Journal of Ultrasound
https://doi.org/10.1007/s40477-023-00825-0

REVIEW PAPER

Check for updates

Ultrasound-guided procedures for the management of chronic thoracic back pain: a technical review

Nuno Ferreira-Silva[1] · Rita Ribas[2] · Mark Friedrich B. Hurdle[3] · Sahil Gupta[3] · Steven R. Clendenen[3,4] · Guilherme Ferreira-Dos-Santos[5]

Received: 26 May 2023 / Accepted: 8 August 2023

Abstract
Pain arising from the thoracic region has been reported to be potentially as debilitating as cervical or lumbar back pain, and may stem from a vast number of spinal sources, including zygapophysial, costovertebral and costotransverse joints, intervertebral discs, ligaments, fascia, muscles, and nerve roots. Over the last two decades, the use of ultrasound in interventional spinal procedures has been rapidly evolving, due to the ultrasound capabilities of visualizing soft tissues, including muscle layers, pleura, nerves, and blood vessels, allowing for real-time needle tracking, while also reducing radiation exposure to both patient and physician, when compared to traditional fluoroscopy guidance. However, its limitations still preclude it from being the imaging modality of choice for some thoracic spinal procedures, notably epidural (interlaminar and transforaminal approaches) and intradiscal injections. In this technical review, we provide an overview of five thoracic spinal injections that are amenable to ultrasound guidance. We start by discussing their clinical utility, followed by the relevant topographic anatomy, and then provide an illustrated technical description of each of the procedures discussed: (1) *erector spinae* plane block; (2) intra-articular thoracic zygapophyseal (facet) joint injection; (3) thoracic medial branch block; (4) costotransverse joint injection; and (5) costovertebral joint injection.

Keywords Chronic pain · Neuropathic pain · Pain medicine · Technical review · Thoracic pain

Abbreviations

CT	Computerized tomography
CTJ	Costotransverse joint
CVJ	Costovertebral joint
ESP	*Erector spinae* Plane
FoV	Field of view
MBB	Medial branch block
MRI	Magnetic resonance imaging
RFN	Radiofrequency neurotomy
TFJ	Thoracic facet joint
TP	Transverse process
US	Ultrasound

Nuno Ferreira-Silva and Rita Ribas shared first authorship.

✉ Nuno Ferreira-Silva
nunofranciscodasilva@gmail.com

1 Department of Physical Medicine and Rehabilitation, Hospital Professor Doutor Fernando Fonseca, Amadora, Portugal

2 Department of Anesthesiology, Centro Hospitalar Universitário de Lisboa Norte, Lisbon, Portugal

3 Department of Pain Medicine, Mayo Clinic, Jacksonville, FL, USA

4 Department of Anesthesiology and Perioperative Medicine, Mayo Clinic, Jacksonville, FL, USA

5 Division of Pain Medicine, Department of Anesthesiology, Reanimation, and Pain Medicine, Hospital Clínic de Barcelona, University of Barcelona, Barcelona, Catalonia, Spain

Background

Back pain is a leading problem among chronic pain disorders, with a lifetime prevalence previously reported to be potentially as high as 80% [1–4]. Although thoracic back pain accounts for only 15–20% of all back pain syndromes, pain arising from the thoracic region has been reported to be potentially as debilitating as cervical or lumbar back pain [4, 5].

Pain in the thoracic region may stem from a vast number of spinal sources, including zygapophysial, costovertebral and costotransverse joints, intervertebral discs, ligaments, fascia, muscles, and nerve roots. In addition to causing

Purchased by Slipping Rib Syndrome Organization® Website: Slipping Rib Syndrome INFO - SRSINFO.Org *personal use only*
Published online: 30 August 2023

pain in the thoracic region, these structures may also cause referred pain to the anterior thorax and abdominal viscera, due to the convergence of visceral and somatic afferents at the level of the dorsal horn [6, 7].

Over the last two decades, the use of ultrasound (US) in Pain Medicine for interventional axial procedures has been rapidly evolving, due to the US capabilities of visualizing soft tissues, including muscle layers, pleura, nerves, and blood vessels, allowing for real-time needle tracking, while also reducing radiation exposure to both patient and physician, when compared to traditional fluoroscopy guidance. Nonetheless, US-guidance has its technical challenges and limitations. Deeper structures, including vertebral discs and the spinal cord are difficult to identify, given the acoustic shadowing of bone. In addition, as was demonstrated by Sullivan et al. (2000), in a multicentric observational study, pre-injection aspiration does not reliably identify intravascular uptake of injectate. As such, contrast-enhanced fluoroscopic guidance remains a necessity when there is risk of complications due to intravascular uptake [8]. Other anatomical constraints, such as large body habitus, bone hyperplasia, and degenerative changes can further reduce the ability to clearly delineate anatomical landmarks [9]. As such, despite the notable advantages that US-guidance brought to the field of Interventional Pain Medicine, its limitations still preclude it from being the imaging modality of choice for some thoracic procedures, notably epidural (interlaminar and transforaminal approaches) and intradiscal injections.

In this technical review, we provide an overview of five thoracic spinal injections that are amenable to US-guidance. We start by discussing their clinical utility, followed by the relevant topographic anatomy, and then provide an illustrated technical description of each of the procedures discussed (Fig. 1): (1) *erector spinae* plane (ESP) block; (2) intra-articular thoracic zygapophyseal (facet) joint injection; (3) thoracic medial branch block (MBB); (4) costotransverse joint (CTJ) injection; and (5) costovertebral joint (CVJ) injection. Table 1 summarizes important technical considerations for each of the five procedures.

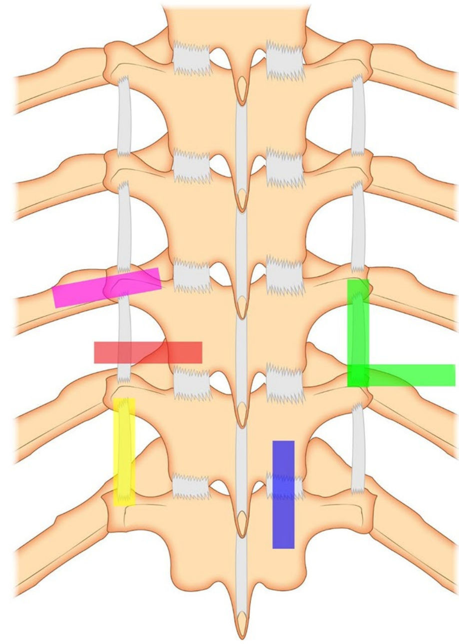

Fig. 1 Ultrasound transducer position for each of the five thoracic interventions described. Pink—costotransverse joint injection; red—costovertebral joint injection; yellow—*erector spinae* plane block; green—medial branch block (parasagittal and axial approaches); blue—intra-articular facet joint injection

Erector spinae plane block

Background

The ESP block was first described by Forero et al. (2016) for the management of chronic thoracic neuropathic pain [10]. However, it has since gained popularity in the setting of Regional Anesthesia, where it emerged as an alternative to thoracic paravertebral and epidural blocks, due to its increased safety, relative simplicity, and rare contraindications [11, 12]. In the setting of chronic pain management, the ESP block is used primarily in the treatment of post-herpetic neuralgia, post-thoracotomy pain, metastatic rib cancer-related pain, and myofascial pain [10, 12–14].

