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Effect of Erector spinae plane block in rib fracture

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Abstract: Background: Trauma is a major cause of morbidity and mortality worldwide, and the leading cause of death in the first four decades of life. Rib fractures (RFs)are very common and are detected in at least 10% of all injured patients, the majority of which are as a consequence of blunt thoracic trauma (75%) with road traffic collisions being the main cause. The remaining 25% are due to penetrating injuries. RFs are associated with significant morbidity with increase admission to the ICU and mortality rates as high as 33%. The first published use of US in peripheral nerve block occurred in 1978 when doppler sonography assisted blood flow detection during supraclavicular brachial plexus block. Although the initial technology did not allow for direct nerve visualization this was later corrected in 1994 when advancements in technology allowed the first documented use of US to facilitate visualization of supraclavicular brachial plexus block. Since this time, US use for regional anesthesia has shown increasing popularity, and the utility of US for variety of peripheral nerve blocks continue to emerge. A relatively new procedure, the Erector spinae block (ESPB), first described in 2016 by Forero et al is a technically easy US analgesic procedure that has seen much success in providing pain relief for patients presenting with MRF. In the ESPB, a needle is placed between the transverse process and the erector spinae muscle, and local anesthetic is injected between them, along the fascia of the erector spinae

Keywords: *Ultrasound Guidance, Erector spinae plane block*

Introduction

Trauma is a major cause of morbidity and mortality worldwide, and the leading cause of death in the first four decades of life. Rib fractures (RFs) are very common and are detected in at least 10% of all injured patients, the majority of which are as a consequence of blunt thoracic trauma (75%) with road traffic collisions being the main cause. The remaining 25% are due to penetrating injuries. RFs are associated with significant morbidity with increase admission to the intensive care unit (ICU) and mortality rates as high as 33%[1].

Anatomical consideration

There are 12 ribs to the thorax on each side divided into true ribs and false ribs. The first 7 ribs are “true” ribs, as they form a complete loop between the sternum and vertebrae. The lower 5 ribs are called “false” ribs because the bony components do not reach the sternum anteriorly and are attached to the sternum by cartilage which fuses together and then attaches to the sternum, except for ribs 11 and 12 which do not connect to the sternum and are called “floating ribs”. Nondisplaced rib fractures have over 90% overlap of cortical surfaces.1 Offset rib fractures have some overlap (but < 90%) and displaced rib fractures have no overlap. A flail segment is defined as fractures of 3 or more ribs in 2 or more places. “Flail chest” is a clinical observation of paradoxical movement of the chest with inspiration[2].

The most common ribs to fracture are ribs 4-10. The first three ribs are relatively protected by the clavicle and shoulder girdle, so a significant amount of force is required to fracture these ribs. The lower floating ribs 11 and 12 are more mobile and less likely to fracture. Traumatic fractures tend to occur at the site of impact or at the weakest point, usually the postero lateral curve[3].

Pathophysiology

The morbidity and the mortality associated with RFs are caused by three main problems[4]:

1-Hypoventilation

Hypoventilation due to pain associated with rib movement reduces the tidal volume and predisposes to significant atelectasis. This can further lead to retention of pulmonary secretions and pneumonia.

2- Impaired gas exchange

In damaged lung underlying the fractures, and altered breathing mechanics. An injury severe enough to fracture ribs, especially if so significant as to cause a flail segment, will invariably cause a substantial contusion to the underlying lung. The lung becomes edematous with varying degrees of hemorrhage and necrosis. The damaged lung is poorly compliant and will not take part in gas exchange, leading to intrapulmonary shunting and a decrease in PaO_2.

3-Altered breathing mechanics

In the presence of a flail segment, the generation of negative intrapleural pressure produces paradoxical movement of the flail, causing it to move inward, while the rest of the rib cage moves outward. This means that the underlying lung does not expand and as a result, the tidal volume decreases; this has been demonstrated clinically, although an increase in the respiratory rate means that $PaCO_2$ remains normal. This inefficient breathing results in higher oxygen consumption and has been shown to reduce PaO_2.

Innervation of chest wall

Branches of the intercostal nerves innervate the chest wall and parietal pleura. The anterolateral chest wall is innervated by the anterior cutaneous and lateral cutaneous branches of the T2–T6 nerves, pectoral nerves, and long thoracic and supraclavicular nerves. The intercostal nerves emerge from the intervertebral foramen and enter the paravertebral space (PVS). The spinal nerve roots divide into the ventral and dorsal branches. The anterior branches form the intercostal nerves which enter the intercostal space in between the posterior intercostal membrane and the parietal pleura. They give off lateral and anterior cutaneous branches. The serratus posterior and superior are supplied by the muscular branches. The intercostal muscles, the parietal pleura, and the periosteum of ribs are innervated by the collateral branches. Posterior chest wall is innervated by the dorsal rami branches and posterior divisions of lateral cutaneous branches[5].

