turned away from the arm to be blocked; the shoulder is depressed and the arm abducted to 45° from the chest wall. Once the coracoid process is identified, it is possible to estimate the depth of the injection by palpating with the index finger the axillary arterial pulse as high as possible in the axilla, and placing the thumb of the same hand on the anterior surface of the chest wall over the site at which the index finger palpates the artery. This point usually lies in the deltopectoral groove. The needle is inserted with a right angle to the skin, on a line marked between the point in which the subclavian artery pulsation disappears under the clavicle and the projection on the anterior surface of the chest wall of the axillary arterial pulsation, just inferiorly and medially to the coracoid process, to the depth estimated as indicated above. After an initial injection of 12 mL of local anesthetic, the needle is withdrawn 1 cm and a second similar injection is made (in muscular individuals a third injection of 12 mL is required after withdrawing the needle 1 more centimeter). This technique does not require the use of an ENS because the objective is not to make an injection inside the neurovascular sheath but to lay down a wall of anesthesia through which the plexus must pass.

Anatomy

The brachial plexus is formed by the union of the anterior primary divisions of C5, C6, C7, C8, and T1 spinal nerves with frequent contribution of C4 and T2.^{12,13} It starts from the vertebral column, runs in the groove between the anterior and the middle scalene muscles, passes between the clavicle and the first rib where it is joined by the subclavian artery, which runs deep to the anterior scalene muscle, and proceeding under the pectoralis minor muscle insertion on the coracoid process enters the upper limb in the axilla. In its course from the intervertebral foramina to the arm the plexus is composed consecutively of roots, trunks, divisions, cords, and terminal nerves, formed through a complex process of combining and dividing.

After leaving the intervertebral foramina, the roots of the fifth, sixth, seventh, and eighth cervical nerves pass behind the vertebral artery and travel laterally in the gutters formed by the superior surfaces of the anterior and posterior tubercles of the corresponding cervical transverse processes. At the distal end of the transverse processes the roots descend in front of the middle scalene muscle toward the first rib, above which they fuse with the root of the first thoracic nerve, which passes upward and laterally in front of the neck of the first rib and behind the pleura over the apex of the lung, to form the three trunks of the plexus. In its passage from the cervical transverse processes to the first rib, the plexus, first as roots and then as trunks, is sandwiched between the anterior and middle scalene muscles and so invested by the fascia of those muscles that limit the interscalene space. It is really the fascia covering the scalene muscles, derived from the prevertebral fascia, which constitutes the sheath of the brachial plexus.

As the three trunks, named superior (formed by the union of C5, C6 roots), middle (C7), and inferior (C8, T1), cross the first rib they are arranged one on top of the other vertically, as the name implies, and are joined inside the sheath by the subclavian artery to form the subclavian perivascular space. Not infrequently, the inferior trunk of the brachial plexus gets trapped behind, and even under the artery, which could make a barrier to the diffusion of local anesthetic solution injected higher in the interscalene space.

After the trunks have passed over the first rib and under the clavicle, at about the upper border of the clavicle, each trunk divides into an anterior and posterior division. As the plexus emerges from under the midpoint of the clavicle in the infraclavicular region of the axilla, the fibers of the six divisions recombine to form the three cords of the plexus: medial, lateral, and posterior. They are surrounded by the four walls limiting the axilla: pectoralis major and minor muscles form the anterior; the subscapularis, teres major, and latissimus dorsi muscles complete the posterior wall; the medial wall is made by the first four ribs of the chest wall; and the lateral wall is formed by the medial side of humerus head and by glenoid process of the scapula. In passing under the clavicle, the subclavian artery becomes the axillary artery and lies central to the three cords that are not really medial, lateral, and posterior to the axillary artery until they pass behind the pectoralis minor muscle. Within this space the cords gradually rotate around the artery until, in the second portion of the artery, their position become truly medial, lateral, and posterior to the artery. As it passes over the first rib and under the clavicle, the subclavian vein, in becoming the axillary vein, joins the neurovascular bundle that takes name of axillary fascia, (extension of the prevertebral fascia).¹⁴

It is approximately at the lateral edge of the pectoralis minor muscle that the cords divide into the major terminal nerves. The lateral and medial cords give off as their branches the lateral and medial heads of the median nerve and then the medial cord continues as the ulnar nerve and the lateral cord as the musculocutaneous nerve; the posterior cord gives off the axillary nerve as major branch and then continues as the radial nerve. Only the median, radial, ulnar, and medial antebrachial cutaneous (a medial cord secondary branch) nerves with the brachial artery and vein lie within the axillary sheath at the level at which the axillary block is performed. It is very important to emphasize that the musculocutaneous, the axillary, and the medial brachial cutaneous nerves are not still

Afterwards the musculocutaneous nerve enters the coracobrachialis muscle and descends the arm between the biceps and the brachialis muscle. The intercostobrachial nerve (T2) travels parallel to but always outside the axillary sheath.

