Diaphragm Sparing Blocks for Postoperative Analgesia in Shoulder Surgeries

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Abstract:

The majority of the shoulder is thought to be supplied by the axillary nerve and the suprascapular nerves, with minor contributions From subscapular and lateral pectoral nerves .It is well known from anatomical studies that the innervation to the shoulder joint usually travels through various intermuscular planes before reaching the shoulder, and these intermuscular planes are easily identified by musculoskeletal ultrasonography.

The gold standard for shoulder analgesia is the interscalene block (ISB), but it has its own share of disadvantages such as phrenic nerve block, recurrent laryngeal nerve involvement and Horner's syndrome may lead to patient discomfort.Others, such as intrathecal spread and systemic toxicity of local anesthetic, can have serious consequences.

Phrenic nerve injury is a common complication with regional anesthesia. Its often temporary with Transient Phrenic Nerve Palsy leading to hemidiaphragmatic paresis after interscalene block or other injections of local anesthetic in the neck.

Although studies of ISB have shown a reduction in the incidence in hemidiaphragmatic paralysis with low-volume ISB, the risk of phrenic paralysis is not completely eliminated.

To bypass this complication, distal block of the shoulder innervation is recommended.

Keywords: Diaphragm Sparing blocks, postoperative analgesia, shoulder surgeries

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Introduction:

The shoulder is one of the largest and most complex joints in the body. The shoulder joint is formed where the humerus (upper arm bone) fits into the scapula (shoulder blade), like a ball and socket. Other important bones in the shoulder include:

-The acromion is a bony projection off the scapula.

-The clavicle (collarbone) meets the acromion in the acromioclavicular joint.

-The coracoid process is a hook-like bony projection from the scapula.

Nerve supply of the shoulder:

1. Axillary nerve:

The axillary nerve originates from the brachial plexus (upper trunk, posterior division, and posterior cord) at the level of the axilla and carries nerve fibers from C5 and C6.The axillary nerve travels through the quadrangular space with the posterior circumflex humeral artery and vein to innervate the deltoid and teres minor. The nerve lies at first behind the axillary artery and in front of the subscapularis and passes downward to the lower border of that muscle(1).

The axillary nerve then winds from anterior to posterior around the neck of the humerus, in company with the posterior humeral circumflex artery through the quadrangular space (bounded above by the teres minor, below by the teres major, medially by the long head of the triceps brachii, and laterally by the surgical neck of the humerus) and divides into an anterior, a posterior, and a collateral branch to the long head of the triceps brachii branch(2).

The anterior branch (upper branch) winds around the surgical neck of the humerus beneath the deltoid muscle, with the posterior humeral circumflex vessels. It continues as far as the anterior border of the deltoid to provide motor innervation. The anterior branch also gives off a few small cutaneous branches, which pierce the muscle and supply in the overlaying skin(3).

The posterior branch (lower branch) supplies the teres minor and the posterior part of the deltoid. The posterior branch pierces the deep fascia and continues as the superior (or upper) lateral cutaneous nerve of arm, which sweeps around the posterior border of the deltoid and supplies the skin over the lower two-thirds of the posterior part of this muscle, as well as that covering the long head of the triceps brachii. The motor branch of the long head of the triceps brachii arises, on average, a distance of 6 mm from the terminal division of the posterior cord termination (4).

The trunk of the axillary nerve gives off an articular filament which enters the shoulder joint below the subscapularis. The axillary nerve supplies three muscles in the arm: deltoid (a muscle of the shoulder), triceps (long head) and teres minor (one of the rotator cuff muscles). The axillary nerve also carries sensory information from the shoulder joint. It also innervates the skin covering the inferior region of the deltoid muscle, known as the regimental badge area. This is innervated by the superior lateral cutaneous nerve branch of the axillary nerve **(Fig. 1).**

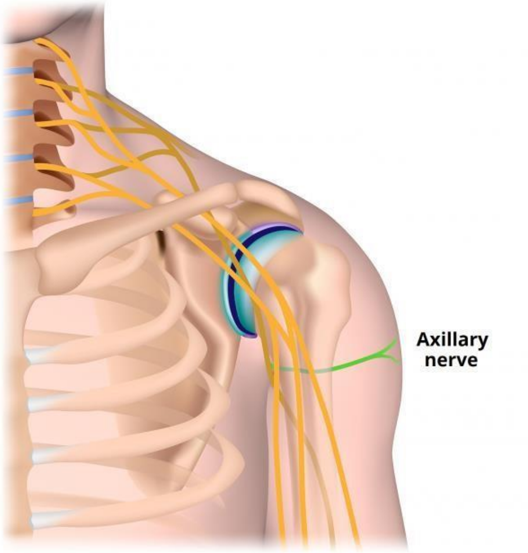

Fig. (1): Course of axillary nerve(5) (Gurushantappa et al., 2015).

2. Suprascapular nerve:

The suprascapular nerve is a nerve that branches from the upper trunk of the brachial plexus. It is responsible for the innervation of two of the muscles that originate from the scapula, namely the supraspinatus and infraspinatus muscles. The suprascapular nerve arises from the upper trunk of the brachial plexus which is formed by the union of the ventral rami of the fifth and sixth cervical nerves. After branching from the upper trunk, the nerve passes across the posterior triangle of the neck parallel to the inferior belly of the omohyoid muscle and deep to the trapezius muscle (Fig. 2). It then runs along the superior border of the scapula through the suprascapular canal in which it enters via the suprascapular notch inferior to the superior transverse scapular ligament and enters the supraspinous fossa. It then passes beneath the supraspinatus, and curves around the lateral border of the spine of the scapula through spinogleniod notch to the infraspinous fossa(6).