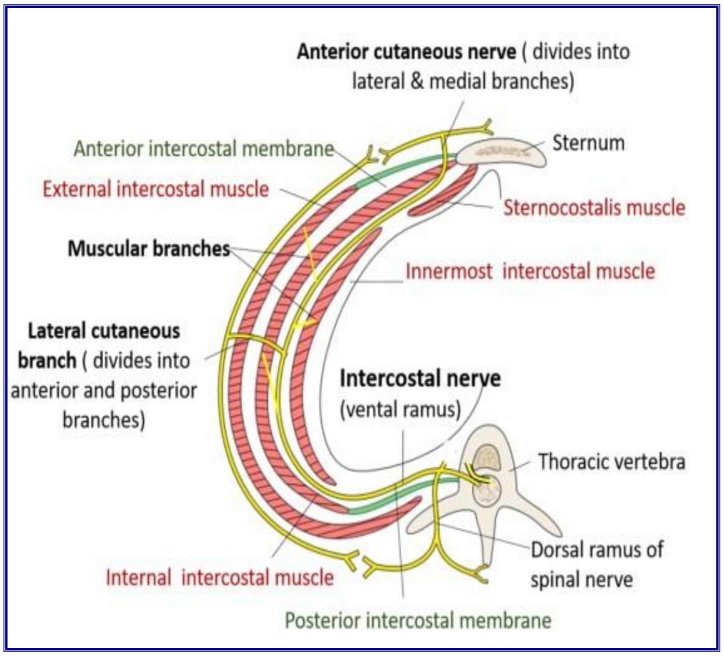

Fig. (1): Intercostal nerve (anterior and lateral cutaneous branches) supply chest wall[6].

Apart from the intercostal nerves, nerves from the brachial plexus also supply sensory and motor function to the skin and muscles of the chest wall. The supraclavicular nerves (cervical plexus) supply the upper chest wall and account for referred pain from the diaphragm in the upper chest and shoulder area. The thoracodorsal nerve (C7, C8 origin) supplies the latissimus dorsi muscle. The lateral and the medial pectoral nerves arise from the lateral (C5–C7) and medial (C8, T1) cords of the brachial plexus and innervate the pectoralis major and pectoralis minor and major muscles, respectively. The long thoracic nerve (C5, C7) runs a relatively long, superficial course in the mid axillary line and supplies the serratus anterior muscle[7].

For procedures involving anterolateral or posterior chest wall, it is, therefore, necessary to block either the pertinent intercostal nerves at their origin or block their lateral/anterior cutaneous branches as they pierce their way into the subcutaneous tissue at around the anterior axillary line or sternal border[8].

It is imperative that effective analgesia is started promptly, preferably in the emergency department upon admission, not just for analgesia and patient comfort, but also to try and prevent the complications that ensue over the subsequent days. Opioid medication which historically had been the mainstay of pain management with rib fractures has been relegated to a very secondary role with the 2014 CDC declaration of prescription drug overdose to be in the top 5 health threats[9].

One successful strategy for decreasing opioid use employed at Texas Medical Center in Houston encompassed multimodal pain regimen (MMPR) to decrease overall opioid use in rib fractures. The MMPR consisted of regularly scheduled medications given around the clock without having the patient request them: acetaminophen (24 h of IV acetaminophen followed by oral acetaminophen), Non steroidal anti inflammatory drugs NSAIDs (48 h of celecoxib followed by naproxen) lidocaine patches and tramadol morphine milligram equivalents (MME) factor of 0.1. This MMPR was supplemented with opioids for breakthrough pain. This regimen resulted in significantly less opioid use per day of 31% MME[10].

The use of multimodal analgesia (MMA) is recommended for acute pain relief. MMA, also known as balanced analgesia, refers to the use of multiple medications as simple analgesic (like paracetamol and NSAIDS) or opioid for analgesia and non-pharmacologic interventions for effective and immediate pain relief[11].