The brachial plexus and the neurovascular bundle terminate in the upper arm sandwiched between the coracobrachialis, the short head of biceps, the long head of triceps muscles, and the head, the neck, and shaft of the humerus.

The perineural compartment of brachial plexus can be entered at any level from the interscalene to the axillary neurovascular space, along the line of anesthesia, and the extent of anesthesia will depend on the level and the volume of anesthetic solution injected over the roots, trunks, cords, or peripheral branches.

Technical Aspects of the Infraclavicular Approach to the Brachial Plexus Block

Position

The patient lies supine with his head turned away from the arm to be blocked. Whereas according to Raj's original technique the arm should be abducted 90° from the chest wall and the physician should stand on the opposite side from the arm to be blocked, in our approach (technique modified by Grossi) the arm is adducted or even abducted but not over 45° from the chest wall. The anesthetist (right-handed) stands beside the patient between the head and the right shoulder if the arm to be operated upon is the right, or behind the head of the patient for a left-sided block; otherwise in the opposite position if the operator is left-handed.

Landmarks

Landmarks (all the landmarks should be traced with a skin pen on the skin, to stress the line of anesthesia): (1) the Chassaignac's tubercle, corresponding to anterior tubercle of sixth cervical vertebra, determined by extending a line laterally from the cricoid cartilage, is identified and marked behind the lateral border of the sternocleidomastoid muscle, on the same neck side; (2) the whole length of the clavicle and particularly the midpoint is marked after palpation; (3) the coracoid process of the scapula and the lateral border of the chest wall are identified and marked in the infraclavicular region. A point on the skin about 2 cm medial and about 2 cm caudad to the tip of the coracoid process identifies the brachial plexus below"; (4) the axillary artery pulse in the axilla is marked, ideally the point where the pulse disappears under the pectoralis major muscle; and (5) the line of anesthesia, passing through the clavicle midpoint and running between the coracoid process and the lateral border of the chest wall, is drawn from the Chassaignac's tubercle to the axillary arterial pulse point.

Procedure

The ground electrode of an ENS is attached to the opposite shoulder.

The exploring hand moves along the line of anesthesia to the point between the coracoid process and the chest wall. Advancing the fingers inferiorly and medially from the coracoid process, they will fall into a depression bordered

by the pectoralis minor muscle and superficial to the thinnest part of the pectoralis major muscle, about 2 cm medially and about 2 cm inferiorly to the tip of the coracoid process of the scapula.

3. After skin cleaning, a skin wheal is raised just inferior and medial to the coracoid process along the line of anesthesia.
4. Afterwards a 22-G 120-mm sheathed needle connected to the ENS and to the ground electrode on the shoulder is introduced through the skin wheal perpendicular to the line of anesthesia and advanced posteriorly, inferiorly, and laterally at an angle of 0 to 15° toward the axilla (Fig 1).
5. At no time should the needle be directed medially or toward the chest wall, the lung, or attempt to reach the periosteum of the osseous structures.
6. The average depth of needle insertion required to reach the brachial plexus is 5.1 cm (2.25 to 7.75 cm in men and 2.25 to 6.5 cm in women) with the arm abducted not over 45°. Greater abduction of the arm will make the performance of the technique easier because the brachial plexus depth is reduced and the cords are more spread, but this implies a normal joint functionality. Our modified technique is particularly useful and advantageous when the abduction of the arm is limited or painful (joint stiffness or ankylosis, fractures, etc).
7. As the sheathed needle connected to the ENS (delivering a 0.5 mA and 2 Hz stimulus) approaches the cords of the brachial plexus, movements (twitch) of the muscles supplied by those fibers will occur. Flexion or extension of the elbow, wrist, or fingers and external or internal rotation of the forearm confirms that the needle point is in close proximity to nerve fibers of the brachial plexus. The needle should be advanced slowly until the maximum muscle movements are observed.
8. Two different twitches should be elicited to improve the success rate of this approach.¹⁶ The twitch of the muscles supplied by the cord, the sensitive zone of which is interested by the surgical treatment, represents the "best" twitch.
9. Holding the needle in that position, 2 mL of anesthetic solution are injected. If the needle is located correctly on

