Ultrasonography and anatomical structure of erector spinae plane block

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Abstract:

Since its inception, the erector spinae plane block has been used for a variety of truncal surgeries with success in both adults and children. However, the anatomical features, route of spread, and dermatomal coverage are still not fully understood in a pediatric population.

Keywords: Erector Spinae Muscle & Plane, US, Echo.

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Introduction:

The basis of ultrasonography is the utilisation of sound waves with frequencies more than 20 kHz, which is higher than the range of human hearing. There are several ways to characterise sound waves: amplitude (measured in decibels), frequency (measured in cycles per second or hertz), wavelength (measured in millimetres), period (the time interval in which each oscillatory phenomenon is reproduced), velocity (greater in rigid or less compressible materials, lower in air, water, and soft tissues), power (measured in watts), and intensity (measured in watts per square centimetre) ***(1).***

A pulse-echo type of measurement allows obtaining ultrasonographic images. The transducer is composed by a number of piezoelectric crystals assembled in a linear or curved disposition. Each crystal is excited by electrical pulses (*reverse piezoelectric effect*) and converts electricity (electrical energy) into sound (mechanical energy). The US beam is created by combining these several beams. The latter is transformed back into electrical pulses (piezoelectric effect) and then appears in the image displayed on the screen when it is reflected to the transducer by tissue structures (returning echoes) ***(2).***

Nowadays, transducers have a variety of ultrasonic frequencies (bandwidth) rather than only one fundamental frequency. Ultrasound pulse-echo data must be acquired and displayed in a complex manner in order to produce US images. A consecutive succession of focussed beams are produced in the same plane by the broadband transducer (scan plane). Every set of target data obtained along a line is included in the image from a single pulse transmission. Each real-time picture frame is made up of a collection of parallel or sector lines that indicate the locations of the interrogating beams in the patient. These beams probe all tissues in the scan plane. The spaces between the image lines are filled in by computer algorithms so that the image appears continuous ***(3).***

When the transmitted US pulse encounters internal tissue targets, part of its energy is deflected (reflected or scattered) back to the transducer (the echo). Because pulse-echo imaging techniques employ the same transducer for both sending and receiving US pulses, only echoes travelling in the direction of the transducer have any chance of being detected. The main pulse-echo parameters used in the formation of images include echo amplitude and target spatial position. Echo amplitude is encoded into shades of grey (greyscale imaging), with the lighter shades representing higher amplitude echoes. The depth of the target along the direction of the beam is accurately calculated from a pulse time-offlight measurement. Assuming US propagation velocity is fairly constant from tissue to tissue (1540 m/s), the time between beam transmission and echo reception is used to determine the exact internal spatial location of all tissue targets ***(4).***

Two key parameters—the spatial and temporal resolutions—represent the quality of the image. The first one speaks of the ability to discriminate between two neighboring spots either parallel to the beam's axis or along its axis (axial resolution) (lateral resolution).

Temporal resolution is linked to real-time identification of anatomical structures according to the pulse repetition frequency (PRF) and the frame (number of encoded images per time unit).

Visualization Systems:

- ***Amplitude mode (A-mode***): it is the simplest form of display. It is a diagram in which echo amplitude is shown according to tissue depth
(echo time of flight).
- ***Time-motion mode (TM-mode):*** echoes returning from moving structures are displayed depending on the time. It is used in cardiac US evaluation.
- **Brightness mode (*B-mode*):** it is a greyscale tomographic imaging ***(Fig. 1) (5).***

(Fig. 1): (a) Linear-array probe (5–12 MHz). **(b)** Convexarray probe (2–5 MHz) ***(5).***

Artefacts

The errors in image display are important to know because it can be induced in an uncorrected interpretation of clinical findings. The artefact can be linked to improper scanning technique or the physical characteristic of the US beam.

Anisotropy is an artefact that originates from a loss of echogenicity in structure. It is strictly related to US beam angle of incidence. If the US beam is not perpendicular to linear structures, the reflection is not specular, and so the returning echoes have low intensity: the structure wrongly appears more hypoechoic. The knowledge and the capability to correct the anisotropy artefacts are very important in order to achieve a high diagnostic accuracy and ultimately an optimal management of patients ***(6).***

Technique for Ultrasonographic Imaging of Peripheral Nerves

For the imaging of peripheral nerves, the patient lies with the 'region of interest' on the examination table. Usually, a linear probe with a frequency greater than 12–18 MHz is used. In the case of obese patients or the evaluation of deeply located nerves, a convex probe may be used, for a deeper penetration of the ultrasound waves.

