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Original Research Article

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Ultrasound-guided costovertebral joint injection—technique description and fluoroscopy and computerized tomography combined controlled cadaveric feasibility study

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Abstract

Objectives: To describe and assess the feasibility of an ultrasound-guided technique for intra-articular injection of the costovertebral joints, in an unembalmed cadaveric specimen, utilizing fluoroscopy and cone beam computerized tomography for confirmation of contrast spread and needle tip position, respectively.

Methodology: A single unembalmed cadaveric specimen was obtained. A single interventionist performed the placement of the needles under ultrasound guidance. Contrast dye was then injected through each of the needles under real-time fluoroscopy. Finally, the specimen was submitted to a cone beam computerized tomography with 3-dimensional acquisition and multiplanar reformatting to assess final needle tip position relative to the costovertebral joints.

Results: In total, 18 spinal needles were placed under ultrasound guidance. Fluoroscopy showed 4 distinct patterns of contrast spread: intra-articular in the costovertebral joint (13 levels in total), epidural (1 level), intra-articular in the facet joint of the target level (3 levels), and undetermined (1 level). Cone-beam computerized tomography confirmed 13 out of 18 needles to be adequately placed in the costovertebral joints (72% of the total) and 5 out of the 18 needles to be misplaced: 3 needles were placed in the facet joint of the target level, and 2 needles were placed in the epidural space.

Conclusions: This study suggests that, when performed by experienced interventionists, this technique has an accuracy rate of 72%. Further studies are warranted before these results can be extrapolated to daily clinical practice.

Keywords: costovertebral; joint; ultrasound; spine.

Abbreviations

CT—Computerized tomography;
CVJ—Costovertebral joint(s);
FoV—Field of view;
Tx—Thoracic vertebra number "x";
US—Ultrasound.

Background

Chronic back pain is 1 of the leading causes of chronic pain, with a lifetime prevalence previously reported to be potentially as high as 80%.[1–4] While thoracic pain is less frequent than cervical and lumbar spinal pain, it has been shown to be potentially as debilitating.[4,5]

There are multiple potential pain generators in the thoracic spine, including the facet joints, intervertebral disks, costovertebral and costotransverse joints.[4,6–8] Among these, the costovertebral joints (CVJ) are often an overlooked source of thoracic pain. Nonetheless, while facetogenic and discogenic pain are responsible for most cases of thoracic back pain, CVJs are also a potential source of pain and disability.[7,9–11] To our knowledge, there is no accurate data on the incidence and demographics of CVJ-related pain. Even though joint degenerative changes are frequently found in asymptomatic patients, which prompts a cautious interpretation of imaging studies, Nathan et al. (1964) performed a large retrospective study of a random series of 100 x-rays of the thoracic spine and found obvious arthritic changes in 17. Furthermore, 346 patients complaining of symptoms that could theoretically be related to the CVJ were also studied, and CVJ arthritis documented in the x-rays was noted in 48%. The authors also reported the increased prevalence of joint degeneration beginning as early as the third decade, remaining stable until old age.[11]

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 the second thoracic

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vertebra (T2) to T10, the ribs articulate with 2 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 2 separate synovial spaces.[11] In contrast, at the T1, T11, and T12 levels the ribs articulate with a single facet of the corresponding vertebral body, without anchoring to the intervertebral disk.[11,12] The absence of this ligament is thought to decrease joint stability and contribute to a higher frequency of degenerative changes at these levels.[11]

Isolating CVJ-related pain in a patient is challenging and before clinicians decide to target this joint, it is reasonable to exclude more common pain sources (disc, facet, costotransverse, myofascial). Pain arising from the CVJ is typically localized at the thoracic paravertebral region, frequently radiating in a bandlike fashion to the anterior chest along the associated ribs or the arm, due to the possible irritation of the adjacent nerve roots.[12,13] Additionally, due to the proximity of the CVJ to the *rami comunicantes* and sympathetic trunk, patients may manifest pseudo-visceral patterns of pain, mimicking urinary, gastrointestinal and heart involvement.[7,14] Symptoms are usually unilateral and triggered by deep inspiration, coughing, sneezing, or rotation of the trunk.[12,13] On physical examination, although not specific of CVJ pathology, passive loading of the joint or the corresponding rib usually exacerbates pain.[13,14]