When performing an ESP block, local anesthetic is injected into the fascial plane between the *erector spinae* muscle group and the tip of the transverse process. In its original description, Forero et al. (2016), in a cadaveric study using three-dimensional computerized tomography (CT) reconstruction, proposed the spread of local anesthetic to the thoracic paravertebral space as the primary mechanism of analgesic action [10]. This mechanism of action has since been challenged in other cadaveric spread studies, in which spread to the paravertebral space was found only in a minority of specimens [15]. Nevertheless, recent in vivo magnetic resonance imaging (MRI) studies have shown that the injectate does spread anteriorly, consistently reaching the paravertebral and intercostal spaces, and in some cases reaching the epidural space, potentially providing somatic analgesia to the ventral and dorsal thoracic walls, and possibly also visceral analgesia (Fig. 2A) [16–18]. This distinct spread pattern in live subjects was theorized to be the result of biomechanical properties that cannot be replicated in cadaveric specimens, notably the negative pressure during inspiration and contraction of the back muscles, which may drive the spread of injectate anteriorly [18, 19]. In addition, several authors have also raised the possibility that postmortem changes may alter the spread of local anesthetic through

Table 1 Technical summary of procedures for chronic thoracic back pain

Procedure	Bony landmarks	Sonographic target	Transducer position	Transducer type	Suggested volume	Indications
Erector spinae plane block	Transverse process	Tip of the transverse process	Parasagittal	Linear* 6–15 MHz	20–30 mL	Post-herpetic neuralgia; post-thoracotomy pain; thoracic myofascial pain; metastatic rib cancer; other chronic neuropathic pain syndromes
Thoracic facet joint injection	Spinous process; lamina	Mid-point between the lateral and medial ends of the two hyperechoic lines of the articular processes	Parasagittal	Curvilinear 2–6 MHz	0,75 mL	Facet joint-mediated pain
Thoracic medial branch block	Transverse process	Tip of the transverse process (T1–T4; T9, T10) – Mid-point between two transverse processes (T5–T8)	Axial (T1–T4; T9, T10) – Parasagittal (T5–T8)	Linear* 6–15 MHz	0.5 Ml (diagnostic) – 1 mL (therapeutic)	Facet joint-mediated pain
Costotransverse joint injection	Transverse process; rib	Merging of the apex of the transverse process and costal tuberosity of the rib	Oblique	Linear* 6–15 MHz	0.5 mL	Costotransverse joint-mediated pain
Costovertebral joint injection	Neck of the rib	Merging of rib head and hemifacet(s)	Axial (with additional caudal tilt)	Curvilinear 2–6 MHz	0.5 mL	Costovertebral joint-mediated pain

*Curvilinear transducer may be required for muscular or obese patients

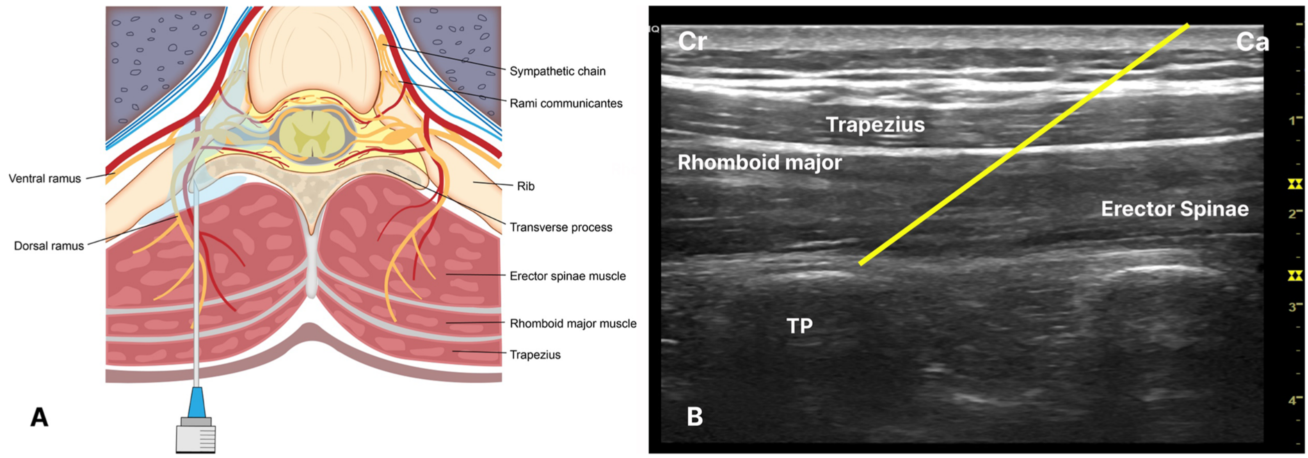

Fig. 2 **A** Final needle tip position during an *erector spinae* plane block, showcasing patterns of injectate spread previously reported in the literature; **B** corresponding ultrasound image. *Ca* caudal, *Cr* cranial, *TP* transverse process

local tissues [20]. Moreover, cephalad-caudad spread has also been found to be inconsistent in both cadaveric and in vivo studies [10, 21]. Of note, multi-dermatomal sensory block spread has been reported to average nine dermatomes after a single injection of 20 mL of 0.5% bupivacaine [21]. Besides the paravertebral spread of local anesthetics, some authors have theorized that nociceptive inhibition of the thoracolumbar fascia may also contribute to the analgesic effect of the ESP [15]. Lastly, recent studies by Ricci et al.(2023) have described the entrapment of cutaneous branches of the dorsal rami in the multiple layers of the fascia as a major contributor to myofascial pain [22, 23]. It has been hypothesized that the ESP block might hydrodissect these points of entrapment and block these nerves, thus providing further pain relief.

Anatomy

At the higher thoracic levels (T5 and above), three muscle layers can be identified superficially to the transverse process—trapezius, rhomboid major and the *erector spinae* muscle group. At the mid and lower thoracic levels, only the trapezius and *erector spinae* muscle group can be identified. The *erector spinae* group is composed of the *iliocostalis*, *longissimus*, and *spinalis* running vertically along the spine from the skull to the pelvis and sacral region, and horizontally from the spinous to the transverse process, extending to the ribs [13]. In the lumbar and thoracic regions, the *erector spinae* muscle group is covered by the thoracolumbar fascia, while at the cervical level it is covered by the nuchal ligament.