For the evaluation of superficial nerves, using a thick layer of US gel or a stand-off pad can be helpful. In particular, such adjuncts are useful in the evaluation of fine nerves of the wrist ***(7).***

Normal US Anatomy and Scanning Technique

Ultrasonography: Basic Principles and Techniques

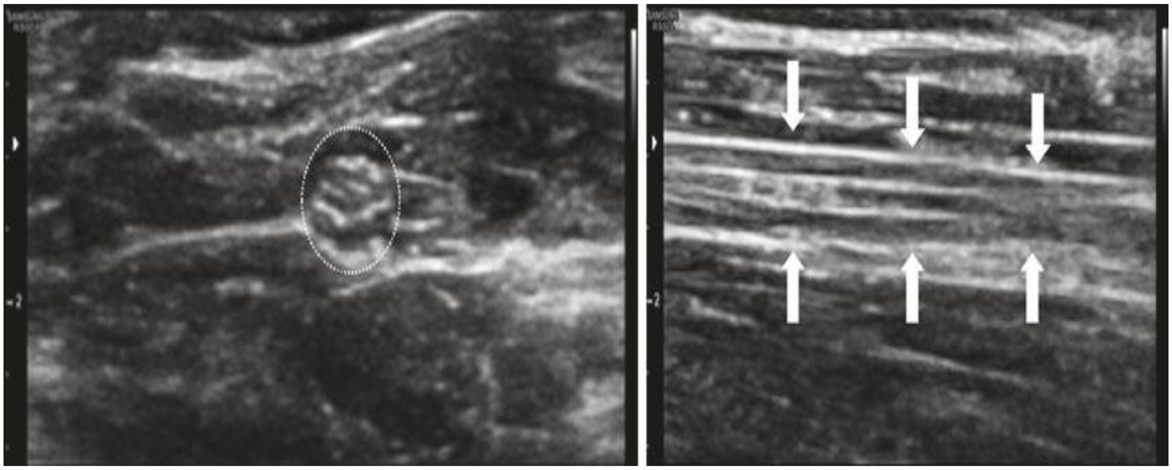
An established technique for visualising peripheral nerves is ultrasonography. It makes it possible to diagnose post-traumatic nerve alterations, neuropathies brought on by compression syndromes, inflammatory or malignant nerve lesions, and surgical consequences. In anesthesiology, its application for regional anaesthetic is growing. Peripheral nerve examinations are noninvasive, reasonably priced, and well-tolerated by patients ***(8).***

Ultrasound of Normal Nerves

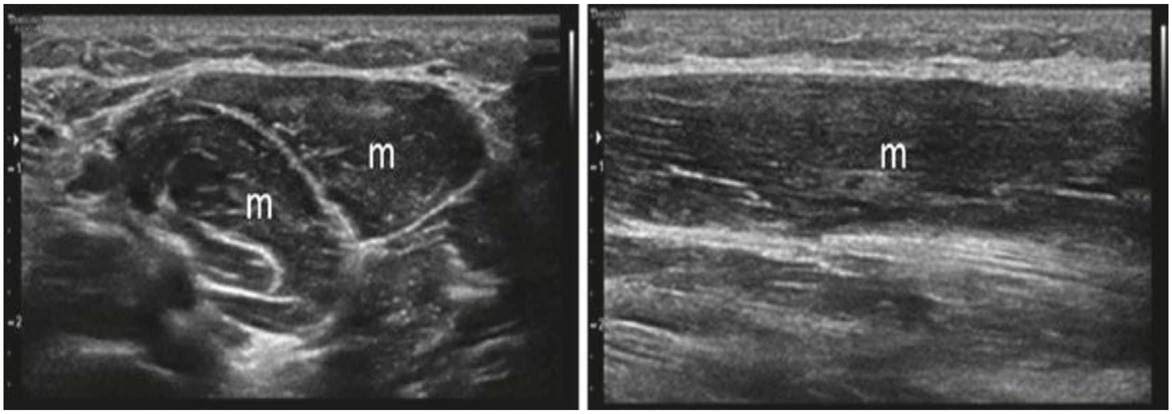
The nerve resembles a honeycomb in the short axis, with a number of rounded hypoechoic regions set against a uniformly hyperechoic background ***(Fig. 2a).*** It appears striated along the long axis and is made up of several parallel bands that are hypoechoic and hyperechoic. This picture looks like an electrical cable ***(Fig. 2b).*** One term for this kind of US look is fascicular structure.

It is also important to distinguish the other anatomical components that surround peripheral nerves and know what their normal echotexture is.