Traditionally, fluoroscopy and computerized tomography (CT) have been the preferred imaging modalities to guide spine injections. However, both these modalities are costly, bulky, and expose the patient and clinician to ionizing radiation. In contrast, ultrasound (US) technology is portable, innocuous and affordable. In addition, US permits the visualization of soft tissues, including muscle layers, pleura, nerves, and blood vessels, while allowing for real-time needle tracking.

In this manuscript, we describe and assess the feasibility of an US-guided technique to inject the CVJ in an unembalmed cadaveric specimen, utilizing contrast-enhanced fluoroscopy and cone-beam CT with 3-dimensional acquisition and multiplanar reformatting for confirmation of contrast spread and needle tip position within the capsule of the joint, respectively.

Methodology

This research project was approved by the Bio-Specimens Subcommittee of the Institutional Review Board of the institution where the study took place, in Florida, United States of America. A single unembalmed cadaveric torso-pelvic specimen was obtained through the institution's Department of Anatomy Bequest Program. The specimen was deformed at the T1, T2, and T12 levels, which prevented the placement of the needles at these levels. No trauma, surgical intervention, or spinal deformity were visible at the remaining levels. A board-certified, fellowship-trained Pain Medicine physician with more than 15 years of experience performing US-guided axial injections (MFBH) performed the placement of the needles under US-guidance, utilizing the technical protocol herein described with a 1-5MHz curvilinear array transducer (LOGIQ S8, GE Healthcare, Chicago, IL, USA).

The needles were placed sequentially in a cephalad-to-caudad order, with the cadaveric specimen placed in the prone position on the procedural table. After final positioning of the needle tips, 0.5 mL of contrast dye was injected through each of the needles under real-time fluoroscopy. Finally, the specimen was submitted to a cone beam CT with 3-dimensional acquisition and multiplanar reformatting to assess final needle tip position relative to the CVJ. All images were analyzed by a fellowship-trained Musculoskeletal Radiologist (JMB) with more than 20 years of experience at the time of the investigation.

Technique description

The unembalmed cadaveric specimen was placed in the prone position on the procedural table. To start, the first rib was identified under US using the technique described by Hurdle et al. (2021).[15] After confirmation of the level of the first rib, the US transducer was translated caudally in a parasagittal plane to the target level for injection. The transducer was then rotated in order to be parallel to the long axis of the rib (transverse oblique plane). It should be noted that the obliquity of the ribs considerably changes between levels, with lower thoracic levels being the most oblique. From this position, the transducer was translated medially along the long axis of the rib until the transverse process of the target level was centered in the field of view (FoV) (Figure 1, Figure 4A). While maintaining the transverse process centered in the FoV, the transducer was then slightly rotated from the transverse oblique plane (of the rib) to an anatomical transverse plane (Figure 4B). The resulting image displayed, from medial to lateral, the spinous process, transverse process and a section of the rib (Figure 2). From here, the transducer was translated cephalad until the transverse process was replaced by the steep angle of the neck of the rib in the FoV, with the CVJ and the facet joint of the target level showing medially (Figure 3, Figure 4C and 4D). From our experience, it may be useful to perform a slight caudal tilt of the transducer in this final position, in order to optimize the view of the CVJ. Following optimization of the CVJ in the FoV, a 22-gauge, 3.5-inch needle was inserted through the skin in a lateral-to-medial approach, and advanced until the needle tip was felt to penetrate the capsule of the joint, thus marking the "end point" of needle placement.