Each thoracic spinal nerve exits the intervertebral foramen and splits into a ventral and dorsal ramus. The ventral ramus travels laterally as the intercostal nerve supplying the anterior and lateral chest wall [11]. The lateral cutaneous branch arises from the intercostal nerve near the midaxillary line, pierces the external intercostal muscle and further subdivides into anterior and posterior branches [10]. The dorsal ramus travels posteriorly through the costotransverse foramen and subdivides into medial, intermediate and lateral branches, supplying the zygapophyseal joints (medial branch), as well as the *erector spinae* muscle group and the remaining muscles of the back (intermediate and lateral branches) [10, 11].

Technique

To start, the patient should be placed in the sitting or prone position. As an alternative, lateral decubitus may be adopted when the patient is unable to tolerate sitting or being prone. A linear transducer (6–15 MHz) is advised in most settings, although a curvilinear transducer (2–6 MHz) may be required for muscular patients, or those with higher than normal body mass index [13]. Identification of the target level can be confirmed either under fluoroscopy, or by counting levels under US, as described by Hurdle et al. (2021) [24]. After confirmation of the target level, the US transducer is placed over the midline in the axial plane and slightly moved cephalad or caudad until a transverse interspinous view (also known as transverse interlaminar view) is obtained. In this view, the transverse process can be easily identified immediately lateral and superficial to the articular process. From this position, a 90º rotation of the transducer will allow for a parasagittal view centered on the transverse process, with the overlying muscle layers superficial to its tip (Fig. 1). From here, a 22–25G, 50–100 mm spinal needle is advanced utilizing an "in-plane" approach, from caudad-to-cephalad or cephalad-to-caudad, until the tip of the needle contacts the top of the transverse process (Fig. 2B). Confirmation of the correct needle tip position may be facilitated by both repositioning at a more horizontal angle, or by pre-injection hydrodissection with sterile saline solution. The injection should be performed under real-time US-guidance, and special attention should be given to confirm the absence of lamination, defined as intramuscular injection into the *erector spinae* muscle group, which can mimic a fascial plane spread. A total injectate volume of 20–30 mL has been previously recommended in the literature [12, 13]. An adequate ESP block is achieved when there is confirmation of linear spread of the injectate in the fascial plane deep to the *erector spinae* muscle group and superficial to the transverse process of the target level [12].

Intra-articular zygapophyseal (facet) joint injection

Background

Thoracic zygapophyseal (facet) joints are less likely to suffer from degenerative joint disease, when compared to the cervical and lumbar regions, due to the increased local stability provided by the ribs. Yet, they are a well-recognized source of pain [25]. In a survey of 500 patients with non-specific thoracic spinal pain, the prevalence of facet joint-mediated pain was 42%, as established by controlled, comparative MBB with local anesthetic [25]. Thus, facet joint-mediated pain is thought to be among the leading sources of chronic thoracic back pain, along with degenerative disc disease [25, 26].

Dreyfuss et al. (1994), in a study using asymptomatic volunteers, mapped the referral patterns of thoracic facetogenic pain by injecting contrast medium into the thoracic facet joints, causing capsular distention [27]. Similarly, in Fukui et al. (1997), the authors selected 15 patients suspected to have thoracic back pain of zygapophyseal origin, and confirmed the diagnosis by the injection of local anesthetic in the joint. Afterwards, contrast medium was used to cause capsular distention and the location of pain was assessed [28]. In both these studies, even though the areas of pain were reproducible, they substantially overlapped each other and with other nearby pain generators (eg. costotransverse joint) [27, 28]. Therefore, identification of thoracic facet pain patterns seems unreliable in diagnosing thoracic facet joint pain [29]. Intra-articular injection and MBB remain the only validated means to diagnose thoracic facet joint-mediated pain in the thoracic region [29].

Anatomy

The thoracic facet joints are diarthrodial synovial joints, composed of a superior and an inferior process involved by a fibrous capsule. These joints differ from their cervical and lumbar counterparts in that they are oriented in the coronal plane, allowing for lateral bending and axial rotation, while minimizing flexion/extension (Fig. 3A) [30]. Cervicothoracic and thoracolumbar joints show transitional cervical and lumbar facet joint features, respectively. C7–T1 joints assume a more transverse orientation while at the lower thoracic levels (T11–T12 and T12–L1) the angle of the joint gradually transitions from a coronal to a parasagittal orientation similar to the lumbar region [31, 32].

Technique

The classic fluoroscopy-guided technique for thoracic facet joint injection can be technically challenging in comparison to the cervical and lumbar regions, due to the steep, coronal orientation of the thoracic facet joints [33]. Performing the technique under US-guidance may allow the interventionist to bypass these technical obstacles. The US-guided technique described below has been validated in a recent cadaveric study, in regards to safety and accuracy [34].

To start the technique, the patient should be placed in the prone position. A low-frequency (2–6 MHz) curvilinear transducer is advised in most patients. Identification of the target level can be confirmed either under fluoroscopy, or in alternative, by counting levels under ultrasound, as described by Hurdle et al. (2021) [24]. Due to the possible existence of a transitional vertebra, counting the vertebral

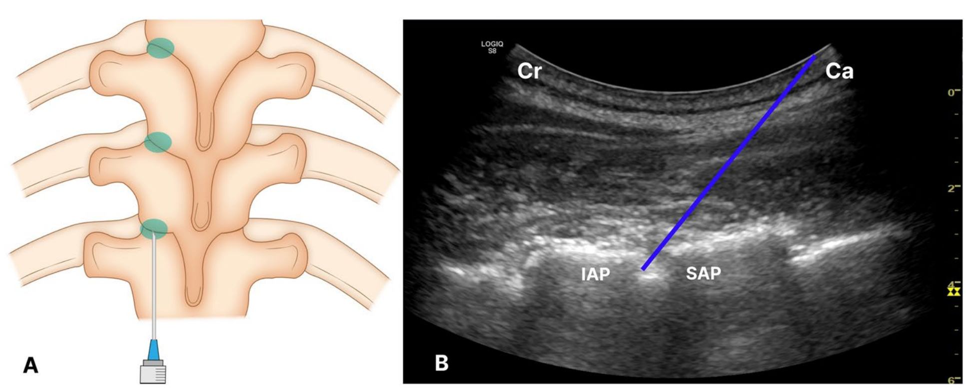

Fig. 3 **A** Final needle tip position for intra-articular injection of the thoracic facet joints; **B** corresponding ultrasound image. *Ca* caudal, *Cr* cranial, *SAP* superior articular process, *IAP* inferior articular process