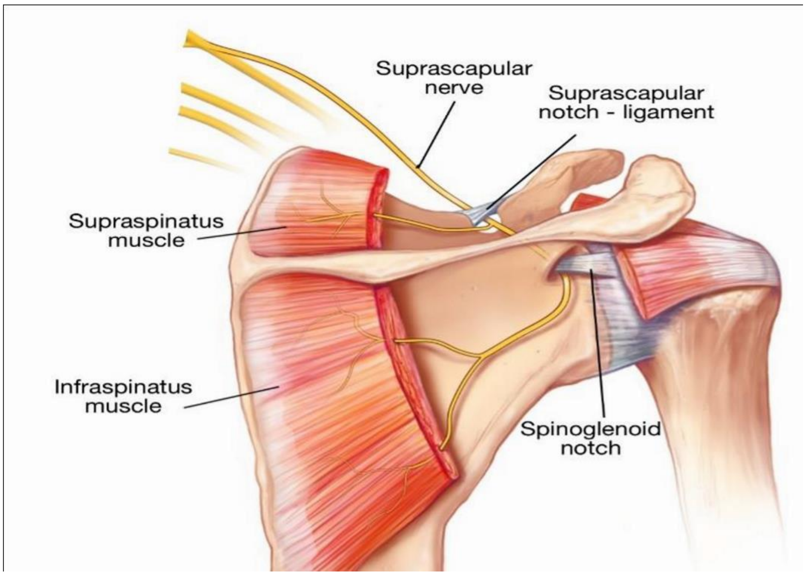

Fig. (2): Course of suprascapular nerve (6).

3. Subscapular nerve:

The subscapular nerves are innervated by the posterior division of the brachial plexus. These nerves are part of a group of nerves that innervate the muscles that move the scapula. The upper subscapular nerve inserts directly into the upper portion of the subscapularis muscle, thus innervating it. The lower subscapular nerve contains two branches. One branch inserts into the lower portion of the subscapularis muscle and the other branch inserts into the teres major. The middle subscapular nerve, known as the thoracodorsal nerve also branches from the posterior division of the brachial plexus **(Fig. 3)**. This nerve innervates the latissimus dorsi muscle (7).

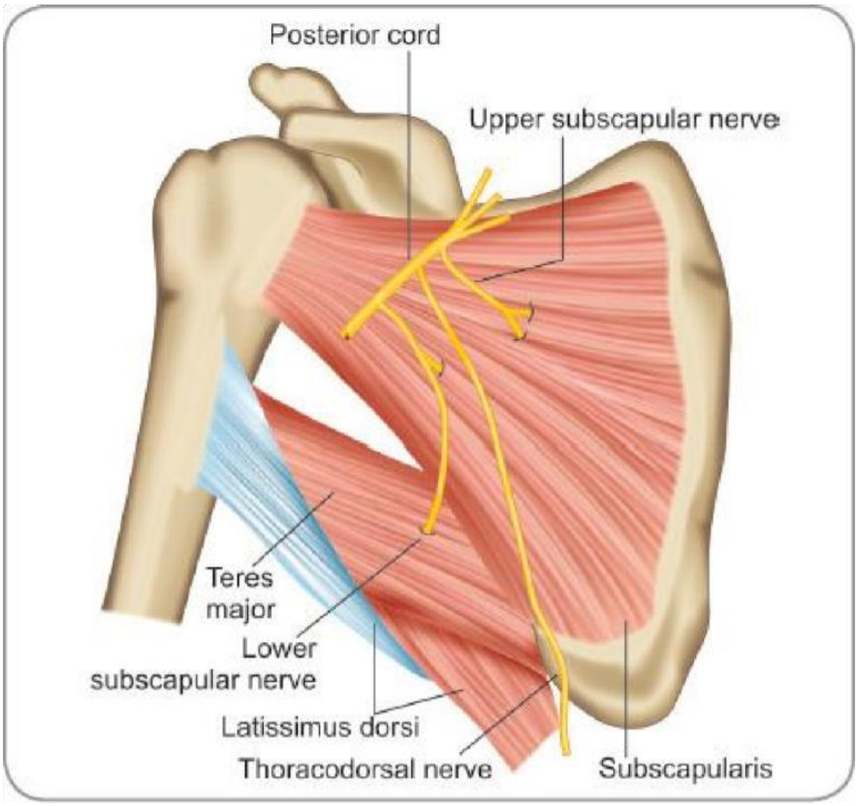

Fig. (3): Course of subscapular nerve(7).

4. Musculocutaneous Nerve:

The sensory component arises from the musculocutaneous motor nerve, which comes off the lateral cord of the brachial plexus and receives a contribution from the C5 to C7 ventral rami. The musculocutaneous nerve passes from the lateral aspect of the shoulder into the front of the axilla and pierces the coracobrachialis muscle, innervating muscles of the anterior arm. It goes through the deep fascia and continues as the lateral antebrachial cutaneous nerve providing sensation to the lateral forearm from wrist to elbow(7).

6. Lateral pectoral nerve:

The lateral pectoral nerve (also known as the lateral anterior thoracic nerve) arises from the lateral cord of the brachial plexus and through it from the C5-7. It passes across the axillary artery and vein, pierces the clavipectoral (coracoclavicular) fascia, and enters the deep surface of the pectoralis major to innervate it(8).

Blockade of the lateral pectoral nerve is helpful in cases such as shoulder dislocation and other orthopedic procedures, involving the shoulder. Spasms of the pectoralis major muscle and resulting severe pain (acute or chronic) may be reduced by pectoral nerve block or neuromuscular relaxation(9).

Phrenic nerve and its relation to brachial plexus:

Origin and course: The phrenic nerve is a deep branch of the cervical plexus arising mainly from the C4 spinal nerve, but also receives contributions from C3 and C5 spinal nerves.This fact can be remembered by the mnemonic: C3, 4, 5, keep the diaphragm alive.The phrenicnerve arises in the neck, at the upper lateral border of the scalenus anterior muscle, and descends along its anterior surface, deep to the prevertebral layer of the deep cervical fascia. The nerve runs posterior to the sternocleidomastoid muscle, the inferior belly of omohyoid muscle, the internal jugular vein, transverse cervical and suprascapular arteries(10).

From this point on, the pathway of the left and right phrenic nerves has several differences. However, on both sides, the nerves run behind the subclavian vein and anterior to the internal thoracic artery to enter the thoracic cavity through the superior thoracic aperture. In addition, both phrenic nerves are accompanied by the pericardiacophrenic vessels along their course in the thorax. Left phrenic nerve passes anteriorly over the first part of the left subclavian artery and deep to the thoracic duct. Right phrenic nerve descends anteriorly over the second part of the right subclavian artery and passes lateral to the right brachiocephalic vein and the superior vena cava. The phrenic nerve and the ventral ramus of C5 were separated by only 1.8 mm–2.0 mm at the cricoid cartilage level, and the distance between these 2 structures increased by an additional 3 mm for every centimeter of nerve length(11).