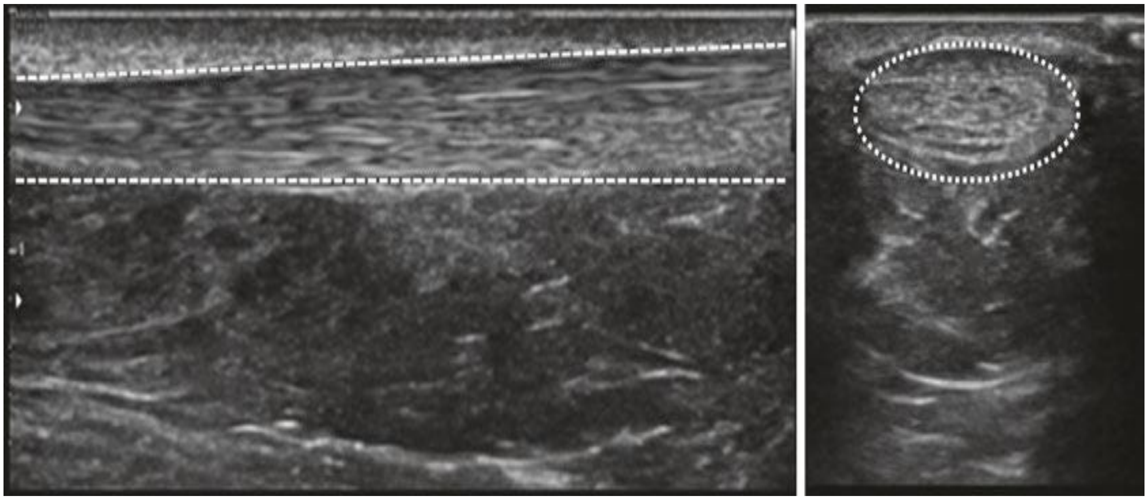
Skeletal muscle: The ratio of muscle to connective tissue can be seen in ultrasound anatomy. The epimysium, or outer muscle fascia, appears as a clearly defined echogenic envelope enclosing the hypoechoic muscle along the short axis, whereas the intramuscular tendons are shown as hyperechoic strands ***(Fig. 3a).*** While the fibroadipose septa (perimysium) resemble hyperechoic lines with a broadly parallel arrangement, the echotexture of muscle fibres in the long axis is comparatively hypoechoic. ***(Fig. 3b) (5).***



(Fig. 2): Ultrasound anatomy of normal nerve: (a) short axis; (b) long axis ***(5).***



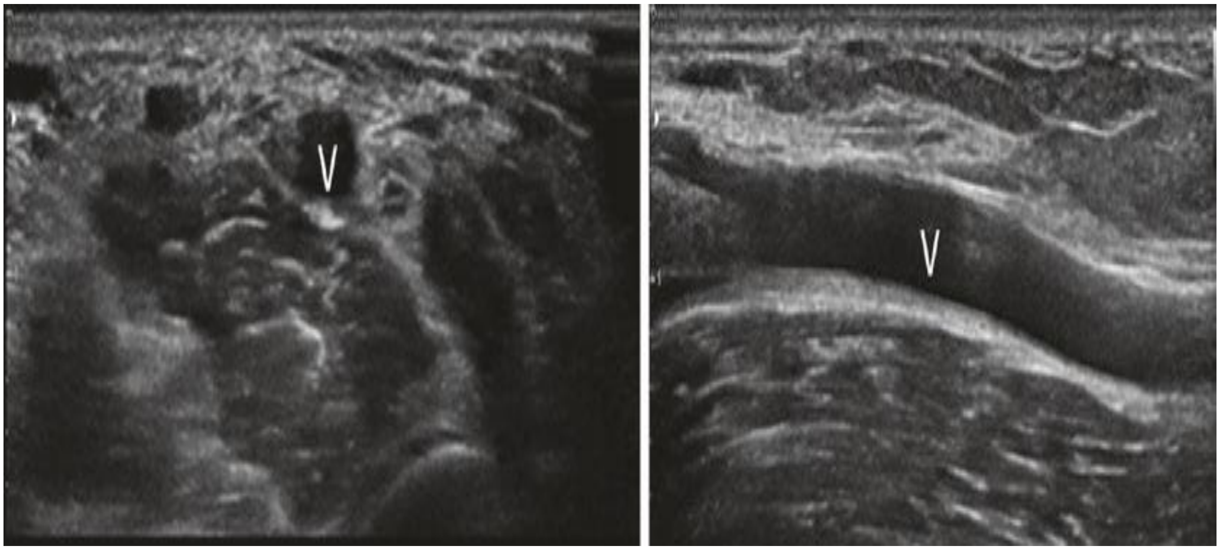
(Fig. 3): Ultrasound anatomy of normal muscle: (a) short axis; (b) long axis ***(5).***



(Fig. 4): Ultrasound anatomy of normal tendon: (**a**) long axis; (**b**) short axis ***(5).***

Tendon**:** Tendons consist of linear fibrils of collagen with a supporting matrix. The normal echotexture reflects this model called fibrillar pattern.

- The tendon appears as a hyperechoic ribbon-like structure in the long axis ***(Fig. 4a).*** A series of thin, hyperechoic fibrillar bands make up the tendon; when the tendon is relaxed, the bands tend to spread apart, and when the tendon is stiff, they tend to converge. The acoustic contact between the endotenon septa determines the specular reflections within the tendon that result in this fibrillar echotexture. Hyperechoic bands that match the paratenon are present around the tendon.
- In a transverse view (short axis), the tendons appear as round- or oval-shaped structures, characterized by several homogeneously scattered spotty echoes ***(Fig. 4b).***
- Vessels: In short and long axes, the vessel appears like an anechoic round or tubular structure, respectively ***(Fig. 5) (5).***



(Fig. 5): Ultrasound anatomy of normal vessel: (a) short axis; (b) long axis ***(5).***

Anatomical Considerations of the Erector Spinae Muscle

The ESM, sometimes referred to as the Sacro spinalis, originates from the deep back muscles in certain sources. It is located deep within the intermediate group of back muscles, the serratus posterior superior and inferior, and superficially beneath the transversospinalis muscle group. ***(9).***