levels starting from L5–S1 should be avoided. Once the target level for injection is correctly identified, the US transducer should be placed over the ipsilateral rib in an axial plane (longitudinal view of the rib). From this position, the transducer should be translated medially and slightly superiorly, until the CTJ appears in the field of view (FoV). This is valid only for the 1st to 10th ribs, as the CTJ is absent in the last two levels. At this point the probe is rotated to the parasagittal plane and further translated slightly medially and inferiorly, revealing the lamina and the spinous process of the corresponding level. The latter is the most superficial hyperechoic structure of the vertebra and serves as a "starting" landmark for the technique. The transducer should then be moved laterally over the lamina and advanced superiorly and slightly laterally until the superior articular process of the corresponding level and the inferior articular process of the level above are visualized, appearing as two hyperechoic lines, together forming the facet joint. Once the joint is clearly visualized, the transducer should be tilted medially and laterally to demarcate the medial and lateral borders of the joint, and the US transducer centered at its mid-point. At this site, a 22–25G, 50–100 mm spinal needle is inserted using an "in-plane" approach, approximately 1 to 2 finger breadths inferior to the caudal extremity of the transducer, in a caudad-cephalad direction, until the tip of the needle pierces the facet capsule, which can be seen in the US screen as the needle tip disappearing below the inferior articular process (Fig. 3B). A maximum of 0.75 mL of a mixture of local anesthetic and steroid is routinely used, as larger volumes may rupture the joint capsule and increase pain [35].

Medial branch block

Background

A MBB is an alternative intervention to intra-articular facet joint injections for the diagnosis of facet joint-mediated pain. Analogous to the cervical and lumbar facets, MBBs remain the prognostic screening test of choice for patient selection for medial branch radiofrequency neurotomy (RFN) in the thoracic spine [36]. Furthermore, some authors have also suggested that thoracic MBB may have value as a standalone therapeutic modality for thoracic facetogenic pain [35, 37]. Manchikanti et al. (2012) conducted a randomized, double-blind, active-control trial of 100 patients to evaluate the effectiveness of therapeutic thoracic MBB with and without the use of corticosteroids in patients with chronic function-limiting thoracic facet joint-mediated pain confirmed by means of a comparative, controlled, local anesthetic blocks. The authors reported clinically significant functional improvement and pain relief (defined as at least 50% reduction in the Oswestry Disability Index and in the Numeric Rating Scale, respectively) in 80% of the patients, with average duration of pain relief of 20 weeks per procedure. The data from this clinical trial suggests that the addition of steroids may not increase the overall therapeutic effect of the procedure [38].

Anatomy

The thoracic medial branches supply innervation to the facet joints, adjacent intrinsic muscles of the back and the skin overlying the thoracic region [39]. Thoracic facet joints (TFJ) have an abundant nerve supply, and analogous to the innervation of the cervical and lumbar facet joints, the TFJ receive bi-segmental innervation from the medial branches of the dorsal ramus of the same level and the level above [39].

The anatomical topography of the thoracic medial branches has been a topic of controversy in the literature [39, 42]. According to Chua and Bogduk's cadaveric dissection study (1995), the TFJ is innervated by 2 articular branches originating from the medial branch [39]. In their study, the authors reported that the medial branches of the thoracic dorsal rami, from T1 through T4, T9 and T10, lie on the tip of the thoracic transverse processes, while the medial branches from T5 through T8 are suspended in the intertransverse space, with no osseous contact. As for the T11 and T12 branches, they show a gradually more approximate course to the lumbar medial branches, running across the junction of the superior articular process and the base of the transverse process [39]. In contrast, Ishizuca et al. (2012), described articular branches to the TFJ not originating from the medial branch but rather arising from a descending branch. This descending branch originated from the dorsal ramus before its bifurcation into medial and lateral branches, and coursed in close relation to the lateral surface of the TFJ [40]. More recently, Koupt et al. (2022), in a cadaveric dissection study, described the topography of the TFJ innervation based on the dissection of over 400 thoracic medial branches [41]. Articular branches to the TFJ were found to originate from the medial thoracic branches, bifurcating early in its course before its lateral excursion, in close relation to the TFJ. Furthermore, contrary to previous studies, TFJ from T1 to T9 were found to receive uni-segmental innervation from the medial branch of the same level [41].

The knowledge of the exact anatomical course of the medial branches is mandatory when performing RFN, in order to maximize the area of contact between the tip of the cannulae and the nerve. However, when performing MBB, one can benefit from the dispersion of local anesthetic to cover small variations of the medial branch course [40, 41]. For the purpose of this technical description, the earlier anatomical description by Chua and Bogduk (1995) was used [40].

Technique

In contrast to the lumbar and cervical regions, the feasibility and accuracy of US-guided thoracic MBB have not been demonstrated yet. The patient should be placed in the prone position. A high-frequency (6–15 MHz) linear transducer and a 22–25G, 50–100 mm spinal needle are recommended for most patients. When performing diagnostic blocks, a total injectate volume not higher than 0.5 mL of short or long-acting local anesthetic is recommended, in order to prevent spread of injectate to adjacent structures and decrease the rate of false-positives [42, 43]. In contrast, when performing a therapeutic block, volumes of up to 1 mL are generally used, with or without corticosteroids [38].

The medial branches at the mid-thoracic levels (T5 through T8) do not have reliable target needle end points, as they are suspended in the intertransverse space, with no bony structures to serve as reliable landmarks (Fig. 4A). Thus, when aiming to anesthetize these branches under US-guidance, the goal is to aim for the middle point between two successive transverse processes, with needle tip final position being at the same depth as the transverse process of the target level. This can be done using the same transducer placement as for the ESP block, but instead of targeting the tip of the transverse process, aiming for the middle point between the two transverse processes, without going deeper than the osseous contour of the transverse processes, so as not to risk puncturing the pleura (Fig. 4B).

At the upper thoracic levels (T1 through T4) and lower levels (T9 and T10), the target is the tip of the respective transverse process (Fig. 4C). After identification of the desired thoracic level, as per the technique of Hurdle et al. (2021), while scanning the ribs in the parasagittal plane, the probe should be rotated to be in line with the long axis of the rib and moved with continuous visualization of the rib surface towards the median plane until the transverse process appears in the FoV [24]. Thereafter, using an in-plane approach, a 22–25G, 50–100 mm spinal needle is inserted through the skin until the needle tip touches the superolateral corner of the transverse process (Fig. 4D).

When targeting the T11 and T12 segments, US-guided techniques described for the lumbar MBB are recommended, as the trajectory of the nerves at these levels is analogous to the lumbar region.

Intra-articular costotransverse joint injection

Background

When compared to other potential pain generators in the thoracic spine, the literature regarding CTJ is sparse. However, several authors have suggested that the CTJ can be the origin of clinically significant thoracic back pain [44–48]. Young et al. (2008), in a study performed on asymptomatic male volunteers, determined the pain referral patterns of the CTJ via provocative intra-articular injection. In contrast with thoracic facet joint-mediated pain, distribution patterns of CTJ-mediated pain were localized, with no significant overlap between levels [47].