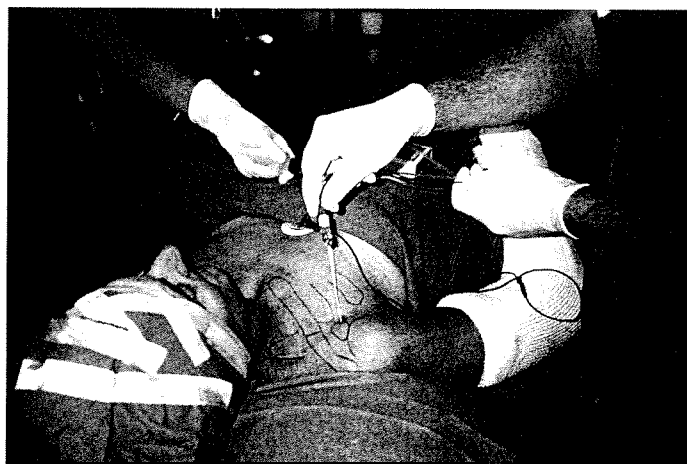


Fig 1. Vertical introduction of the 120-mm needle, along the anesthetic line, 2 cm below the coracoid process; the arm of the patient is adducted to the body.

the nerve fibers there will be an immediate loss of previously observed muscle movements. If not, the needle may have been pushed through the nerve and it should be withdrawn slightly. If acute pain is elicited by the injection, the needle could have been advanced inside the nerve and it should be withdrawn immediately.

10. After careful aspiration, the volume of local anesthetic solution is injected at that site. The needle may then be removed from the patient.
11. After the deposition of the anesthetic solution in the infraclavicular region, anesthesia develops from the top down in 10 to 30 minutes (onset time depending on the anesthetic solution). The extent of anesthesia is from the hand to the medium part of the humerus, including the sensitive area supplied by the musculocutaneous nerve. There is not involvement of the phrenic nerve. As for the axillary approach to the brachial plexus, the shoulder and the clavicle are not involved in the block.

Drugs Volume and Dosage

The neurovascular bundle in the infraclavicular region is very compliant, thus it is possible to inject a large volume of anesthetic solution: 30 to 40 mL (depending on the patient body weight). A contrast medium injected inside the brachial plexus sheath in the infraclavicular region is observed spreading from the axilla to the inferior border of the clavicle (Fig 2).

The anesthetic solutions used are: mepivacaine 1.5% (30 to 40 mL, max 600 mg), bupivacaine 0.25% to 0.5% (30 to 40 mL, max 150 mg), or ropivacaine 0.5% to 0.75% (30 to 40 mL, max 225 mg).

Indications

The infraclavicular brachial plexus block is indicated for the surgery of the hand, forearm, and elbow. This approach is also very effective for postoperative or emergency analgesia and ideal for long-term catheter placement (Fig 3),¹⁷ more effective than the axillary approach in which the movement and dislocation of the catheter are easier and the infectious risk increased.

It is also indicated for all the conditions in which the axillary block is difficult to perform: shoulder ankylosis or stiffness, upper limb fractures, previous lymphadenectomy of the axilla, and scars or local infection, because it is possible to perform it with the arm adducted.



Fig 2. Spread of anesthetic solution (with contrast medium)



Fig 3. This approach is ideal for catheterization, especially when a long period of analgesia is required, as for rehabilitation of posttraumatic ankylosis of the elbow in children.

Another important advantage of the infraclavicular approach is the large analgesia extent, comprehending also the area supplied by the musculocutaneous and axillary nerves, so the patient can better tolerate the placement of a tourniquet at the proximal extremity of the arm. The performance of the block is easy and safe because the risk of pneumothorax is just theoretical and it can not provoke paralysis of the phrenic nerve.¹⁸

Moreover, patient comfort is optimal, even in the case of humeral fracture and in young people. Psychologically, patients tolerate this kind of approach better than the axillary or the interscalene. Furthermore the risk of infection is very low.

In obese patients, because of the difficulty to identify the landmarks, localization of the correct site of injection may be more difficult.