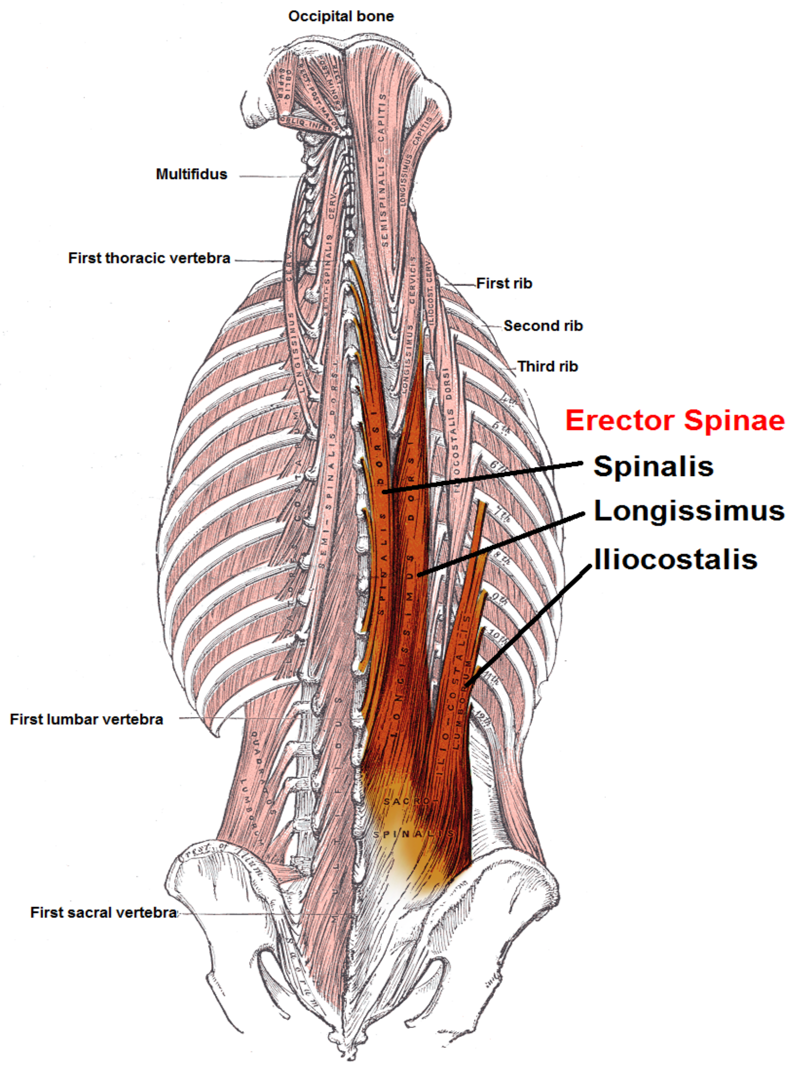
The vertebral column is extended by the ESM. It is composed of three muscles, and the fibres in the lumbar, thoracic, and cervical areas run almost exactly vertically. It is located in the vertebral column's side groove. The nuchal ligament covers it in the cervical region, and the thoracolumbar fascia covers it in the thoracic and lumber regions. It is composed of three muscles: Iliocostalis, located laterally, Spinalis, located medially, and Longissimus, located centrally. ***(Fig. 5) (9).***

Each of these have 3 parts further ***(Table 1).***

(Table 1): Parts of the 3 components of ESM:

Spinalis Muscle	Longissimus Muscle	Iliocostalis Muscle
1. Spinalis capitis	1. Longissimus Capitis	1. Iliocostalis Cervicis
2. Spinalis cervicis	2. Longissimus Cervicis	2. Iliocostalis Thoracis

3. Spinalis thoracis	3. Longissimus Thoracis	3. Iliocostalis Lumborum



(Fig. 6): Anatomy of the ESM ***(9).***

1) Spinalis Muscle

Is the area closest to the spine that is the most medial. It establishes a connection between the next vertebrae's spinous processes. It splits into three sections. ***(10) (Table 2).***

(Table 2): Parts of spinalis muscle

Muscle	**Origin**	**Insertion**

1. Spinalis capitis	Usually blends with semispinalis capitis	With semispinalis capitis
2. Spinalis cervicis	Spinous process of C7 (sometimes T1 to T2) and ligamentum nuchae	Spinous process of C2 and C3-C4
3. Spinalis thoracis	Spinous process of T11 to L2	Spinous process of upper thoracic vertebrae

2) Longissimus Muscle

Laterally to the spinalis, it makes up the central portion of the ESM. The bulk of the erector group is made up of the longissimus muscle. It affixes along the vertebrae's transverse process (TP). It is split into three sections. ***(Table 3) (11).***

(Table 3): Parts of longissimus muscle

Muscle	**Origin**	**Insertion**
1. Longissimus Capitis	C4-T4 transverse process	Posterior edge of the mastoid process
2. Longissimus cervicis	T1-T4 transverse process	C2 to C6 transverse process
3. Longissimus Thoracis	TP of lumbar vertebra and blends with iliocostalis in the lumbar region	TP of all thoracic vertebrae