Surgical Considerations: The phrenic nerve originates at the C3 through C5 nerve roots, which exits the spinal canal at the neck root and descends caudally, parallel to the pericardial sac to provide the motor innervation to the diaphragm. The phrenic nerve must be identified in cervical and thoracic surgical dissection to preserve the neuromuscular pathways. Superior to the clavicle, the phrenic nerve can be located in the posterior triangle of the neck, superficial to the anterior scalene. In the mediastinum, the phrenic nerves can be identified with lateral retraction of the lungs to reveal the pericardial sac where the phrenic nerves pass anteriorly to the root of the lung. The phrenic nerves are located on the lateral aspects with accompanying pericardiophrenic arteries and superior phrenic veins(12).

•Phrenic nerve damage:

Since the phrenic nerve provides the sole motor innervation to the diaphragm, damage of the phrenic nerve can result in paralysis or palsy of the diaphragm. Causes of phrenic nerve damage can include the following: Mechanical trauma: such as phrenic nerve block during interscalene block. •

Bilateral damage of the phrenic nerve can be a life-threatening condition, as it results in the paralysis of the entire diaphragm. On the other hand, unilateral damage to either the left or right phrenic nerve, and the subsequent paralysis of one hemidiaphragm, can be an asymptomatic condition and an incidental finding on chest X-ray.A unilateral paralysis of one hemidiaphragm causes paradoxical movement of the diaphragm during respiration, where the affected side moves upwards during inspiration, and downwards during expiration(13).

Diaphragmatic anatomy and Motion:

Assessing the anatomy and function of the diaphragm can be an auxiliary or, in many conditions, an invaluable tool to diagnose, characterize, and monitor both acute and chronic respiratory diseases. Ultrasonography is particularly promising for this purpose, due to its availability, fast execution, repeatability, low costs, and safety; moreover, it can be easily deployed bedside, which is very helpful in the acute or critical care setting (14).

The diaphragm can be visualized by deploying high-frequency (10–15 MHz) probes between the seventh and the ninth intercostal space on the median anterior axillary line, transversal to the ribcage. Since the thickness of the diaphragm is variable over the surface of the muscle, a precise note regarding the position of the probe is essential to ensure the repeatability of this measure on the same patient, or to compare the values found in different patients. The diaphragm can be visualized as a three-layered band, which includes (from the outer to the inner layer) the hyperechogenic diaphragmatic pleura, the relatively hypoechogenic muscle, and the hyperechogenic peritoneal pleura(15).

Methods of diaphragmatic function assessment:

1- Diaphragmatic excursion:

Diaphragmatic excursion is the movement of the thoracic diaphragm during breathing. Normal diaphragmatic excursion should be 3–5 cm, but can be increased in well-conditioned persons to 7–8 cm. This measures the contraction of the diaphragm. It is performed by asking the patient to exhale and hold it. The doctor then percusses down their back in the intercostal margins (bone will be dull), starting below the scapula, until sounds change from resonant to dull (lungs are resonant, solid organs should be dull). That is where the provider marks the spot. Then the patient takes a deep breath in and holds it as the provider percusses down again, marking the spot where the sound changes from resonant to dull again. Then the provider will measure the distance between the two spots. Repeat on the other side, is usually higher up on the right side. If it is less than 3–5 cm the patient may have pneumonia or a pneumothorax in which a chest x-ray is diagnostic for either(16).

Diaphragmatic motion could be recorded using M-mode or two-dimensional mode (B-mode) ultrasonography. To assess the diaphragmatic motion by M-mode, they used a curved probe. B-mode is used to search for a better position of the probe to obtain a good visualization of the motion of each hemidiaphragm. B-mode is important for selecting the exploration line. Indeed, to measure the larger excursion of the hemidiaphragm, the line of the M-mode should be perpendicular to the posterior part of the hemidiaphragm. In most patients, a subcostal or a low intercostal probe position is appropriate. The excursion of both hemidiaphragms can be measured using M-mode US(17).

To record the diaphragmatic motion of the right hemidiaphragm, the liver is used as a window. The probe is placed between the mid-clavicular and the mean axillary lines, below the right costal margin, and directed medially, cephalad and dorsally, so that the ultrasound beam reaches the posterior part of the vault of the right hemidiaphragm perpendicularly. After correct visualization of the right hemidiaphragm by B-mode, M-mode is used to display the motion of the diaphragm along the selected line. The inspiratory and expiratory craniocaudal displacements of the diaphragm (seen as a bright line), lead to a shortening and a lengthening of the probe-diaphragm distance, respectively **(Fig. 4).** For the left hemidiaphragmatic motion recording, the spleen window is used to obtain a two-dimensional image of the diaphragm. The probe is placed subcostally or on the last coasts between the anterior and the posterior axillary lines, to obtain the best imaging of the left hemidiaphragm.