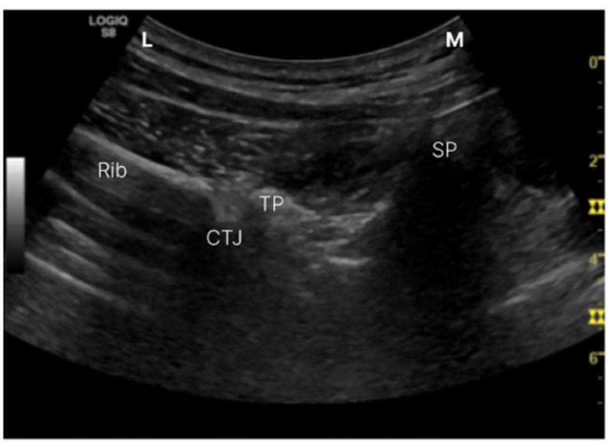

Figure 1. Resulting ultrasound image after step 1 of the technique. Medial displacement of the transducer along the long axis of the rib until the transverse process appears in the center of the field of view. Abbreviations: CTJ = costotransverse joint; L = lateral; M = medial; SP = spinous process; TP = transverse process.

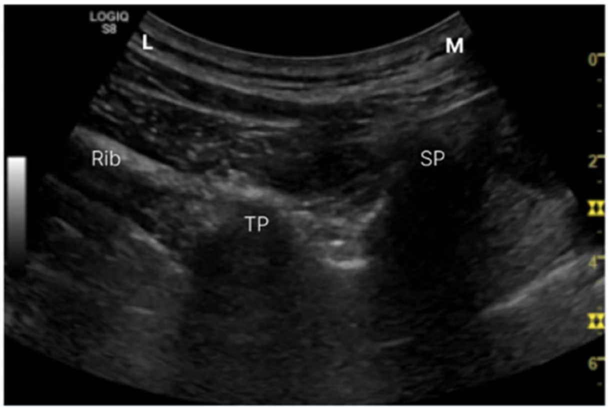

Figure 2. Resulting ultrasound image after step 2 of the technique. Rotation of the transducer from the oblique plane of the rib to the anatomical transverse plane keeping the transverse process in the center of the field of view. Abbreviations: L = lateral; M = medial; SP = spinous process; TP = transverse process.

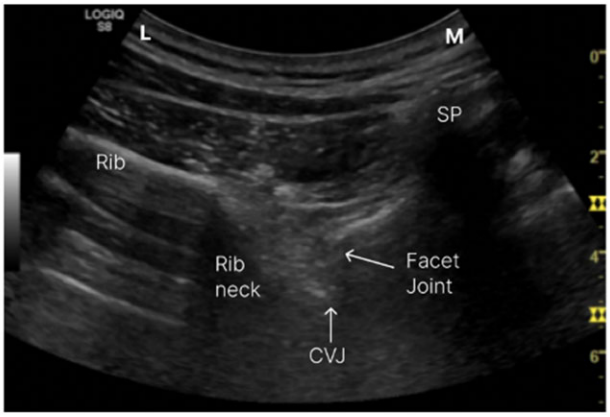

Figure 3. Resulting ultrasound image after step 3 of the technique. Slight cephalad movement of the transducer showing the steep angle of the neck of the rib, and medially the costovertebral and facet joints. Abbreviations: CVJ = costovertebral joint; L = lateral; M = medial; SP = spinous process.

Results

A total of 18 22-gauge, 3.5-inch, spinal needles were placed under US-guidance in a single unembalmed torso-pelvic cadaveric specimen, bilaterally from T3 to T11. Besides T1, T2, and T12 on both sides, no other levels exhibited any identifiable deformities or anatomical variations as determined by US and CT, besides moderate multilevel degenerative changes compatible with a mid-aged cadaveric specimen.

Fluoroscopy showed 4 distinct apparent patterns of contrast spread: intra-articular in the CVJ (on 13 levels in total, 8 on the left side and 5 on the right side) (Figure 5), epidural (on the left side at the T4 level) (Figure 6), intra-articular in the facet joint of the target level (on the right side at the T3, T8, and T9 levels) and undetermined (on the right side at the T6 level).