3) Iliocostalis Muscle

It is the ESM's most lateral section. It attaches to the ribs. A tight iliocostalis can raise the hip or pull the rib cage in the direction of the hip because of its lateral location. It is split into three sections. ***(10) (Table 4)***

(Table 4): Iliocostalis Muscle

Muscle	**Origin**	**Insertion**
1. Iliocostalis cervicis	Angle of ribs 3-6	TP of C4-C6
2. Iliocostalis thoracis	Angle of lower six ribs	Angles of upper six ribs and TP of C7

3. Iliocostalis lumborum	Iliac crest	L1-L4 lumbar transverse processes, angle of 4-12 ribs and thoracolumbar fascia

Action

They help control the bending of the vertebral column by pulling the head posteriorly and straightening the back through bilateral contraction. The head is turned to the contracting side and the spinal column is bent laterally by unilateral contraction.

Nerve Supply

Dorsal rami of spinal nerves.

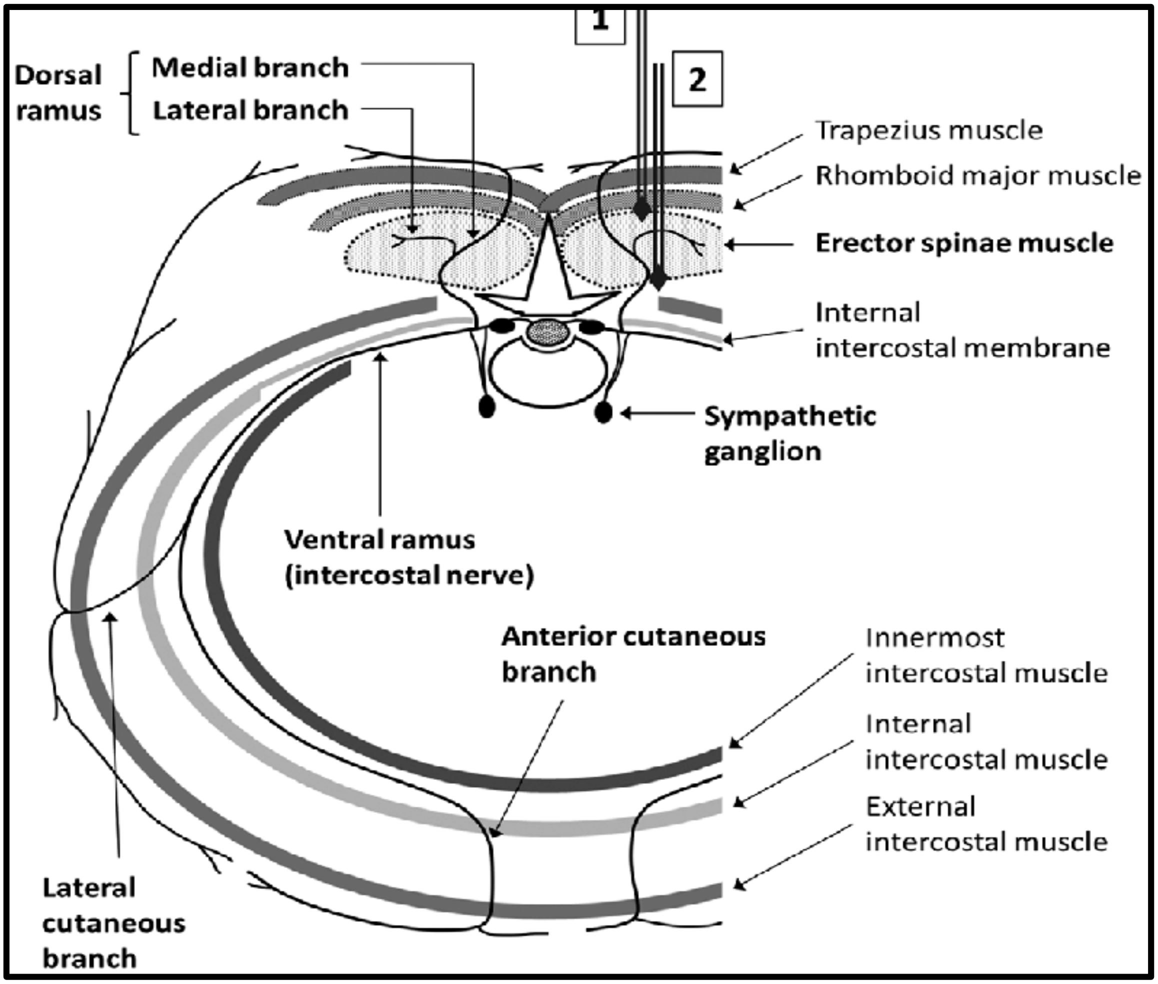
Blood Supply

Branches of the vertebral, deep cervical, occipital, transverse cervical, posterior intercostal, subcostal, lumbar and lateral sacral arteries ***(10).***