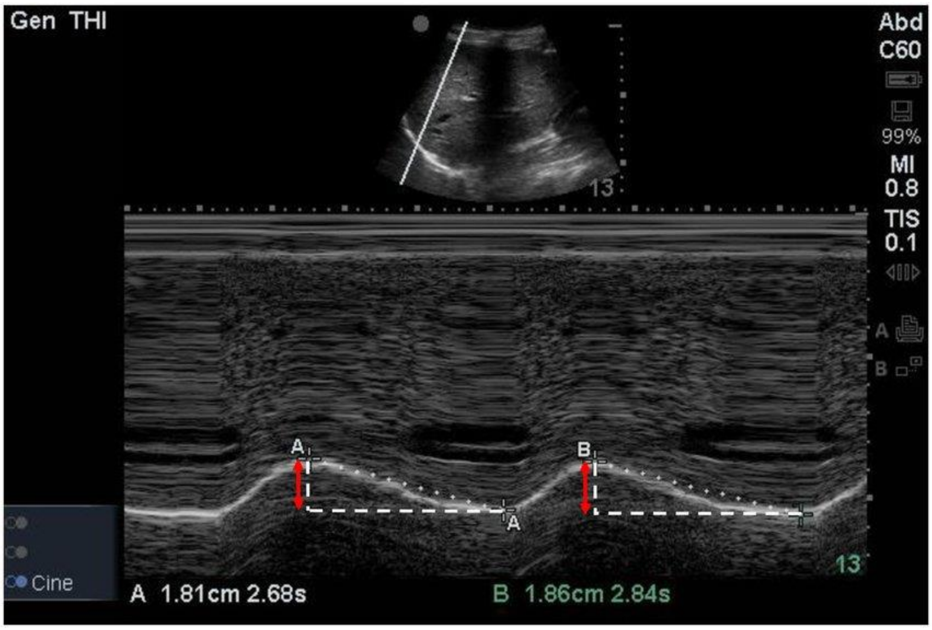

Fig. (4): M-mode sonography of diaphragmatic excursion. The amplitude of excursion (red arrow) was measured on the vertical axis of the tracing from the baseline to the point of maximum height of inspiration (18).

- Normal values:

During quiet breathing the excursions have been measured by most authors as between 10 mm and 25 mm on both sides(19).

Using M-mode US, sniffing leads to a sharp downstroke of the hemidiaphragm. Mean excursion is around 3 cm on both sides and lower limit values are calculated at 1.6 cm in women and 1.8 cm in men. The diaphragmatic motion induced by the sniff maneuver can also be studied by tissue Doppler imaging (TDI). Using a cardiac probe, the TDI process is activated and the sample volume is placed perpendicular to the diaphragmatic motion. It has been demonstrated that the TDI velocities were significantly related to sniff nasal pressure. In healthy volunteers, the median normal peak sniff TDI was estimated at 13 cm/s and 12 cm/s for the right and left hemidiaphragm, respectively(20).

Several previous studies have estimated the excursion of both hemidiaphragms during deep breathing. The maximal excursion of the right hemidiaphragm was estimated to be about 6-7 cm. Indeed, the mean excursion measured in volunteers of both sexes was 6 ± 0.7 cm(21).

2- The diaphragmatic thickness:

The distance between the inner margins of the diaphragmatic and peritoneal sheets is defined as the thickness of the diaphragm, the normal median (interquartile range) value of which is highly variable, with the majority of measurements ranging 3.3 (1.3– 7.6) mm **(Fig. 5).** Thickness is lower in female than in male patients, and is positively correlated to height and body weight, but independent of age(22).

Moreover, it should be noted that diaphragm thickness is increased in standing and sitting position compared with the recumbent position, and that it is greater at the lower intercostal spaces(23).

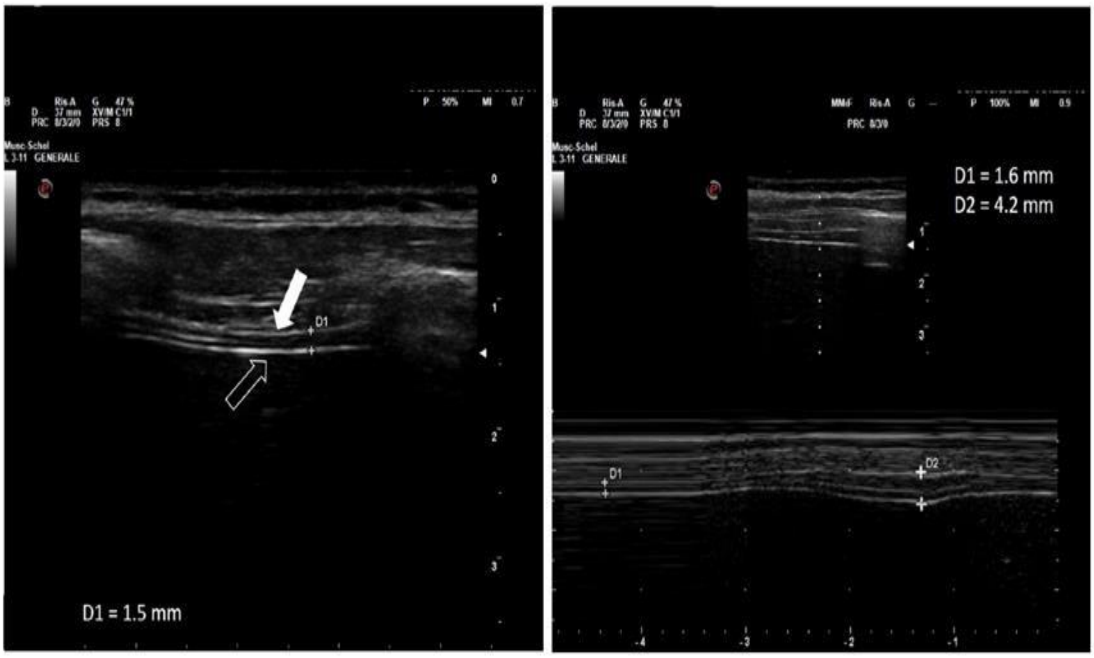

Fig. (5): Thickness of the right hemi-diaphragm at the zone of opposition (left panel) and diaphragm thickening during maximal inspiration (right panel) in a healthy woman in her thirties while semi-recumbent. Left panel: note the two hyperechoic lines (arrows) representing the peritoneum (empty arrow) and parietal pleura (filled arrow)(24).

The thickness of the diaphragm can be measured best at the zone of apposition. Zone of apposition is an area of the chest wall where abdominal contents and rib cage are in proximity. High resolution linear ultrasound probe is used to measure the diaphragmatic thickness (DT) using b- mode. The probe is positioned between the anterior axillary and mid axillary lines, perpendicular to the chest wall**(fig.6)** .

With B mode, the hemidiaphragm is identified beneath the intercostal muscles as a hypo-echogenic layer of muscle tissue located between two hyper-echogenic lines (the pleural line and the peritoneal line.The diaphragmatic thickness is the difference between thickness at the end of inspiration and the end of expiration. The diaphragmatic thickness fraction is measured as (thickness at end of inspiration – thickness at end of expiration) / thickness at end of expiration x 100 (25).