Cone-beam CT with 3-dimensional acquisition and multiplanar reformatting confirmed 13 out of 18 needles to be adequately placed in the CVJ (72% of the total) (Figure 7) and 5 out of the 18 needles to be misplaced: 3 needles were placed in the facet joint of the target level (on the right side at the T3, T8, and T9 levels), and 2 needles were placed in the epidural space (on the left side at the T4 level and on the right side at the T6 level).

Discussion

In this study, an US-guided technique for performing an intra-articular injection of the CVJ was described and assessed in a cadaveric feasibility study, utilizing fluoroscopy and cone beam CT with 3-dimensional acquisition and multiplanar reformatting for confirmation of contrast spread and needle tip position within the capsule of the joint. The results of this study show that, when performed by an experienced interventionist, this US-guided technique has an overall accuracy rate of 72%.

Several limitations and technical aspects of this study should be taken into consideration when analyzing the reported accuracy rate of the technique: (1) first, given the depth and location of the CVJ in the thoracic spine, we expect the overall accuracy rate of the technique to be lower, when not performed by an interventionist with extensive experience in US-guided procedures. For this reason, although we have demonstrated the possible feasibility of this US technique, we advise that only experienced physicians should consider it; (2) second, the use of a single specimen and a sample size of 18 joints is relatively small for assessing both overall accuracy and safety of any procedure in the clinical setting. In particularly arthritic CVJ joints, the joint may be hypertrophic and present with osteophytes, which may decrease the overall accuracy of the procedure. However, the sample size in this study was limited by the availability of cadaveric specimens and access to a cone beam CT equipment available for studies in cadaveric specimens; (3) finally, there are technical limitations to the use of US-guidance in spinal procedures, when compared to fluoroscopy or CT-guidance, that should be considered when applying this technique in the clinical setting. Of note, the inability of US to reliably detect intravascular, intradiscal or epidural injection, in addition to the inability of US to detect the presence of intra-articular contrast uptake. Furthermore, because of the US's poor visibility of deep structures, a high BMI may be listed as an exclusion criterion.

It is also important to discuss the relevance of misplaced needles for patient safety. Of the 5 incorrect needle placements, 2 were found to be in the epidural space of the target level. In the clinical setting, this would likely result in an inadvertent thoracic transforaminal epidural injection. Although rare, it is possible for the Adamkiewicz artery to traverse at the level of the inferior foraminal epidural space.[16] This means that, in such a case, there is a possibility of accidental arterial puncture. As such, it seems reasonable to advise nonparticulate steroids when utilizing this technique in the clinical setting, in order to avoid theoretically rare but potentially catastrophic complications. Additionally, after final needle placement under US, a fluoroscopic image should be obtained to exclude misplacement of the needle tip and, confirm intra-articular CVJ contrast spread.

The remaining 3 needles were found to be placed in the facet joint of the corresponding level. This represents a more posterior final position of the needle versus the desired end location at the CVJ. From our experience, this was likely caused by hypertrophy of the thoracic facet joints of the corresponding levels, which might induce misplacement of the needles by obliterating the view of the "true" target, by means of their acoustic shadow.

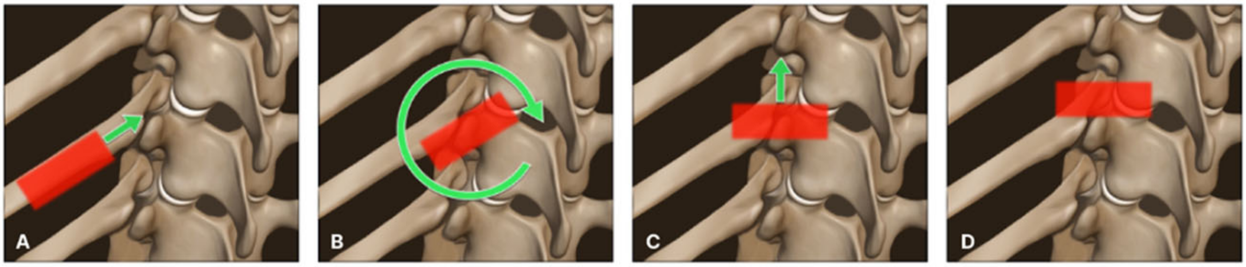

Figure 4. Step-by-step guide showing the translation of the ultrasound transducer. (**A**) Step 1, showing medial displacement of the transducer along the long axis of the rib until the transverse process appears at the center of the field of view. (**B)** Step 2, showing rotation of the transducer from the oblique plane of the rib to the axial plane keeping the transverse process in the center of the field of view. (**C**) Step 3, showing slight cephalad movement of the transducer. (**D**) Step 4, showing the final position of the ultrasound transducer over the costovertebral joint.