Regional analgesia

Thoracic epidural

The use of epidurals has, historically, been the mainstay of the neuraxial anesthesia of pain control for RFs. By blocking spinal nerves as they emerge from the spinal cord within the epidural space, nociceptive inputs from intercostal nerves are prevented from transmitting central pain signals. Thoracic epidurals have been suggested to reduce mortality in trauma centers and have benefits on analgesia, postoperative pulmonary ventilation and duration of stay[12]

Epidural analgesia has many contraindications that vary depending on the facility and can limit epidural use in trauma patients. Common contraindications include coagulopathy, spinal evaluation, spinal cord injury or epidural hematomas, and associated injuries such as traumatic brain injury or hemodynamic instability. Complications that occur with epidurals include epidural hematomas, epidural abscess, postdural puncture headache and local anesthetic toxicity[13].

Paravertebral block

The PVB is a neuraxial analgesia procedure that involves the injection of a local anesthetic agent, commonly ropivacaine or bupivacaine, into the paravertebral space near where the spinal nerves exit the intervertebral foramina. The local anesthetic is administered in a single injection or continuous infusion through a catheter or pump. While the PVB is an older procedure, recent studies have been conducted to determine its efficacy, especially in patients presenting with MRF[14]

Interfascial plane blocks

1-Serratus anterior plane block (SAP)

The SAP block provides analgesia to the lateral branches of the intercostal nerves T2–T9 through the injection of local anesthetic either superficial or deep to serratus anterior muscle. Notably, SAP block will provide coverage to the anterior two-thirds of the hemothorax only, limiting its utility to rib fractures at these locations. Several case reports have demonstrated a reduction in opioid use and improvement in pain scores after the performance of SAP block in patients with MRFs[15].

2-Intercostal nerve block (ICNB)

An intercostal nerve block (ICNB) is an analgesic procedure that has been used to treat thoracic pain for many years. It involves the numbing of the intercostal nerves through the injection of local anesthetic just under the desired rib. For longer-term pain relief, an indwelling catheter can be placed to provide continuous analgesia[14]. Intercostal nerve block (ICNB) induces analgesia by blocking the ipsilateral sensory and motor fibers of the intercostal nerves. The injection site for ICNB can be anywhere proximal to the midaxillary line the land mark for the origin of the lateral cutaneous branch two dermatomes above and two below the analgesic target. The block is usually performed at the angle of the rib, which is superficial and easily located via palpation while the patient is in the prone, sitting, or lateral position. In the subcostal groove, the widest part of the angle of the rib, the intercostal nerve, is located inferior to the posterior intercostal artery, which is inferior to the intercostal vein[16].

3-Rhomboid intercostal and sub-serratus block

The region described is known as the triangle of auscultation that is bounded medially by inferior part of the trapezius, inferiorly by the superior border of latissimus dorsi, and laterally by the medial border of the scapula. In this ultrasound-guided block, the local anesthetic drug is administered between the rhomboid major and the intercostal muscle fascia at the level of T6–T7 and provides analgesia of T3–T8 dermatomes[17].

Modification to the rhomboid intercostal block was performed to expand dermatomal coverage. They describe the RISS (Rhomboid Intercostal and Sub-Serratus) block that is a two-injection block of both the rhomboid intercostal and sub-serratus space. After the first injection, the ultrasound probe advances caudally and laterally distal to the inferior angle of the scapula, the second injection apply between the serratus and intercostal muscle fascia[18]**.**

4-Erector spinea plane block

Erector spinae block provides analgesia to the anterior, lateral, and posterior hemithorax through the injection of local anesthetic deep to the erector spinae muscle[19]

Erector spinae plane block (ESPB)

A relatively new procedure, the ESPB, first described in 2016 by Forero et al is a technically easy US analgesic procedure that has seen much success in providing pain relief for patients presenting with MRF. In the ESPB, a needle is placed between the transverse process and the erector spinae muscle, and local anesthetic is injected between them, along the fascia of the erector spinae[19].

Local anesthetic can be administered as a single injection or continuously through a catheter. It should also be noted that a benefit to the ESPB is that it is safe for patients currently on anticoagulants or for whom full restoration of hemostasis is in progress, which is a risk factor in other neuraxial anesthetic procedures[19].

Anatomy and Physiology

<u>Erector Spinae Muscle</u>

The architecture of the erector spinae muscle is complex, with three muscle bellies distributing in the lumbar, thoracic, and cervical area and surrounded by fascia. The thoracolumbar fascia covers the deep muscles of the back and the trunk. Medially, it is attached to the spines of the thoracic vertebrae and laterally to the angles of the ribs[20].