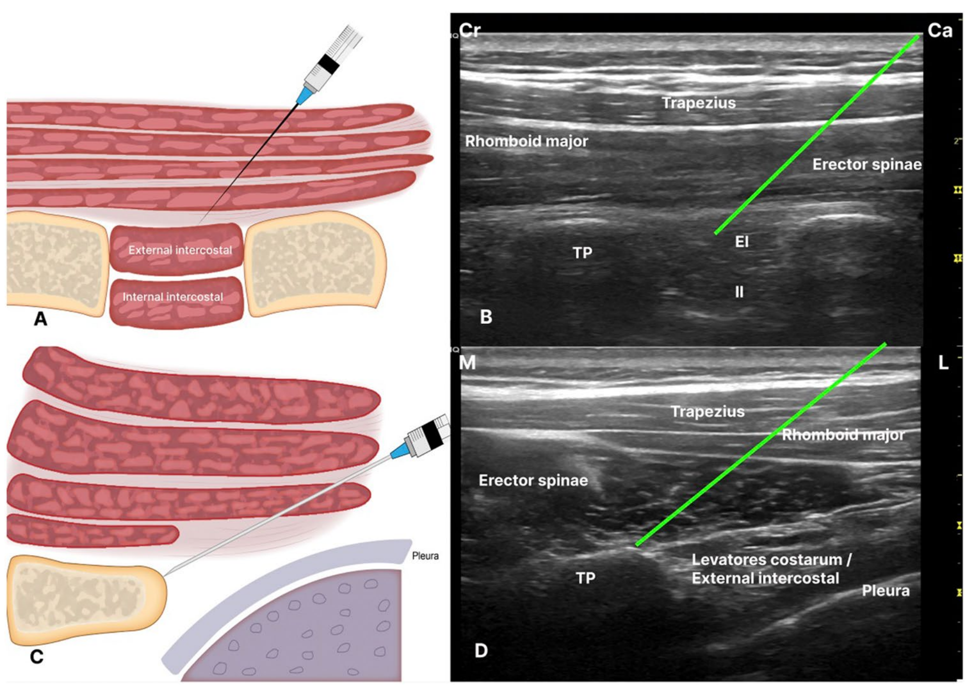

Fig. 4 **A** Final needle tip position during a thoracic medial branch block at T5–T8 levels; **B** corresponding ultrasound image; **C** final needle tip position during a thoracic medial branch block at T1–T4, T9, and T10 levels; **D** corresponding ultrasound image. *Ca* caudal, *Cr* cranial, *EI* external intercostal muscle, *II* internal intercostal muscle, *L* lateral, *M* medial, *P* proximal; *TP* transverse process

On physical examination, patients typically present with localized paraspinal tenderness 2–3 cm lateral to the midline, in the region where the transverse processes meet the ribs. Imaging studies may also reveal suggestive findings of CTJ-mediated pain. Notably, US scanning may detect the presence of a fluid collection within the joint, usually accompanied by a distended joint capsule. Additionally, there may also be evidence of thickening of the costotransverse ligament, as well as a power Doppler sign over the joint capsule, characteristic of CTJ inflammation [48].

Yoon et al. (2016), in a retrospective observational study, performed US-guided CTJ injections in 20 patients presenting with localized parasagittal tenderness over the CTJ area, reporting 70% of excellent or good pain relief at two weeks of post-procedure follow-up [49].

Anatomy

The CTJ are synovial joints formed by the costal tuberosity of a rib and the transverse process of the corresponding thoracic vertebra. These joints span from T1 to T10, but are not present at the T11 and T12 levels, as the floating ribs do not possess a costal tuberosity. The CTJ are oriented 45º to 60º on the parasagittal plane (Fig. 5A). At the upper 5 levels the articular surfaces are reciprocally curved, while at the lower joints the articular surfaces are flattened. Each joint is enclosed by a thin fibrous capsule and reinforced by three ligaments: the costotransverse ligament, that runs from the transverse process to the posterior surface of the rib neck; the superior costotransverse ligament, running from the lower edge of the transverse process to the upper edge of the neck of the underlying rib; and the lateral costotransverse ligament, that runs from the apex of the transverse process to the external portion of the costal tuberosity. These joints together with the CVJ joints form the connection points between the ribs and the thoracic vertebrae and contribute to the stability of the thoracic spine [50, 51]. Innervation of the CTJ is supplied by the lateral branch of the thoracic dorsal rami [52].

Technique

The use of US-guidance for CTJ injection has been described and validated by Deimel et al. (2013), in a cadaveric study, in which the authors performed 16 US-guided CTJ injections followed by assessment by CT arthrogram. In their study, the authors reported an accuracy of 69% with US-guidance, in comparison with a 76% accuracy rate with the traditional fluoroscopic-guided technique, previously reported in the literature [53].

To start the technique, the patient should be placed in the prone position. The pre-procedural US scanning is generally carried out using a high-frequency (6–15 MHz) linear transducer, except in obese patients or in particularly muscular individuals, in which cases the use of a lower-frequency curvilinear transducer is recommended. After identification of the desired thoracic level, as per the technique of Hurdle et al. (2021), while scanning the ribs in the parasagittal plane, the probe should be rotated to be in line with the long axis of the rib and moved with continuous visualization of the rib surface towards midline until the CTJ appears in the field of view [24]. The transducer should then be adjusted to provide an adequate appreciation of the joint capsule and lateral costotransverse ligament, so that the center of the

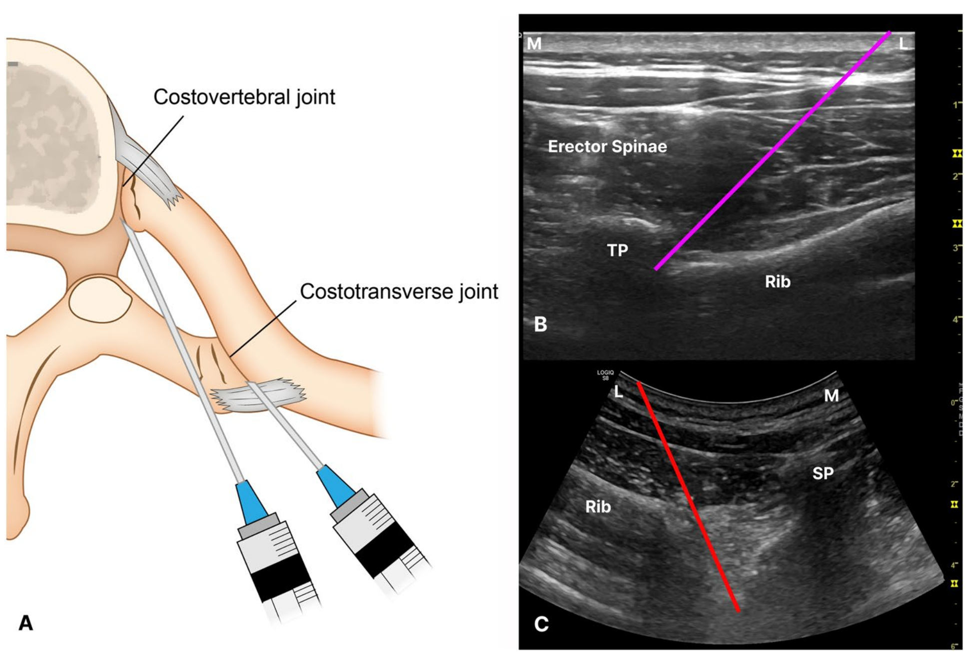

Fig. 5 **A** Final needle tip position for injection of the costotransverse and costovertebral joints; **B** ultrasound image of the costotransverse joint injection; **C** ultrasound image of the costovertebral joint injection. *L* lateral, *M* medial, *TP* transverse process, *SP* spinous process