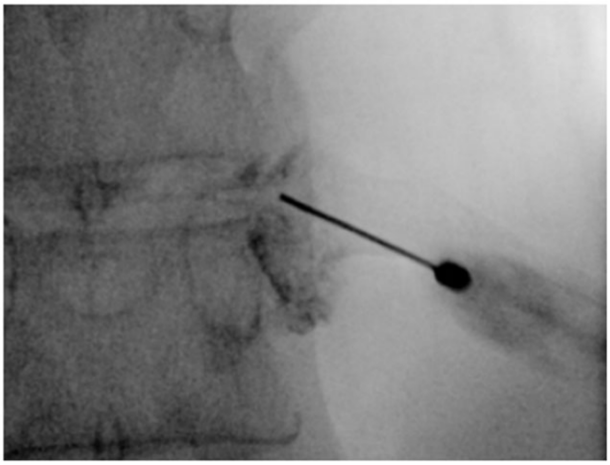

Figure 5. Antero-posterior fluoroscopic image showing intra-articular spread pattern of contrast within the costovertebral joint.

Figure 7. Computerized tomography image showing a needle correctly placed within the capsule of the costovertebral joint.

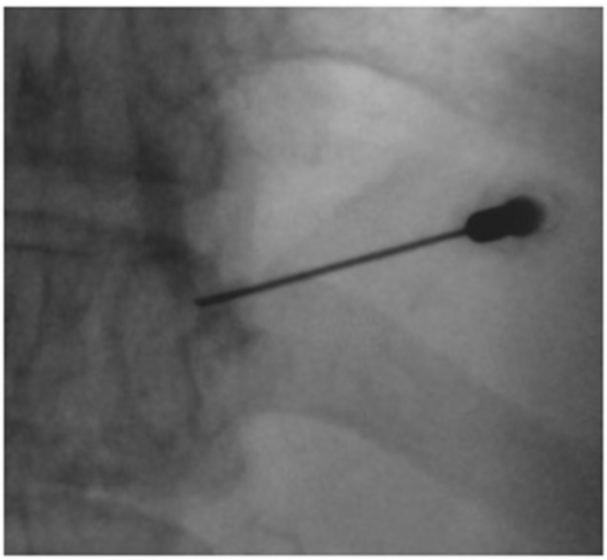

Figure 6. Example picture of a misplaced needle seen under fluoroscopy, showing epidural spread.

Finally, it should also be noted that, due to the intricate relation of the CVJ with the intervertebral disk between the two adjacent hemi-facets, from T2 through T10, there is also the risk of intradiscal injection. So as to avoid this, we recommend measuring the depth of the CVJ from the point of skin puncture, thus preventing insertion of the needle past that depth and inadvertent puncture of the disk. Likewise, although the risk of pneumothorax doesn't seem likely due to the medial orientation of the needle and US capability of visualizing the sliding of the pleuras, by taking the same preventive measure, this complication can be mitigated.

Conclusions

To our best knowledge, this is the first study in the literature to describe and analyze the feasibility of a US-guided technique for intra-articular injection of the CVJ in the thoracic spine.

This technique was found to have an overall 72% accuracy rate, when performed by an experienced interventionist (with more than 15 years of experience). However, the limitation in sample size impacts greatly the reproducibility of this study. As such, the true accuracy and safety of the technique when applied to the clinical setting cannot be extrapolated. This study should be considered preliminary, future studies are warranted in order to validate the overall accuracy and safety of this technique in the clinical setting, as well as to compare it to the traditional fluoroscopy-guided injection.

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