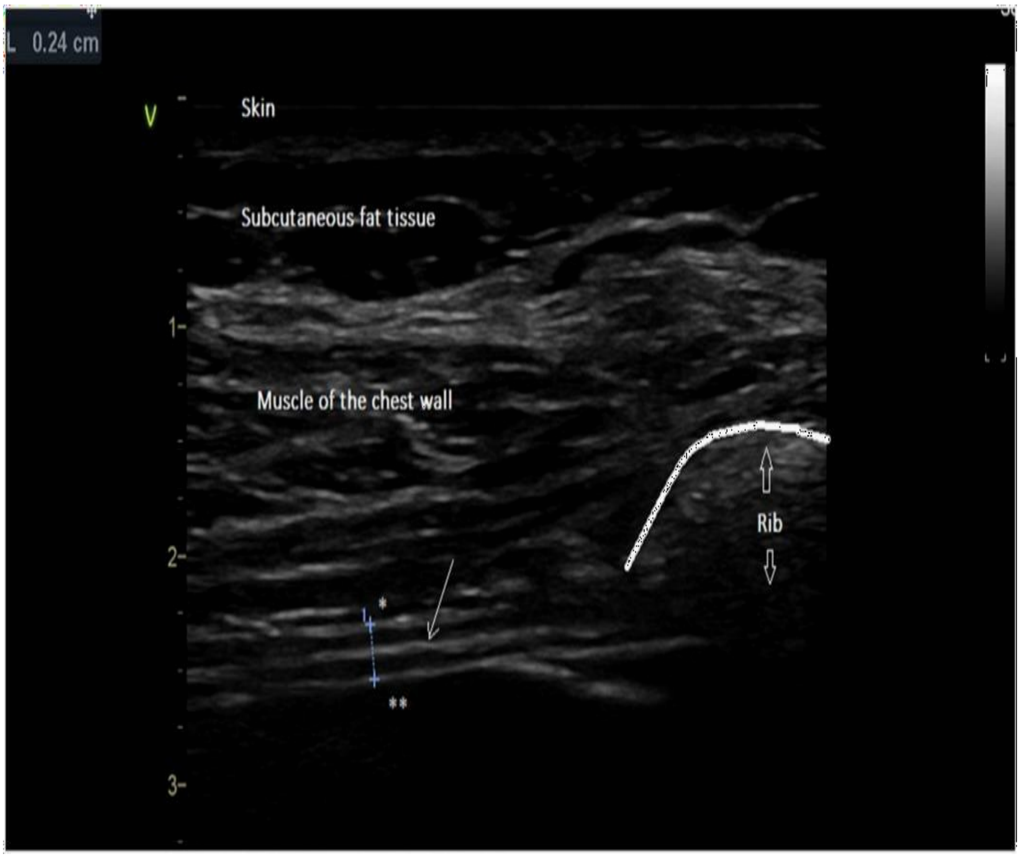

Fig. (6): Diaphragmatic thickness: Diaphragm thickness at end-expiration (L = 0.24 cm) was measured from the middle of the pleural line * to the middle of the peritoneal line **. Thin arrow= fibrous center line. Large arrow = acoustic shadow generated by rib(25).

- **Detection of phrenic nerve injury:**

Phrenic nerve injury is the main cause of unilateral diaphragm paralysis. A lesion of the phrenic nerve can be secondary to thoracic and cervical surgery or to medical invasive procedures such as atrial fibrillation ablation. Furthermore, nerve conduction can be impaired by an inflammatory process or cord compression(26).

To assess the contribution of phrenic neuropathy to diaphragmatic dysfunction, it had beenproposed combining diaphragm US with phrenic nerve conduction studies. The cervical stimulation of the phrenic nerve leads to a diaphragmatic movement of on average 2 cm on both sides in healthy subjects. The magnitude of displacement is correlated with the stimulus intensity. In patients with phrenic neuropathy, the hemidiaphragmatic displacement induced by stimulation is reduced when compared with the healthy side and with the range of normal values(27).

1. Different regional blocks for pain management after shoulder surgeries:

a- Interscalene brachial plexus blockade:

Different volumes of local anesthetics can be used. Recently it is recommended to start with low volumeof local anesthetics to decrease the incidence if phrenic nerve block. It can start from 5 ml up to 25 ml of local anesthetics (fig. 7)29).