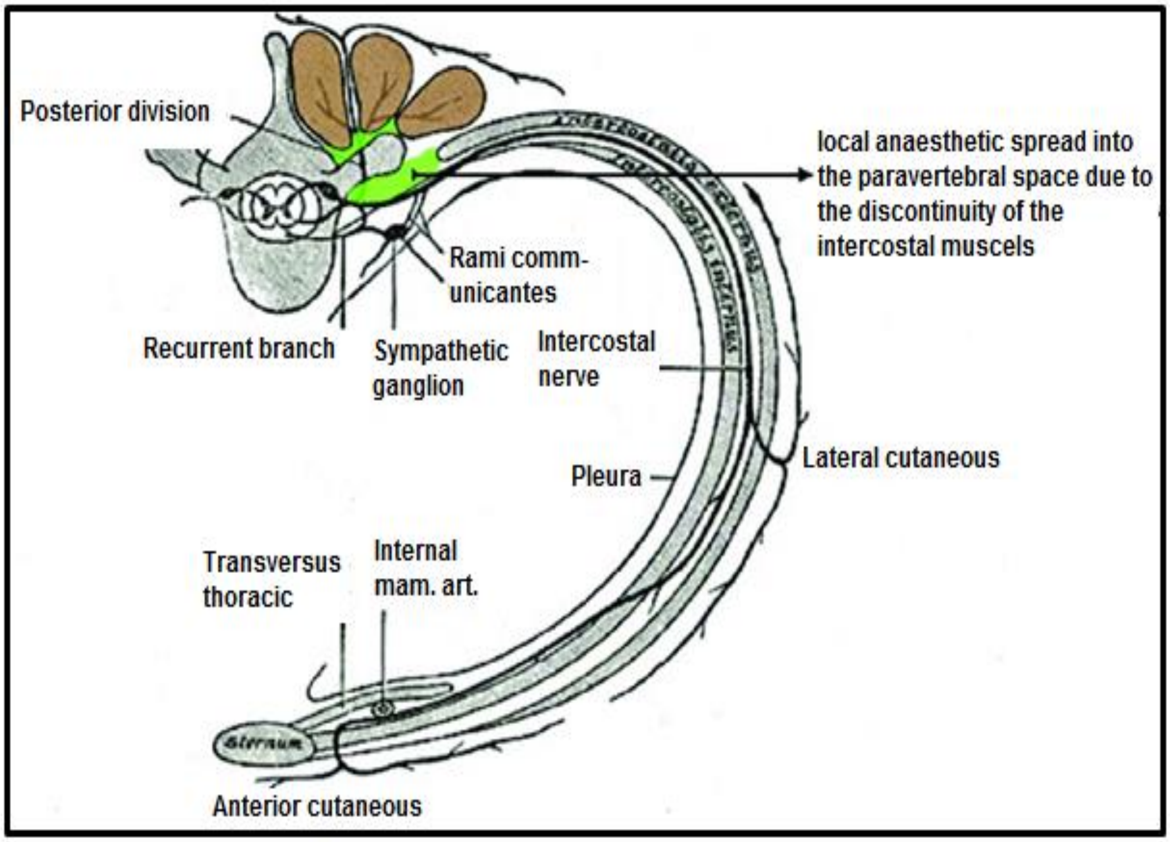
i- ESP Block

The US-guided interfacial plane block, which was mainly utilised to treat thoracic neuropathic pain, was supplemented with ESP block more recently ***(12).*** Where the injected LA spreads cranio-caudally up to many levels from the injection site, ESP is a potential space deep to ESM.

According to research by ***Chin and colleagues (13)***, in cadavers, the erector spinae fascia reaches from the nuchal fascia cranially to the sacrum caudally. The injected LA passes through the costotransverse foramina and obstructs the sympathetic fibres' rami communicants, ventral rami, and dorsal rami of spinal nerves. The concentration, volume of LA utilised, and point of entrance determine which dermatomes are covered by the ESP block. A schematic image illustrating the normal course of the upper thoracic spinal nerve is shown in ***(Fig. 7,8).*** Since its first description, ESP block has been utilised with varying degrees of efficacy to provide preoperative analgesia for abdominal and thoracic procedures***. (14).***



(Figure 7): Schematic diagram of the course of a typical upper thoracic spinal nerve ***(14).***