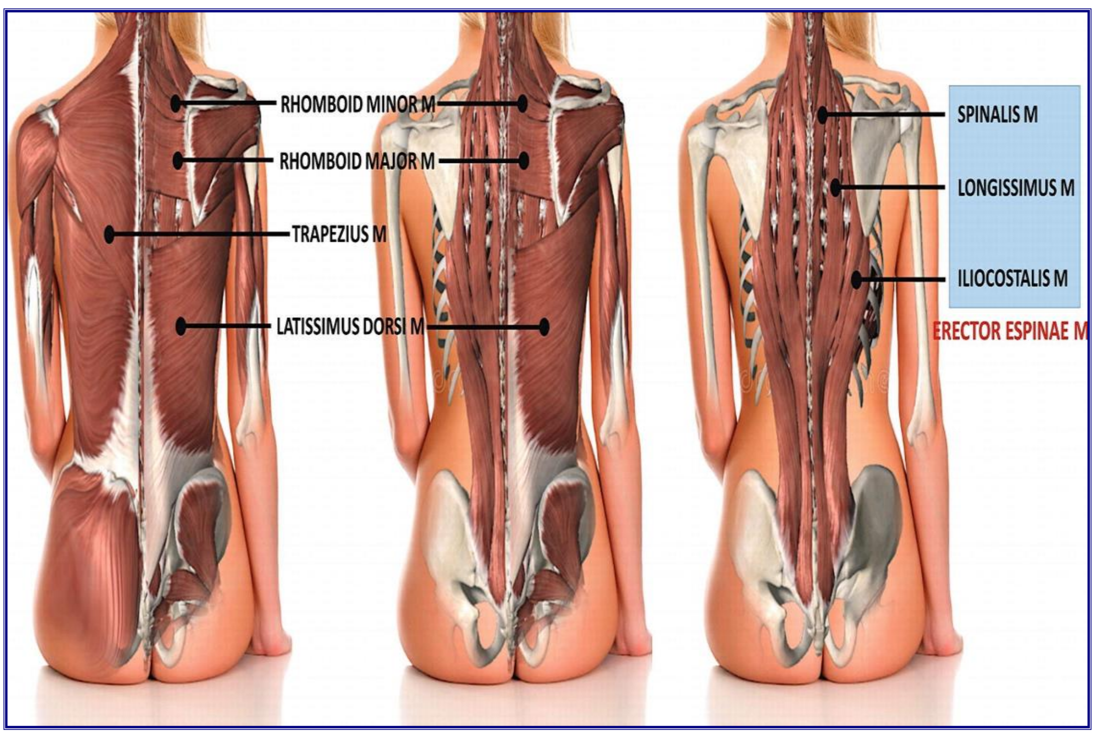

Fig. (7): Muscular anatomy of the back. Note the different muscle planes encountered at different spinal levels when the most superficial muscles are removed[20].

Three muscles are in the plane of the ESP block at upper thoracic levels. Trapezius is the most superficial (posterior), rhomboid major in the middle, and erector spinae anterior (deeper). They are identified superficial to the tip of the hyperechoic transverse processes. It originates from the sacrum and the lumbar spinous processes and extends upward as a gradually tapering column of muscle in the paravertebral groove on either side of the spinous processes, with insertions on the thoracic and cervical vertebrae as high as C2. This muscular column is encased in a retinaculum (blended aponeuroses and fasciae) that extends from the sacrum to the skull base. In the lower back, this retinaculum is referred to as the thoracolumbar fascia. This thoracolumbar fascia, extending from the posterior thorax and abdomen in continuity with the nuchal fascia, facilitates the spread of the injectate or multiple thoracic and lumbosacral levels during ESP blocks at lower thoracic levels[20].

Spread of local anaesthetic

The target of the ESP block is to place the local anesthetic between the deepest layer (most anterior) of the erector spinae muscle and the tip of the transverse process. This place allows cranial-caudal spread in multiple spinal segments. The injectate is placed in close relation to the inter transverse connective soft tissue, which allows the spread of the local anesthetic to the paravertebral or epidural space. ESP block is most often performed using an in-plane ultrasound-guided technique. It is a paraspinal fascial plane block in which the needle placement is between the erector spinae muscle and the thoracic transverse processes, and a local anesthetic is administered, blocking the dorsal and ventral rami of the thoracic and abdominal spinal nerves .This blockage of the dorsal and ventral rami of the spinal nerves helps to achieve a multi-dermatomal sensory block of the anterior, posterior, and lateral thoracic and abdominal walls[19].