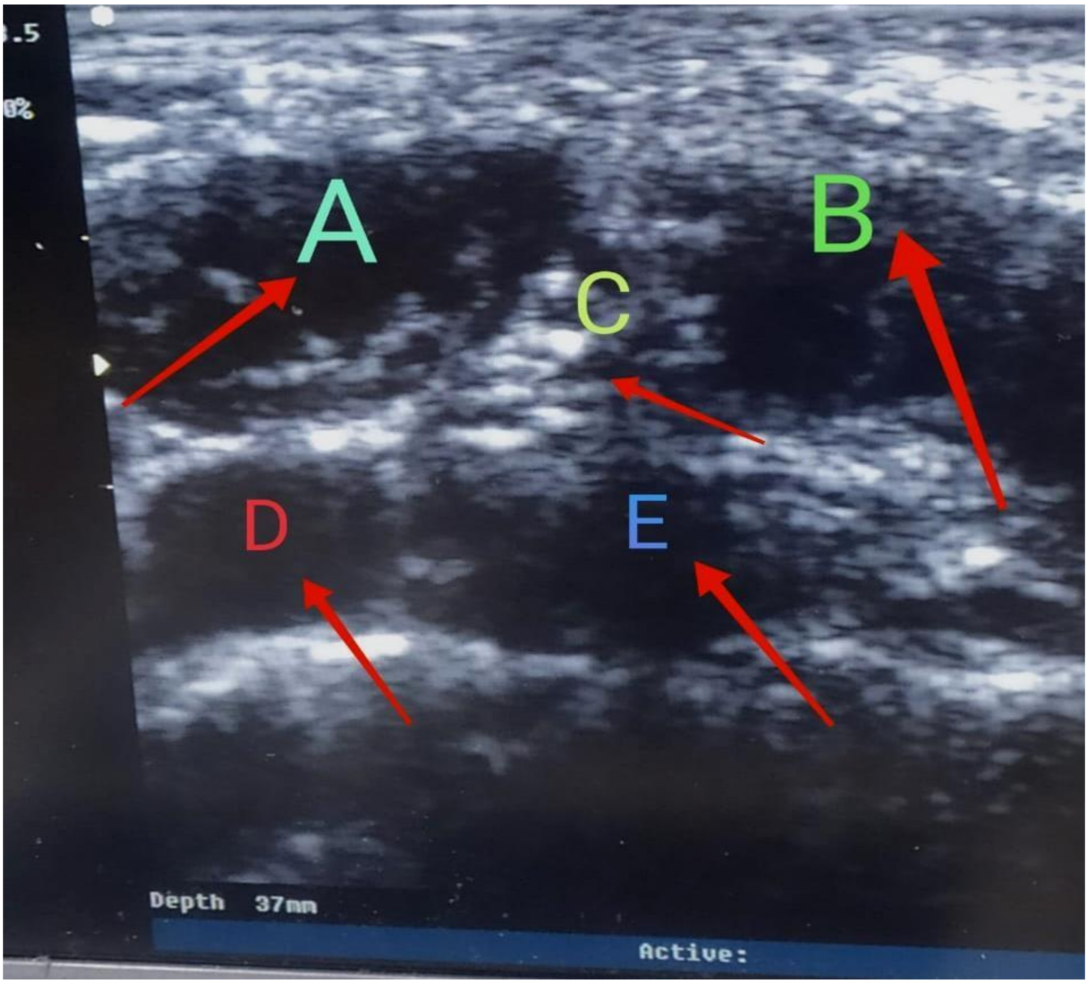

Fig. (7): Interscalene block. Photo showed A: scalenus ant. B: scalenus medius while C : roots of brachial plexus.D subclvian artery. E subclaivian vein(28).

Side Effects:

Side effects of interscalene block include:

A misguided needle placement can result in pneumothorax, nerve damage, epidural or intrathecal placement, and spinal cord trauma.

(30).

Contraindications:

This block is contraindicated in patients with respiratory insufficiency due to the high likelihood of ipsilateral phrenic nerve block and diaphragmatic hemiparesis. This can lead to a 25% reduction in pulmonary function. Additionally, the recurrent laryngeal nerve may be blocked, which could cause complete airway obstruction with anyone who has an existing vocal cord palsy(31).

Alternative blocks for postoperative shoulder pain management:

Although ISB is the most commonly used regional technique for pain management after shoulder surgery, a number of other approaches have been investigated in an attempt to avoid unwanted adverse effects such as phrenic nerve blockade.

1- Superior trunk block:

The C5 and C6 nerve roots may be tracked distally in the interscalene groove, where they fuse to form the superior trunk. This will effectively block the major nervous innervation to the shoulder joint. The suprascapular nerve originates from the superior trunk and moves laterally deep to omohyoid muscle. The block is therefore performed proximal to this point. As the course of the suprascapular and transverse cervical arteries is highly variable, these vessels should be sought and their position noted before needling. Using a posterior-lateral to anteriormedial in-plane approach and a hydrodissection technique, the superior trunk may be surrounded with 10-15 ml local anesthetic(32).

2- Interscalene block with small volume.

To preserve the respiratory function in these patients, it was suggested to use either a modified interscalene block or a distal BP block of either cords or branches. Low volume interscalene block (LVSB), using 5 mL, was reported to provide adequate shoulder analgesia and decrease the phrenic nerve injury incidence by 50% as compared with a standard block using 20 mL(29).

3- Distal brachial plexus block.

- Axillary nerve block.
- Suprascapular nerve block.

4- Phrenic Nerve Sparing Blocks

A. **Infraclavicular subomohyoid block**:

Technique:

The patient is lied in the supine position with his head tilted to the other site of the block. Betadine is inserted to the skin under complete aseptic conditions. The linear probe is placed in the infraclavicular region targeting to visualize the axillary artery and moving it to see cords of brachial plexus deep to pectoralis minor muscle.

The needle is introduced in the supraclavicular region laterally abd pass behind the clavicle and proceed till it reach cords of brachial plexus around axillary artery and local anesthetics is injected thus doing infraclavicular block.

Then the needle return subcutaneously and the needle is then redirected parallel to the clavicle to target inferior belly of subomohyoid muscle till complete visualization of the muscle and local anethetics are injected beneath the sheath of muscle targeting suprascapular nerve (**Fig. 8)(33).**