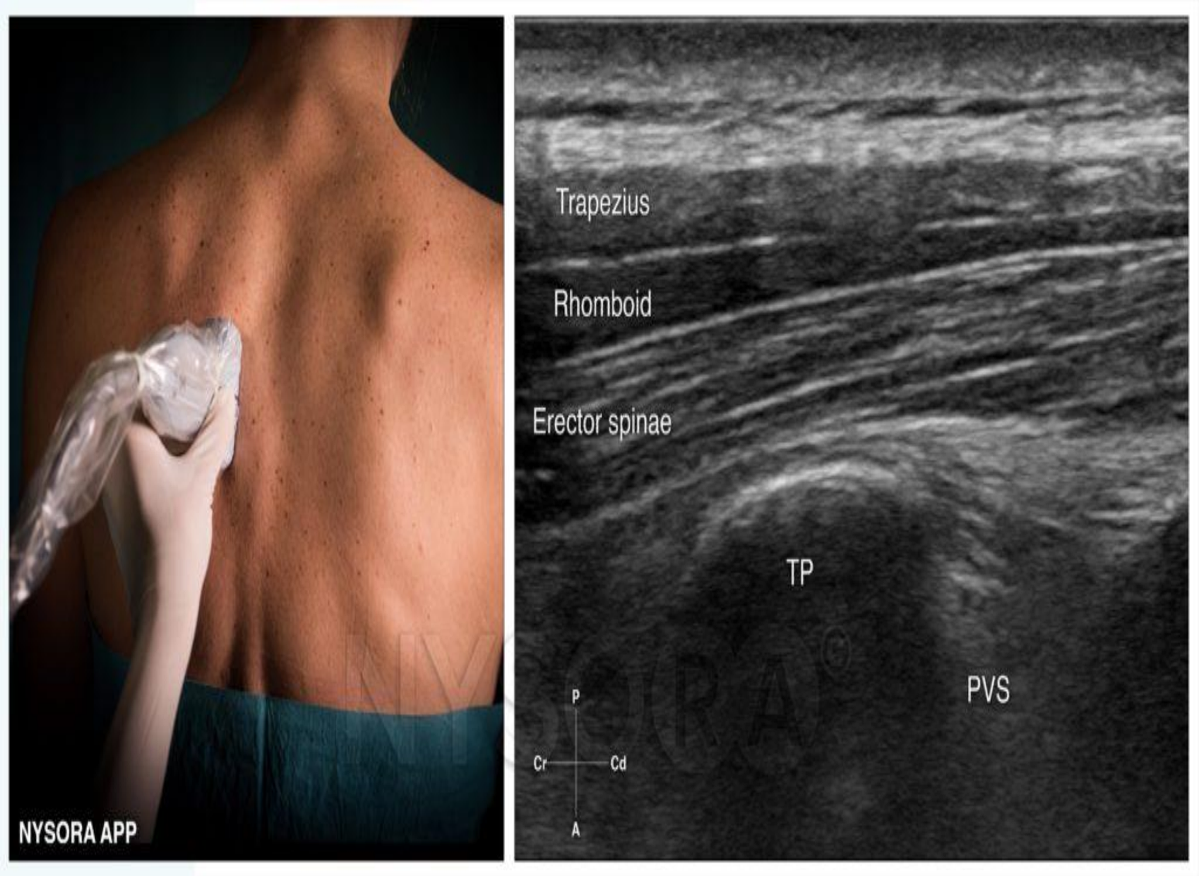


(Fig. 8): Diagram shows LA spread into the paravertebral space, ESM parts (brown color) from medial to lateral: spinalis, longissimus, and iliocostalis**,** green color: areas of LA spread ***(9).***

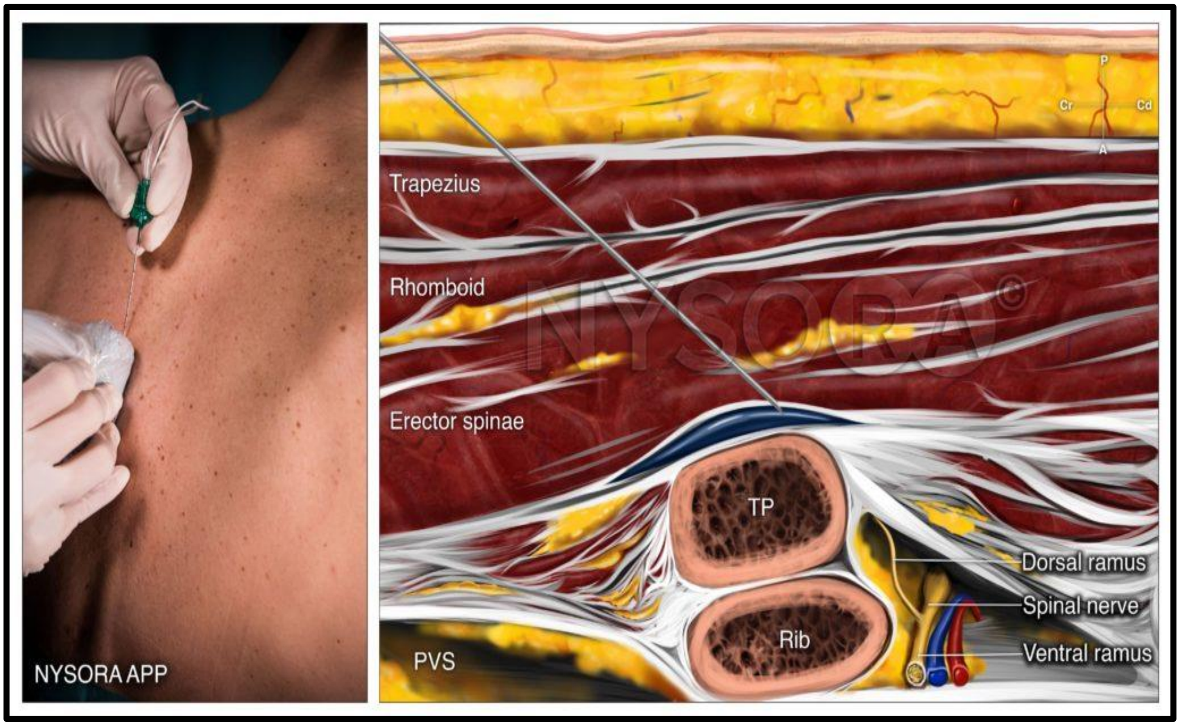
ii- US-guided ESP block.