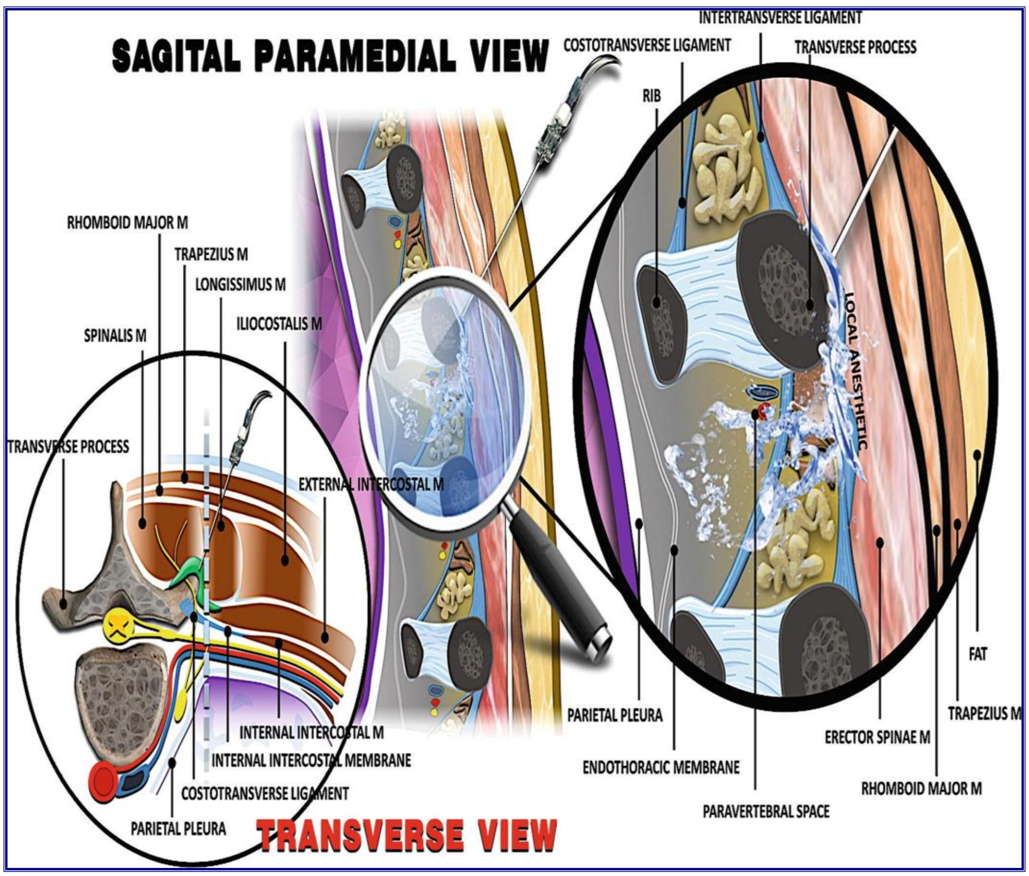

Fig. (9): Possible mechanism of in vivo erector spinae plane block, facilitating the spread of the injectate with muscle contraction and negative intrathoracic pressure during inspiration[20].

Technique of erector spinae block

For patients in the sitting position, ESPB is performed at the level where the desired vertebral level corresponded to the middle of the extent of the broken ribs. The linear high frequency US probe is used to localize the tip of the transverse process of the desired vertebra. The probe is placed longitudinally, 2–3 cm lateral from the midline. The sonographic anatomy is visualized above the transverse process shadow. The needle created a puncture in the cranial-caudal direction with an in-plane technique. For correction of the injection site, a 2-mL volume of normal saline is injected into the interfascial area below the erector spinae muscle with real-time visualization. After the injectate spreads deeply throughout the interfascial area, a 20-mL volume of 0.25% bupivacaine is administered for ESPB[21].