transducer lies over the mid-portion of the joint. Using an in-plane approach, a 22–25G, 50–100 mm spinal needle is inserted through the skin approximately 1 finger-breath lateral to the transducer, and advanced medially towards the CTJ. As the needle dives underneath the transverse process, the needle tip will no longer be visible due to the acoustic shadow of the bone (Fig. 5B). Thereafter, with further progression the piercing of the joint capsule should be felt, indicating the correct final needle tip placement. Considering the small size of this joint in comparison to the thoracic facet joints, a total volume of injectate of no more than 0.5 mL has been recommended in the literature [47].

Intra-articular costovertebral joint injection

Background

The role of the CVJ in the genesis of thoracic back pain remains poorly understood in the literature. Despite the fairly common prevalence of osteoarthritic changes as early as the 3rd decade, most subjects remain asymptomatic [54]. Other than joint osteoarthritis, trauma to the chest wall has also been reported to potentially cause CVJ dysfunction/strain, and consequently pain [55, 57].

Patients typically present with unilateral sharp paravertebral pain, worsened by coughing, deep inspiration, torsional movements of the trunk and passive mobilization of the affected rib, significantly limiting activities of daily living and sleep quality. Frequently, pain radiates in a bandlike fashion to the thorax, arm or abdomen, masquerading as a visceral disease [54, 56–58] These pain radiation patterns may be explained by the close relation of the intercostal nerves to the CVJ, resulting in the irritation of the nerves and perception of pain along the corresponding dermatomes.

Anatomy

The CVJ are situated between the head of the ribs and the lateral bodies of the thoracic vertebrae, and their anatomy differs at the various thoracic levels. From T2 to T10, the ribs articulate with two hemi-facets of the two adjacent vertebral bodies and are bound to the intervertebral disc by a strong intra-articular ligament that divides the joint into two separate synovial spaces. In contrast, at the T1, T11 and T12 levels the ribs articulate with a single facet of the corresponding vertebral body, without an anchoring intervertebral ligament [54]. The absence of this ligament is thought to decrease joint stability and contribute to the highest frequency of degenerative changes at these levels [54]. CVJ may receive innervation by the lateral branch of the thoracic dorsal rami as well as the neighboring sympathetic segment [47, 59].

Technique

To our best knowledge, no US-guided technique targeting CVJ has been described in the literature. The depth and the hidden location of the CVJ make it hard-to-reach joints under US, which may pose technical challenges and raise safety concerns.

The patient should be placed in the prone position. A low-frequency (2–6 MHz) curvilinear transducer is recommended. After counting and identification of the target thoracic level as previously described, the transducer should be rotated in order to be parallel with the long axis of the rib. From this point, the transducer is moved medially with continuous visualization of the rib, while at the same time progressively rotated from the oblique plane of the rib to the horizontal plane (an anatomical transverse plane) until the transverse process is identified at the center of the US screen [24]. The resulting image will show, from medial to lateral, the spinous process, lamina, transverse process and rib. Thereafter, the transducer is directed slightly cephalad until the view of transverse process is replaced by the steep angle of the neck of the rib and more medially, the CVJ. It might be useful, at some levels, to tilt the probe caudally to obtain a clearer image of the CVJ. Using this FoV, a 22–25G, 50–100 mm spinal needle is inserted through the skin using a lateral-to-medial approach. The needle is then advanced until the tip is felt to penetrate the capsule, thus marking the "end point" of needle placement (Fig. 5C). From our clinical experience, an injectate volume of 0.5 mL per joint is sufficient to appropriately fill the joint space.

Conclusions

Thoracic back pain has been historically disregarded due to its low prevalence; however, it has been previously reported to be potentially as debilitating as cervical or lumbar back pain [4, 5]. When first-line conservative treatment options fail, minimally invasive interventional pain procedures are the standard next step of treatment. These have been traditionally performed under fluoroscopic-guidance, though with the advent of modern US equipment and interest in the technology by the Interventional Pain Medicine community, US has become a modality of choice for several axial and peripheral procedures. US advantages and disadvantages as compared to fluoroscopy, especially in the setting of guided interventions of the thoracic spine, should be weighed carefully. In the future, further clinical trials investigating the efficacy and safety of US-guided procedures in the thoracic spine are warranted.

Funding The authors did not receive any direct or indirect financial benefits for the publication of this manuscript—Level 0.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Consent to publish The authors affirm that the human volunteers provided informed consent for the publication of the US images in Figs. 2B, 3B, 4B, D, 5B,C.