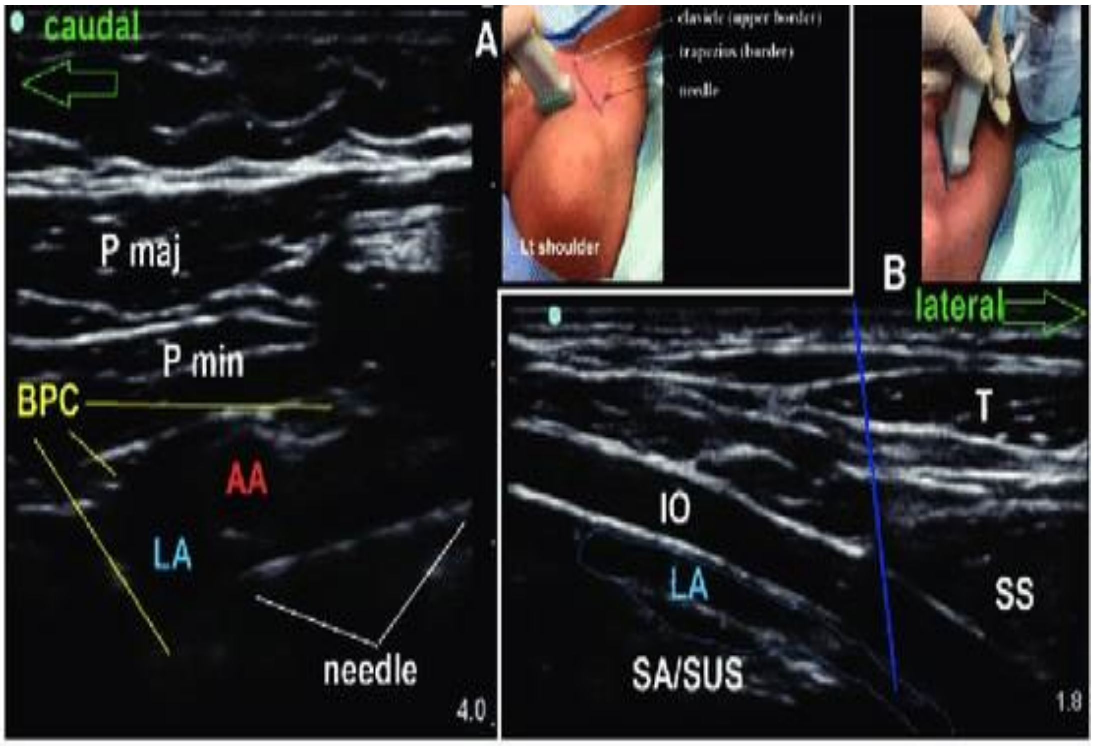

Fig. (8): Ultrasound-guided infraclavicular subomohyoid nerve block: a medial-tolateral probe movement is used to avoid the area where the needle advanced in the parasagittal plane could enter the pleura. On the left: Parasagittal lateral view: the serratus anterior is seen between the neurovascular bundle and the pleura. On right side appear subomohyoid muscle with needle tip beneah it(33).

- Complications:

Side effects and complications of the block include:

Infection, hematoma vascular injection and pneumothorax(34).

B-Subomohyoid Subscapularis block:

Technique:

Patient position: supine position with head tilted to the opposite side and arm is adducted and externally rotated.

The skin is sterilized with betadine with complete aseptic circumstances. The subscapularis block is done firstly. The probe is placed over the shoulder between the greater and lesser trochanters of the humerous. Then, the probe is moved and patient is asked to externally rotating his arm. Thus, the subscapularis muscle is obviously seen on ultrasound screen. Local anethetics is injected over subscapularis muscle anterior surface.

Then the subomohyoid block is done by the same method discussed before and local anethetics is injected beneath inferior belly of subomohyoid muscle to block suprascapular nerve **(Fig.9)(35).**

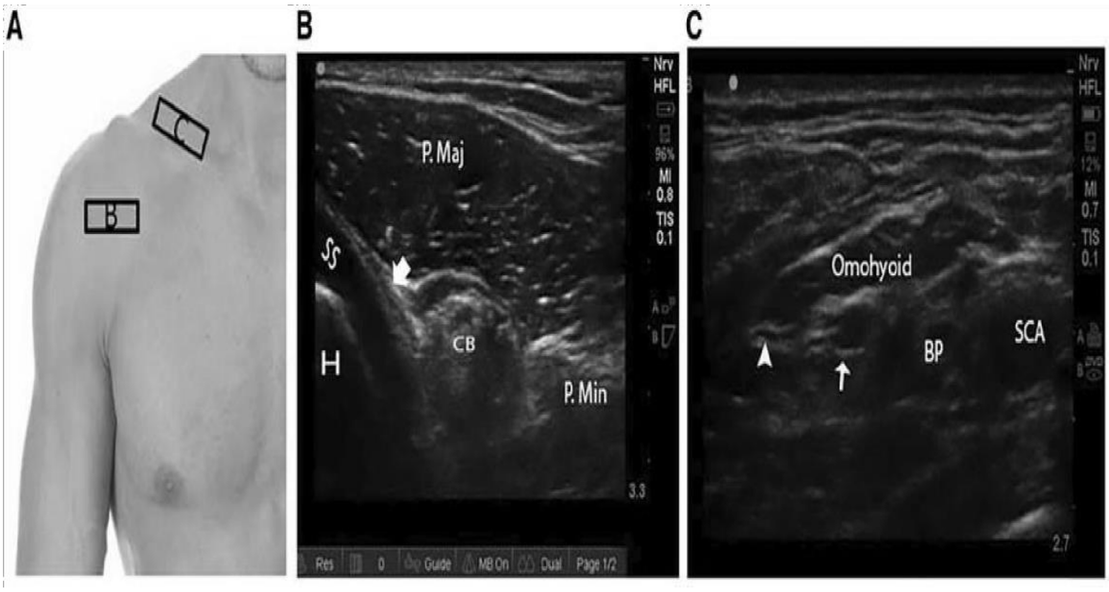

Fig. (9): (a) Probe position for subscapularis plane block (b) and sub-omohyoid block (c).

References:

1- **Jacob, S et al., (2008):** "Chapter 2 - Upper Limb", Human Anatomy, Churchill Livingstone: 5–49.

2- **Jones H, Royden, Darras, Basil T.; Jones, H. Royden et al., (2015):** "Chapter 14- Mononeuropathies", Neuromuscular Disorders of Infancy, Childhood, and Adolescence (Second Edition), San Diego: Academic Press: 243–73.

3- **Al-Redouan, Azzat; Holding, keiv; Kachlik and David (2020):** ""Suprascapular canal": Anatomical and topographical description and its Clinical implication in entrapment syndrome". Annals of Anatomy: 233: 151-593.

4- **Sager, Brian; Gates, Stephen; Collett, Garen et al., (2019):** "Innervation of the subscapularis: an anatomic study". JSES Open Access: 3 (2): 65–69.

5- **Gurushantappa PK and Kuppasad S. (2015):** Anatomy of axillary nerve and its clinical importance:acadaveric study. J Clin Diagn Res;9(3):13-17.

6- **Linsell L, Dawson J, Zondervan K et al., (2006):** Prevalence and incidence of adults consulting for shoulder conditions in UK primary care; patterns of diagnosis and referral. Rheumatology: 45: 215-21.

7- **Hewson D.W. and Oldman M. (2019):** Bedforth. Regional anesthesia for shoulder surgery. BJA Education: 19(4): 98-104.

8- **Baur, Dale A.; Horan, Michael P.; Rodriguez, Juan C et al., (2012):** "Chapter 68 - The Pectoralis Major Myocutaneous Flap", Current Therapy in Oral and Maxillofacial Surgery, Saint Louis: W.B. Saunders. pp. 566–72.