The T4 spinous process is recognised and marked after counting down from the C7 spinous process. The patient may be in a sitting or lateral posture with the side to be blocked upwards. The block is typically performed with a linear array high-frequency US probe positioned in the midline in a craniocaudal orientation. After that, the probe advanced laterally to locate T4 TP, which is often located 2-3 cm laterally from the spinous process. ***(Fig. 9-11) (15).***

It is necessary to identify the ESM, rhomboid major, and trapezius muscle. After applying 2% lidocaine to the skin and following aseptic measures, a 10-cm block needle should be inserted in the craniocaudal plane under vision and moved until the TP is reached. To verify that ESM and TP are separated, hydro-dissection is performed. The LA is to be injected in accordance with US guidelines, and the drug spread will be visible in real time in the ESP craniocaudally. ***(15).***



(Fig. 9): Administration of US- guided ESP block **(15).**



(Fig. 10): **Reverse ultrasound anatomy of an ESP block with needle insertion in-plane from a cranial to caudal direction**. The spinal nerve is exiting the paravertebral space with the dorsal ramus branching and traveling posterior to innervate the posterior back muscles. TP, transverse process; PVS, paravertebral space. Cr, cranial, Cd, caudad; A, anterior; P, posterior ***(15).***

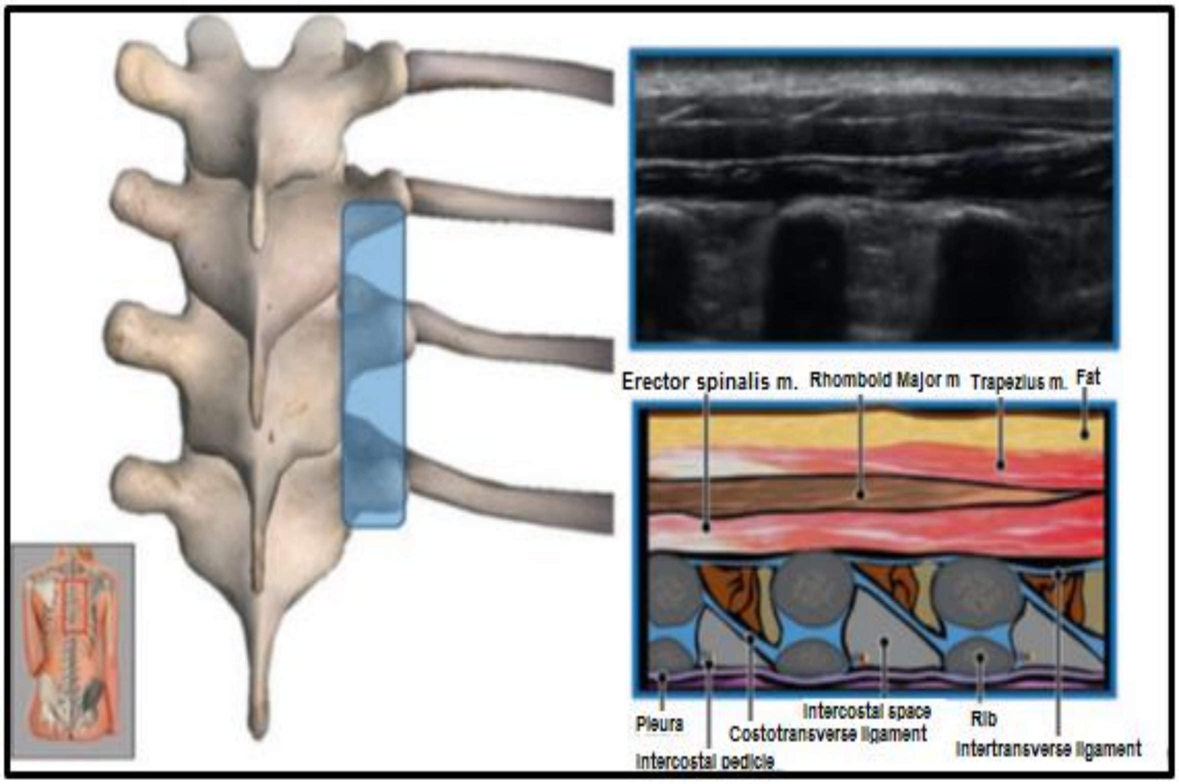


Figure (11): Sonoanatomy of ESM **(16).**

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