References

1. Macfarlane GJ (2016) The epidemiology of chronic pain. Pain 157(10):2158–2159. https://doi.org/10.1097/j.pain.0000000000000676
2. Von Korff M, Dworkin SF, Le Resche L, Kruger A (1988) An epidemiologic comparison of pain complaints. Pain 32(2):173–183. https://doi.org/10.1016/0304-3959(88)90066-8
3. Rubin DI (2007) Epidemiology and risk factors for spine pain. Neurol Clin 25(2):353–371. https://doi.org/10.1016/j.ncl.2007.01.004
4. Linton SJ, Hellsing AL, Halldén K (1998) A population-based study of spinal pain among 35–45-year-old individuals: prevalence, sick leave, and health care use. Spine (Phila Pa 1976) 23(13):1457–1463. https://doi.org/10.1097/00007632-199807010-00006
5. Briggs AM, Smith AJ, Straker LM, Bragge P (2009) Thoracic spine pain in the general population: prevalence, incidence and associated factors in children, adolescents and adults. A systematic review. BMC Musculoskelet Disord 10:77. https://doi.org/10.1186/1471-2474-10-77
6. Singer KP, Edmondston SJ (2000) Introduction: the enigma of the thoracic spine. In: Giles LGF, Singer KP (eds) The clinical anatomy and management of thoracic spine pain. Butterworth-Heinemann, Oxford, pp 3–10
7. Singer KP (2000) Pathology of the thoracic spine. In: Giles LGF, Singer KP (eds) The clinical anatomy and management of thoracic spine pain. Butterworth-Heinemann, Oxford, p 79
8. Sullivan WJ, Willick SE, Chira-Adisai W, Zuhosky J, Tyburski M, Dreyfuss P, Prather H, Press JM (2000) Incidence of intravascular uptake in lumbar spinal injection procedures. Spine (Phila Pa 1976) 25(4):481–486. https://doi.org/10.1097/00007632-200002150-00015
9. Provenzano DA, Narouze S (2013) Sonographically guided lumbar spine procedures. J Ultrasound Med 32(7):1109–1116. https://doi.org/10.7863/ultra.32.7.1109
10. Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ (2016) The erector spinae plane block: a novel analgesic technique in thoracic neuropathic pain. Reg Anesth Pain Med 41(5):621–627. https://doi.org/10.1097/AAP.0000000000000451
11. De Cassai A, Bonvicini D, Correale C, Sandei L, Tulgar S, Tonetti T (2019) Erector spinae plane block: a systematic qualitative review. Minerva Anestesiol 85(3):308–319. https://doi.org/10.23736/S0375-9393.18.13341-4
12. Forero M, Rajarathinam M, Adhikary S, Chin KJ (2017) Erector spinae plane (ESP) block in the management of post-thoracotomy pain syndrome: a case series. Scand J Pain 17:325–329. https://doi.org/10.1016/j.sjpain.2017.08.013
13. Tulgar S, Ahiskalioglu A, De Cassai A, Gurkan Y (2019) Efficacy of bilateral erector spinae plane block in the management of pain: current insights. J Pain Res 12:2597–2613. https://doi.org/10.2147/JPR.S182128
14. Yürük D, Akkaya ÖT, Polat ÖE, Alptekin HA (2022) Ultrasound-guided erector spinae plane block and trapezius muscle injection for myofascial pain syndrome. J Ultrasound Med 41(1):185–191. https://doi.org/10.1002/jum.15694
15. Chin KJ, El-Boghdadly K (2021) Mechanisms of action of the erector spinae plane (ESP) block: a narrative review. Can J Anaesth 68(3):387–408. https://doi.org/10.1007/s12630-020-01875-2
16. Diwan S, Nair A (2020) Is paravertebral-epidural spread the underlying mechanism of action of erector spinae plane block? Turk J Anaesthesiol Reanim 48(1):86–87. https://doi.org/10.5152/TJAR.2019.81226
17. Celik M, Tulgar S, Ahiskalioglu A et al (2019) Is high volume lumbar erector spinae plane block an alternative to transforaminal epidural injection? Evaluation with MRI. Reg Anesth Pain Med 44:906–907. https://doi.org/10.1136/rapm-2019-100514
18. Schwartzman A, Peng P, Maciel MA et al (2020) A magnetic resonance imaging study of local anesthetic spread in patients receiving an erector spinae plane block. Can J Anesth 67:942–948. https://doi.org/10.1007/s12630-020-01613-8
19. Elsharkawy H, Pawa A, Mariano ER (2018) Interfascial plane blocks: back to basics. Reg Anesth Pain Med 43(4):341–346. https://doi.org/10.1097/AAP.0000000000000750
20. Cornish P (2019) Erector spinae plane block and 'a cadaveric conundrum.' Reg Anesth Pain Med 44:269–270. https://doi.org/10.1136/rapm-2018-100066
21. Barrios A, Camelo J, Gomez J, Forero M, Peng PWH, Visbal K, Cadavid A (2020) Evaluation of sensory mapping of erector spinae plane block. Pain Phys 23(3):E289–E296
22. Ricci V, Mezian K, Chang K-V, Tarantino D, Güvener O, Gervasoni F, Naňka O, Özçakar L (2023) Ultrasound imaging and guidance for cervical myofascial pain: a narrative review. Int J Environ Res Public Health 20(5):3838. https://doi.org/10.3390/ijerph20053838
23. Ricci V, Ricci C, Mezian K, Naňka O, Özçakar L (2023) Trapezius muscle and the cutaneous branches of spinal nerves: sonographic/anatomic discussion of myofascial pain and superficial injections. Pain Med 24(3):221–225. https://doi.org/10.1093/pm/pnac125
24. Hurdle MFB, Ferreira-Dos-Santos G, Rosario-Concepcion R, Gil LV, Eldrige JS, Clendenen SR (2021) Counting ribs and thoracic levels under ultrasound: a systematized technical protocol for both posterior and anterior approaches. Reg Anesth Pain Med 46(5):452–454. https://doi.org/10.1136/rapm-2020-102050
25. Manchikanti L, Boswell MV, Singh V, Pampati VS, Damron KS, Beyer CD (2004) Prevalence of facet joint pain in chronic spinal pain of cervical, thoracic, and lumbar regions. BMC Musculoskelet Disord 5:15. https://doi.org/10.1186/1471-2474-5-15
26. Manchikanti L, Singh V, Pampati V, Beyer CD, Damron KS (2002) Evaluation of the prevalence of facet joint pain in chronic thoracic pain. Pain Phys 5(4):354–359
27. Dreyfuss P, Tibiletti C, Dreyer SJ (1994) Thoracic zygapophyseal joint pain patterns. A study in normal volunteers. Spine 19(7):807–811. https://doi.org/10.1097/00007632-199404000-00014
28. Fukui S, Ohseto K, Shiotani M (1997) Patterns of pain induced by distending the thoracic zygapophyseal joints. Reg Anesth 22:332–336. https://doi.org/10.1016/s1098-7339(97)80007-7
29. Atluri S, Singh V, Datta S, Geffert S, Sehgal N, Falco FJ (2012) Diagnostic accuracy of thoracic facet joint nerve blocks: an update of the assessment of evidence. Pain Phys 15(4):E483–E496
30. I. A. F. (2000) Stokes: biomechanics of the thoracic spine rib cage. In: Giles LGF, Singer KP (eds) The clinical anatomy and