Complications and Limitations

Our modified technique appears safe and rarely complicated. Nevertheless, an anesthetist experienced in regional anesthesia technique is necessary. If the site of puncture and the direction of the needle are correct the worst complication, pneumothorax, will be avoided. Moreover, there is no involvement of the phrenic nerve, thus no danger of respiratory function impairment. Vascular puncture (Fig 4) and, eventually, hematoma

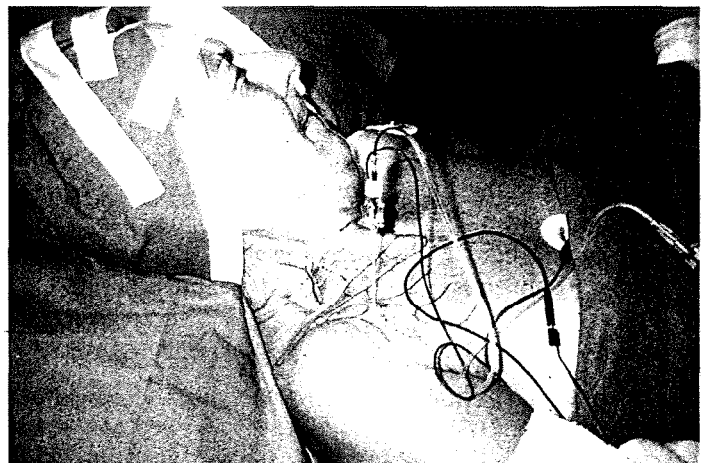


Fig 4. Vascular puncture is a possible complication of the infraclavicular approach due to the large size of vessels.

compared with other techniques (interscalene or axillary approach). As with other approaches, intravascular injection is possible and so it is very important to perform an aspiration test before injecting. The use of ENS may prevent neural damage after traumatic injuries determined by the needle or intraneural injection.

Limitations are the same as with the other approaches: uncooperative patient, coagulopathies, preexisting neural pathologies, previous adverse reaction to a local anesthetic, local or systemic infection, and uncorrected metabolic derangements.

Conclusions

The infraclavicular approach to the brachial plexus is similar to other types of upper-extremity sheath blocks, such as the axillary, the supraclavicular and the interscalene, in which an amount of local anesthetic agent sufficient to fill the fascial sheath is injected to bathe all the nerves contained. Blocking the plexus through the infraclavicular approach has advantages when compared with other approaches.¹⁹⁻²¹ The tip of the needle is pointed away from the lung, avoiding the complications of supraclavicular (pneumothorax) and interscalene brachial plexus block (injection into the carotid or vertebral arteries, the jugular vein, into subarachnoid or epidural space, 4th cranial nerve, vagus or stellate ganglion). The injection appears to be less distressing for the patient than the supraclavicular approach. This approach offers all the advantages of the supraclavicular approach. However, the level of the block is lower than that obtained from a supraclavicular block, but the level of anesthesia is higher than that obtained from the axillary block. It provides a complete, effective, and safe anesthesia of the whole arm and permits surgery of the hand, forearm, elbow, and antecubital fossa. Moreover patients requiring prolonged analgesia or sympathectomy of the upper extremity for postoperative analgesia or complex regional pain syndromes may be especially eligible for infraclavicular catheter placement because this region is ideal for securing the catheter to the anterior chest wall.

The advantages of the infraclavicular block techniques (Raj's, Sims', Whiffler's, and Grossi's), that make these approaches a safe alternative to the axillary brachial plexus block are: aseptical field, ability to block the musculocutaneous nerve of the brachial plexus using a single injection, better comfort of the patient, possibility to apply a constrictive tourniquet without discomfort, ease of securing a continuous brachial plexus catheter to the chest wall, minimization of the pneumothorax risk, and no impairment of respiratory function.

The Grossi technique differs from previous infraclavicular techniques in the arm position, which is adducted or abducted 0°/45°, the needle is introduced medially and inferiorly to the coracoid process, perpendicular to the line of anesthesia, and advanced posteriorly and slightly inferiorly and laterally at an angle of 0°/15° towards the axilla so that the needle is always outside of the thoracic cavity and there is no real danger of pneumothorax. Moreover the almost direct posterior insertion of the needle will make a perpendicular contact with the cords of the brachial plexus in which they surround the second part of the axillary artery. This avoids spread of the injected solution laterally to the neurovascular bundle, thus missing the musculocutaneous and axillary nerves, as it happens when an axillary

Our description of the vertical approach to infraclavicular brachial plexus block may provide advantages over the existing techniques (ie, Raj's approach): the ability to perform the block with the arm in a rest position, which allows for patient comfort. This makes it an effective and safe alternative when axillary block is impossible because of joint stiffness or ankylosis, local scars or infection, upper limb fractures, or axillary lymphadenectomy. Furthermore because of the presence of a consistent, palpable bony landmark is likely to be easily understood, taught, and performed.

On the other hand, with this approach the needle is advanced blindly with respect to the vessels and vascular puncture with possible hematoma formation. A possible disadvantage may be the inability to externally compress the source of hematoma. Proper technique and careful avoidance of the block in patients with coagulopathies would limit the occurrence of this problem.

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