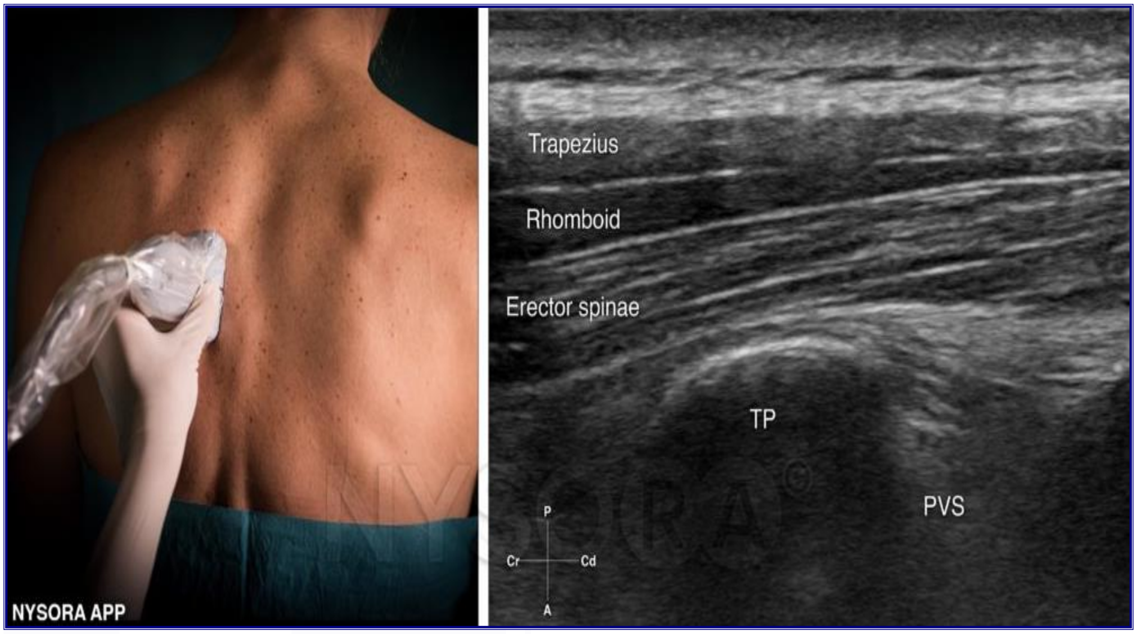

Fig. (10): Administration of US guided ESPB[22].

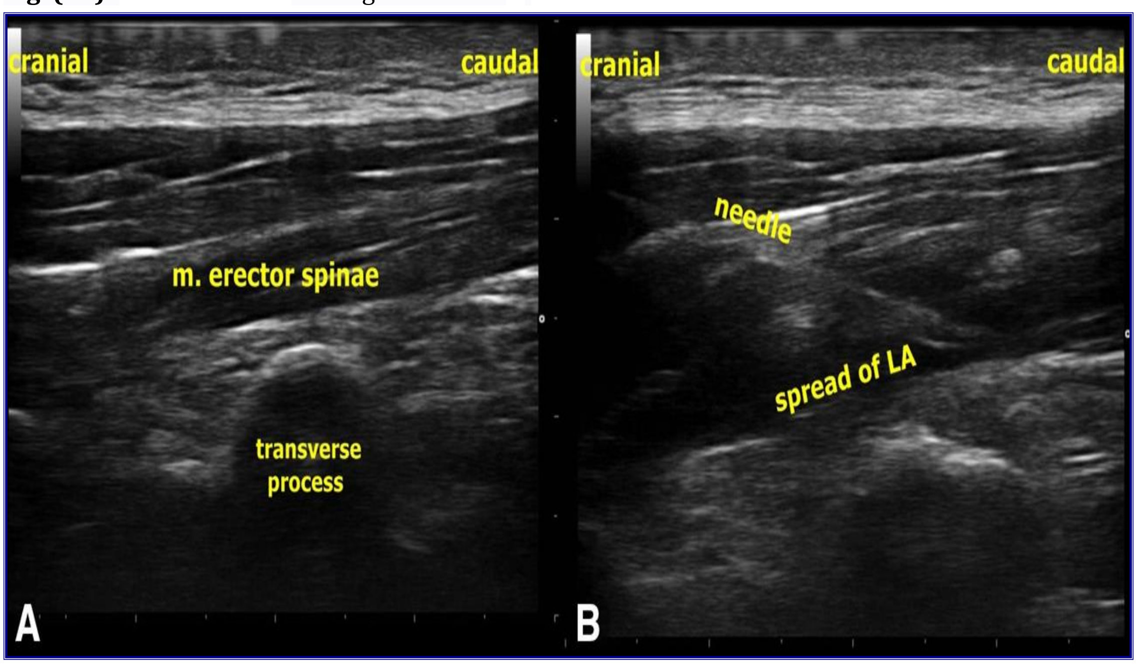

Fig. (11): A) Sonographic anatomy of the erector spinae plane block. The erector spinae muscle and transverse process are seen. B) Needle direction, craniocaudal spread of local anesthetic during erector spinae plane block[21].

Indications

The ESP block can be used to deliver regional analgesia for a wide variety of surgical procedures in the anterior, posterior, and lateral thoracic and abdominal areas, as well as for the management of acute and chronic pain syndromes. The vast majority of indications for ESP block have their basis in case reports and anecdotal clinical experience[23].

Contraindications

Infection at the site of injection in the paraspinal region or patient refusal, are absolute contraindications for performing an ESP block. Anticoagulation may be a relative contraindication to ESP block, although there are no specific guidelines. The most recent 2018 ASRA consensus statement does not specifically address paraspinal blocks and anticoagulation[23].