management of thoracic spine pain. Butterworth-Heinemann, Oxford, pp 45–59
31. Ebraheim N, Xu R, Ahmad M, Yeasting R (1997) The quantitative anatomy of the thoracic facet and the posterior projection of its inferior facet. Spine 22(16):1811–1817. https://doi.org/10.1097/00007632-199708150-00002
32. Masharawi Y, Rothschild B, Dar G, Peleg S, Robinson D, Been E, Hershkovitz I (2004) Facet orientation in the thoracolumbar spine: three-dimensional anatomic and biomechanical analysis. Spine (Phila Pa 1976) 29(16):1755–1763. https://doi.org/10.1097/01.brs.0000134575.04084
33. Fortin JD, McKee MJ (2003) Thoracic facet blocks: bent needle technique. Pain Phys 6(4):513–516
34. Stulc SM, Hurdle MF, Pingree MJ, Brault JS, Porter CA (2011) Ultrasound-guided thoracic facet injections: description of a technique. J Ultrasound Med 30(3):357–362. https://doi.org/10.7863/jum.2011.30.3.357
35. Lee DG, Ahn SH, Cho YW, Do KH, Kwak SG, Chang MC (2018) Comparison of intra-articular thoracic facet joint steroid injection and thoracic medial branch block for the management of thoracic facet joint pain. Spine (Phila Pa 1976) 43(2):76–80. https://doi.org/10.1097/BRS.0000000000002269
36. Cohen SP, Moon JY, Brummett CM, White RL, Larkin TM (2015) Medial branch blocks or intra-articular injections as a prognostic tool before lumbar facet radiofrequency denervation: a multicenter, case–control study. Reg Anesth Pain Med 40(4):376–383. https://doi.org/10.1097/AAP.0000000000000229
37. Manchikanti L, Manchinkanti KN, Manchukonda R et al (2006) Evaluation of therapeutic thoracic medial branch block effectiveness in chronic thoracic pain: a prospective outcome study with minimum 1-year follow-up. Pain Phys 9:97–105
38. Manchikanti L, Singh V, Falco FJ, Cash KA, Pampati V, Fellows B (2012) The role of thoracic medial branch blocks in managing chronic mid and upper back pain: a randomized, double-blind, active-control trial with a 2-year follow-up. Anesthesiol Res Pract. https://doi.org/10.1155/2012/585806
39. Chua WH, Bogduk N (1995) The surgical anatomy of thoracic facet denervation. Acta Neurochir (Wien) 136(3–4):140–144. https://doi.org/10.1007/BF01410616
40. Ishizuka K, Sakai H, Tsuzuki N, Nagashima M (2012) Topographic anatomy of the posterior ramus of thoracic spinal nerve and surrounding structures. Spine (Phila Pa 1976) 37(14):E817–E822. https://doi.org/10.1097/BRS.0b013e31824b65ea
41. Koutp A, Sadoghi P, Petritsch J, Skias C, Grechenig P, Andrianakis A, Feigl GC (2022) Anatomic-topographic investigation of the branches of the dorsal ramus of thoracic spinal nerves. Pain Med 23(11):1869–1874. https://doi.org/10.1093/pm/pnac072
42. Wahezi SE, Alexeev E, Georgy JS, Haramati N, Erosa SA, Shah JM, Downie S (2018) Lumbar medial branch block volume-dependent dispersion patterns as a predictor for ablation success: a cadaveric study. PMR 10(6):616–622. https://doi.org/10.1016/j.pmrj.2017.11.011
43. Cohen SP, Bhaskar A, Bhatia A et al (2020) Consensus practice guidelines on interventions for lumbar facet joint pain from a multispecialty, International Working Group. Reg Anesth Pain Med 45(6):424–467. https://doi.org/10.1136/rapm-2019-101243
44. Fruth SJ (2006) Differential diagnosis and treatment in a patient with posterior upper thoracic pain. Phys Ther 86(2):254–268
45. Sanzhang C, Rothschild BM (1993) Zygapophyseal and costovertebral/costotransverse joints: an anatomic assessment of arthritis impact. Br J Rheumatol 32:1066–1071. https://doi.org/10.1093/rheumatology/32.12.1066
46. Lau LS, Littlejohn GO (1987) Costotransverse joint injection description of technique. Australas Radiol 31(1):47–49. https://doi.org/10.1111/j.1440-1673.1987.tb01781.x
47. Young BA, Gill HE, Wainner RS, Flynn TW (2008) Thoracic costotransverse joint pain patterns: a study in normal volunteers. BMC Musculoskelet Disord 9:140. https://doi.org/10.1186/1471-2474-9-140
48. Del Chiaro A, Ciampi B, Franzoni F, Miccoli M, Galletti S, Stella SM (2022) Inflammatory disease of the costotransverse joints: US evaluation in 15 symptomatic patients. J Ultrasound 25(2):167–175. https://doi.org/10.1007/s40477-021-00589-5
49. Yoon KB, Kim SH, Park SJ, Moon JA, Yoon DM (2016) Clinical effectiveness of ultrasound-guided costotransverse joint injection in thoracic back pain patients. Korean J Pain 29(3):197–201. https://doi.org/10.3344/kjp.2016.29.3.197
50. Oda I, Abumi K, Lü D, Shono Y, Kaneda K (1996) Biomechanical role of the posterior elements, costovertebral joints, and rib cage in the stability of the thoracic. Spine 21(12):1423–1429. https://doi.org/10.1097/00007632-199606150-00005
51. Watkins R IV, Watkins R III, Williams L, Ahlbrand S, Garcia R, Karamanian A, Sharp L, Vo C, Hedman T (2005) Stability provided by the sternum and rib cage in the thoracic spine. Spine 30(11):1283–1286. https://doi.org/10.1097/01.brs.0000164257.69354.bb
52. Bogduk N (2002) Innervations and pain patterns of the thoracic spine. In: Grant R (ed) Physical therapy of the cervical and thoracic spine. Churchill Livingstone, New York, p 77
53. Deimel GW, Hurdle MF, Murthy N, Cartwright JA, Smith J, Pingree MJ (2013) Sonographically guided costotransverse joint injections: a computed tomographically controlled cadaveric feasibility study. J Ultrasound Med 32(12):2083–2089. https://doi.org/10.7863/ultra.32.12.2083
54. Nathan H, Weinberg H, Robin GC et al (1964) The costovertebral joints, anatomical-clinical observations in arthritis. Arthritis Rheum 7:228–240. https://doi.org/10.1002/art.1780070306
55. Gundersen A, Borgstrom H, McInnis KC (2021) Trunk injuries in athletes. Curr Sports Med Rep 20(3):150–156. https://doi.org/10.1249/JSR.0000000000000819
56. Goldthwait JE (1940) The rib joints. N Engl J Med 223:568–573. https://doi.org/10.1056/nejm194010102231503
57. Arroyo JF, Jolliet P, Junod AF (1992) Costovertebral joint dysfunction: another misdiagnosed cause of atypical chest pain. Postgrad Med J 68(802):655–659. https://doi.org/10.1136/pgmj.68.802.655
58. Afonso JR, Soares D, Lopes DB, Matos RM, Pinto RP (2021) Costovertebral osteoarthritis: rare differential diagnosis of back pain in young patients. Rev Bras Ortop (São Paulo) 57(2):345–347. https://doi.org/10.1055/s-0040-1722587
59. Groen GJ, Baljet B, Boekelaar AB, Drukker J (1987) Branches of the thoracic sympathetic trunk in the human fetus. Anat Embryol (Berl) 176(4):401–411. https://doi.org/10.1007/BF00310082

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.