9- **Titiz, Izzet; Ozel; Ozel; Toros; Marur; Yildirim; Erdogdu; Kara (2010):** "Denervation Point for Neuromuscular Blockade on Lateral Pectoral Nerves: A Cadaver Study". Surgical and Radiologic Anatomy. 33 (2): 105–8.

10- **Bains KNS, Kashyap S, Lappin SL. et al., (2023):** StatPearls [Internet]. StatPearls Publishing; Treasure Island (FL): Jul 24. Anatomy, Thorax, Diaphragm.

11- **Mahabadi N, Goizueta AA and Bordoni B. (2022):** StatPearls [Internet]. StatPearls Publishing; Treasure Island (FL): Anatomy, Thorax, Lung Pleura And Mediastinum.

12- **Graves MJ, Henry BM, Hsieh WC et al., (2017):** Origin and prevalence of the accessory phrenic nerve: A meta-analysis and clinical appraisal. Clin Anat. 30 (8): 1077-1082.

13- **Morgan JA, Morales DL, John R et al., (2003):** Endoscopic, robotically assisted implantation of phrenic pacemakers. J Thorac Cardiovasc Surg.; 126(2):582-3.

14- **Laghi F.A., Saad M. and Shaikh, H. (2021):** Ultrasound and NonUltrasound Imaging Techniques in the Assessment of Diaphragmatic Dysfunction. BMC Pulm. Med. 21: 85.

15- **Haaksma M.E.; Smit J.M.; Boussuges A et al., (2022):** Expert Consensus on Diaphragm Ultrasonography in the Critically Ill (Exodus): A Delphi Consensus Statement on the Measurement of Diaphragm Ultrasound-Derived Parameters in a Critical Care Setting. Crit. Care. 26: 99.

16- **Kantarci F, Mihmanli I, Demirel MK et al., (2004):** Normal diaphragmatic motion and the effects of body composition: determination with M-mode sonography. J Ultrasound Med: 23: 255-60.

17- **Ayoub J, Cohendy R, Dauzat M et al., (1994):** Non-invasive quantification of diaphragm kinetics using m-mode sonography. Can J Anaesth: 44: 739-44.

18- **Kim K, Jang D M , Park J Y et al., (2018):** Changes of diaphragmatic excursion and lung compliance during major laparoscopic pelvic surgery: A prospective observational study. PLoS ONE.13(11): 0207841.

19- **Cardenas LZ, Santana PV, Caruso P et al., (2018):** Diaphragmatic Ultrasound Correlates with Inspiratory Muscle Strength and Pulmonary Function in Healthy Subjects. Ultrasound Med Biol.44: 786-93.

20- **Fayssoil A, Nguyen LS, Ogna A et al., (2019):** Diaphragm sniff ultrasound: Normal values, relationship with sniff nasal pressure and accuracy for predicting respiratory involvement in patients with neuromuscular disorders. PLoS One: 14: 214-88.

21- **Scheibe N, Sosnowski N, Pinkhasik A, Vonderbank S and Bastian A. (2015):**Sonographic evaluation of diaphragmatic dysfunction in COPD patients. Int J Chron Obstruct Pulmon Dis:10:1925–30.

22- **Hale J.; Dowlen H.; Cartwright, M. and Sarwal A. (2013):** Neuromuscular Ultrasound for Evaluation of the Normal and Abnormal Diaphragm. AAN Enterprises: Faridabad, India:05:84.

23- **Boon AJ, Harper CJ, Ghahfarokhi LS et al., (2013):** Two-dimensional ultrasound imaging of the diaphragm: quantitative values in normal subjects. Muscle Nerve:47: 884-9.

24- **Saad, M.; Pini, S.; Danzo, F et al., (2023):** Ultrasonographic Assessment of Diaphragmatic Function and Its Clinical Application in the Management of Patients with Acute Respiratory Failure. Diagnostics: 13:411.

25- **Renes SH, Rettig HC, Gielen MJ et al., (2009):** Ultrasound-guided lowdose interscalene brachial plexus block reduces the incidence of hemidiaphragmatic paresis. Reg Anesth Pain Med; 34:498–502.

26- **Boussuges A, Chaumet G and Poirette L. (2015):** Interest of ultrasonographic assessment of diaphragmatic function in cardiac rehabilitation center: a case report. Medicine (Baltimore): 94: 801.

27- **Johnson NE, Utz M, Patrick E et al., (2014):** Visualization of the diaphragm muscle with ultrasound improves diagnostic accuracy of phrenic nerve conduction studies. Muscle Nerve: 49: 669-75.

28- **Burckett ST, Laurent D, Chan V and Chin KJ (2014):** Refining the ultrasound-guided interscalene brachial plexus block: the superior trunk approach. Can J Anaesth; 61:1098–102.

29- **Haas E, Onel E, Miller H et al., (2012):** A double-blind, randomized, active-controlled study for post-hemorrhoidectomy pain management with liposome bupivacaine, a novel local analgesic formulation. Am Surg; 78: 574-81.

30- **Eroglu A (2006):** A comparison of patient-controlled subacromial and i.v. analgesia after open acromioplasty surgery. Br J Anesth: 96: 497–501.

31- **Pyati S and Gan TJ. (2007):** Perioperative pain management. CNS Drugs; 21: 185-211.

32- **Ireland KC and Lalkhen AG (2019):** Postoperative analgesia. Anesth Intensive Care Med [Internet]; 20(2):98–104.

33- **Taha AM, Yurdi NA, Elahl M and Abd-Elmaksoud AM. (2017):** ISO (Infraclavicular-Sub Omohyoid) block: a single-puncture technique for diaphragm- and opioid-sparing shoulder anaesthesia .Br J Anaesth; 119:170-71.

34- **Mahajan A and Derian A et al., (2021):** Local Anesthetic Toxicity. StatPearls [Internet].:2:23-31.

35- **Sondekoppam, R. V. Lopera-Velasquez, L-M. Naik L. et al., (2016):** Subscapularis and sub-omohyoid plane blocks: an alternative to peripheral nerve blocks for shoulder analgesia.BJA: British Journal of Anaesthesia,(6):117: 831–2.