Complications

Complications are very rare because the site of injection is far from the pleura, major blood vessels, and the spinal cord. Infection at the needle insertion site, local anesthetic toxicity/allergy, vascular puncture, pleural puncture, pneumothorax, and failed block are the primary complications. Because of the few published data, more investigations (e.g., randomized controlled trials, RCTs) are needed to verify the safety, complications rates, and efficacy of this strategy. A recent evidence-based study, indeed, identified only four RCTs and their endpoints were heterogeneous [23].

Follow up of pain management by Diaphragmatic ultrasound

All things considered, ultrasound diaphragm excursion is critical for assessing diaphragmatic function, tracking the course of healing, assessing the effectiveness of pain management, and maximizing ventilator management. For patients with RFs, US imaging is a vital tool for assessing the effectiveness of pain management. It provides accurate and timely diagnosis, tracks the course of recovery, and has a high degree of accuracy in predicting non invasive ventilation failure. These results highlight how important it is to include ultrasonography in the overall care of patients with rib fractures[24].

Diaphragmatic US is a useful technique to evaluate the anatomy and function of the diaphragm, specifically diaphragmatic excursion, and thickening. The equipment needed to perform diaphragmatic ultrasound is uncomplicated and is widely available at medical facilities. The ultrasound system should be equipped with a 2.5-5.0 MHz convex transducer and a 7.5-10.0 MHz linear transducer[25].

Because of the portability of US equipment, diaphragmatic US can be easily performed as an outpatient procedure or at the bedside in the ward, ICU, or emergency department. Because there is less variability and greater reproducibility in the supine position, that is the preferred positioning for diaphragmatic US[26].

Diaphragmatic excursion

Movement of diaphragm during breathing is called diaphragm mobility. Movement of diaphragm from end-expiration to full inspiration is known as diaphragm excursion. Diaphragmatic excursion(DE) is 1-2 cm during tidal breathing and 7-11Cm during deep inspiration. US is a cost-effective, radiation-free, widely available, and real-time investigation. Many studies have proposed the possible use of US to measure the DE[27].

The use of US in assessing DE and its relation to pulmonary function has been addressed by Shiraishi et al. who found that vital capacity (VC), inspiratory capacity (IC), forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) were positively correlated with the maximum Des of patients with chronic obstructive pulmonary disease (COPD)[28].

Technique of Diaphragmatic excursion

Patients are in a semi-recumbent position with the bed slope at 45°. For the evaluation of diaphragmatic mobility, a 2–5 MHz convex transducer is used. The probe is placed over the right anterior subcostal region between the midclavicular and anterior axillary lines. The transducer is directed medially cephalad and dorsally so that the US beam reached perpendicularly to the posterior third of the right hemidiaphragm. First, the 2-D mode is used to visualize and obtain the best approach, with the liver serving as an acoustic window to the right, to select the exploration line. The M-mode then is used to display and measure the amplitude of the craniocaudal DE during quiet breathing (QB) and deep breathing(DB)[29]. The averaged value of three consecutive measurements is recorded. The mobility of the diaphragm during a sniff test is done to exclude paradoxical movement[29,30].

Diaphragmatic Thickening fraction:

US measurements of diaphragmatic thickness (Tdi) and thickening fraction (TF) have been validated for use in the evaluation of diaphragm function. As contraction produces diaphragm shortening, and muscular diaphragm volume must remain unchanged, the muscle thickens. TF is higher with greater diaphragmatic contraction, as it shortens and thereby thickens. Hence, TF is directly related to lung volumes but inversely related to diaphragm muscle length. TF therefore reflects diaphragm strength, activity, and work of breathing in response to load[31].

Specifically, Tdi by US is known to accurately reflect directly measured diaphragm thickness and to have a positive and direct relationship with lung volumes including IC in normal controls. Tdi can be measured at any lung volume and changes in Tdi during breathing maneuvers can be described by TF[32].

TF is defined as the relationship of change in Tdi between measures taken at two different lung volumes to the minimum of the two measures. TF and IC are reported as directly associated in the normal population. Expected ranges of Tdi and TF have been reported for normal individuals, for neuromuscular conditions, and for patients undergoing mechanical ventilation[33].

A principal reason for evaluating TF is that it is believed that TF provides a global assessment of respiratory function as it incorporates both diaphragm function and mechanical load to the diaphragm. In theory, measurement of TF is superior to measurement of DE because it incorporates active diaphragm contraction[34]

Measurement of Diaphragmatic thickening fraction

Patients are in a semi-recumbent position with the bed slope at 45°.

Diaphragm thickness is measured in B-mode with a 6–13 MHz linear transducer placed over the zone of apposition (ZA) of the diaphragm to the rib cage, between the right anterior and medial axillary lines. In the ZA, the diaphragm is observed as a structure made of three distinct layers: a non-echogenic central layer bordered by two echogenic layers, the peritoneum and the diaphragmatic pleurae. The thickness is measured from the middle of the pleural line to the middle of the peritoneal line[35].

We measure the thickness of the diaphragm during quiet spontaneous breathing at FRC and at breath holding after a maximal inspiratory effort, at TLC. Again, the averaged value of three consecutive measurements is recorded for each. We also calculate the thickening fraction (TF), as the proportional thickening of the diaphragm from FRC to TLC. TF represents an index of diaphragmatic thickening as is defined by the following equation: $TF = ([ThTLC - ThFRC] / ThFRC) \times 100$, where ThFRC is the thickness of the diaphragm measured at the end of a quiet expiration (at FRC) and ThTLC is the maximum thickness of the diaphragm measured at the end of DB (at TLC)[35].

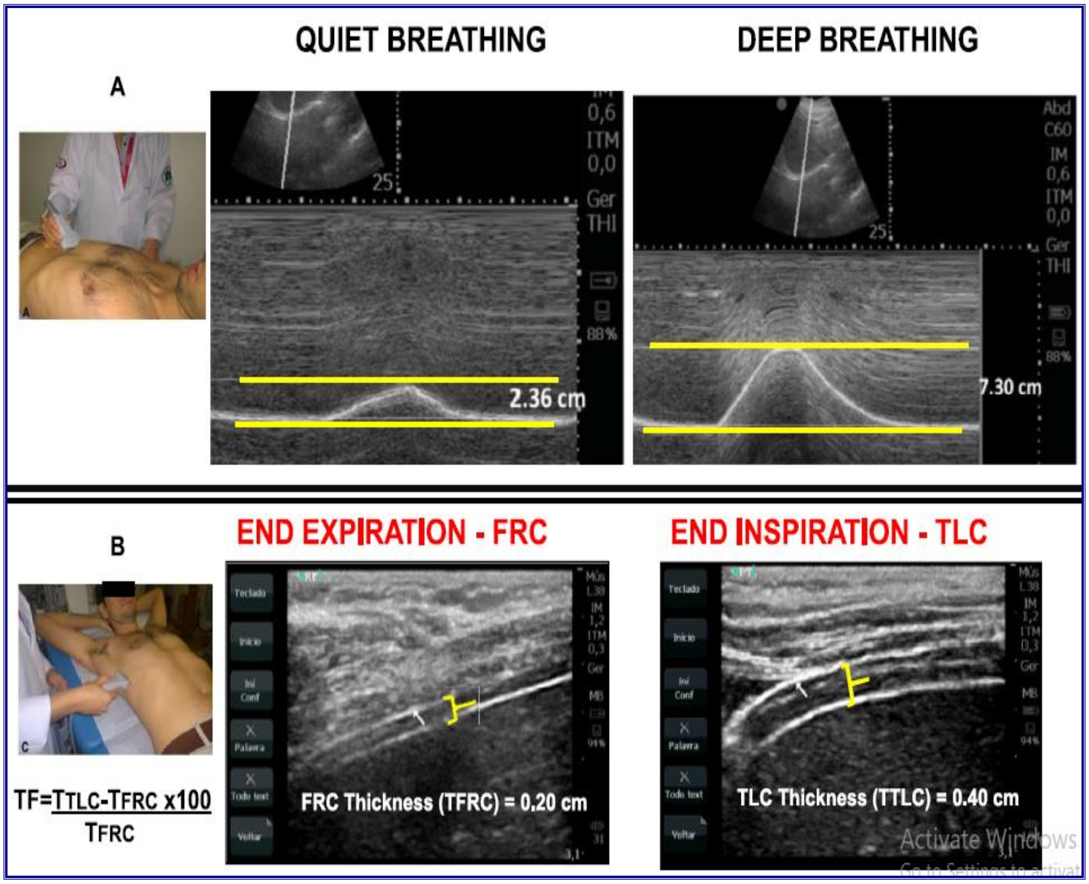

Fig. (17): Ultrasound imaging of the diaphragm to measure mobility (a) during QB and DB, and thickness (b) at FRC and TLC. Thickening fraction was derived by the thickness obtained in both conditions. QB = quiet breathing; DB = deep breathing; FRC = functional residual capacity; TLC = total lung capacity[36].

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