Cervical spine ultrasound: What should the radiologist know to perform interventional procedure?

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Learning objectives

• To learn the suggested technique for cervical spine ultrasound scanning.
• To get familiar with the normal ultrasound anatomy structures of the cervical spine and to recognize most common anatomical variants.
• To analyze possible applications of ultrasound in spinal procedures.

Background

Fluoroscopy is the standard imaging technique employed in spine interventions. Computed tomography (CT) is also largely used as an alternative guidance technique in cervical spine.

Due to its high spatial resolution and the lack of ionizing radiations, ultrasound (US) is gaining strong interest in spinal intervention. However, most of professionals performing spinal injections are unfamiliar with US imaging of the spine and have no or little experience in its application.

Findings and procedure details

EQUIPMENT AND TECHNIQUE

Cervical spine is a superficially structure that can be examined with ultrasound. Multifrequencies probes (use to be frequencies between 7 and 14 Mhz) allow to explore the cervical spine with high spatial resolution and sufficient penetration through the paravertebral tissue. Although the bone cannot be evaluated due to its strong ultrasound beam reflection, the cortical profile appears as a hyperechoic line with posterior acoustic shadowing.

Superficial landmarks can be used to guide the ultrasound exploration. The superior aspect of the thyroid cartilage corresponds to C4, the inferior tip of the mastoid process is situated just superiorly and laterally to the transverses processes of C1 and the spinous process of C7 (vertebra prominens) can be easily recognized at palpation (Fig 1).
For the purpose of ultrasound examination we can divide the cervical spine in three echographic regions or columns: an anterior column accessible by the anterior acoustic window with the patient in supine decubitus with the neck in hyperextension, a lateral column visible by the lateral acoustic window with the patient in lateral decubitus and a posterior column accessible by the posterior acoustic window with the patient lying in prone decubitus, with the neck in anterior flexion.

The echographic anterior column comprises the vertebras bodies, the intervertebral discs and the transverse processes. The lateral column comprises the neural foramina with its bony landmarks. The posterior column comprises the spinous processes, the lamina, the articular pillars and the lateral portion of the facet joints.

How ultrasound permit a dynamic exploration in combination with the movements of the patients, structures of the lateral columns can be visualized from an anterolateral or posterolateral windows, by moving the neck of the patient in a laterolateral direction. The anterolateral and posterolateral windows have the advantage of allowing a bilateral exploration of symmetric structures and the performance of bilateral interventions without moving the patient from a right to left lateral decubitus.

**ULTRASOUND ANATOMY OF THE CERVICAL SPINE**

Cervical spine with its osteochondral structures supports the weight of the skull through the vertebral body and intervertebral disks, gives protection to the spinal cord through its bony structures, and permits mobility through the discovertebral and zygapophyseal joints.

The cervical spine consists of 7 individual vertebrae, aligned in the sagittal plane with a physiological lordosis, characterized by a convex forward curvature, a secondary curvature that appears during the fetal period although it is fully developed only after birth.

A typical cervical vertebra comprises the vertebral body located anteriorly, the vertebral arch located posteriorly, the vertebral foramen, four articular processes, two transverse processes and a spinous process. The first two cervical vertebrae (C1 or Atlas and C2 or Axis) differ in size and shape from the five lower segments.

Cervical vertebrae between C3 and C7 have a vertebral body with a quadrangular morphology that gradually increases in size in caudal direction and exhibits superior projections, the unciform apophysis that articulates to the upper vertebral body to form the uncovertebral joints of Luschka (Fig 2).
The vertebral body presents a concave anterior surface, visible in anterior axial and longitudinal ultrasound scans, and a posterior flat surface which forms the anterior wall of the vertebral foramen and two horizontal surfaces, superior and inferior, which articulate to the adjacent vertebral bodies through the intervertebral discs.

The discovertebral joint is a symphysis which consists of a thin layer of hyaline cartilage covering the upper and lower platforms and intervertebral spinal disc (Fig 3).

The intervertebral discs are composed of a central gelatinous nucleus, the nucleus pulposus, and a peripheral ring of fibrocartilaginous tissue, the annulus fibrosus.

The vertebral arch is formed by two pedicles, robust bony cylinders which originate from the posterolateral portion of the vertebral body and that are only partially visible at the US exploration using an anterolateral axial or sagital scan through the homolateral neural foramen and project posteriorly to form the sidewalls of the vertebral foramen and two lamina, fine bony structures of flattened morphology originating bilaterally form the pedicles and that fuse at the midline to form the posterior wall of the vertebral foramen (Fig 4).

Neural foramen is a 4-5 mm long and 8-9 mm high bony canal through which the cervical nerve roots pass anterolaterally and is limited anteriorly by the vertebral body and the intervertebral disk, and posteriorly by the articular pillars and the yellow ligaments. The superior part of the neural foramen is mostly occupied by fat while the inferior third is occupied by the nerve roots. The dorsal root ganglions are located just outside the neural foramen in a notch in the superior facet. At US exploration cervical neural foramen and its content are generally evaluable performing anterolateral axial and parasagital scans with the patients in supine decubitus (Fig 5).

The four articular apophysis, two upper and two lower, originate from the posterolateral and anterolateral portions of the vertebral arch, respectively, at the junction between the pedicles and laminas. At the superior and inferior extreme, the articular apophysis have an articular facet covered by hyaline cartilage involved in the joint with adjacent vertebrae, forming diarthrodial joints involved in spinal movements, the zygapophyseal joints (facet joints).

With the patient lying in prone decubitus and the transducer positioned in an posterior sagital plane, joint spaces appear as anechoic spaces between the articular processes "saw sign". Alternatively, facet joint space can be visualized with the patient in lateral decubitus and the transducer positioned in an anterolateral axial plane (Fig 6).
Bone masses located between the superior and inferior articular processes of the vertebrae are referred as pars interarticularis, which along with the articular facet form a bone column, the articular pillar.

With the transducer positioned in the axial plane between two adjacent facet joints and the patient lying in prone or lateral decubitus the articular pillars appears as a curvilinear hyperechoic line. In longitudinal posterolateral ultrasound scans with the patient in prone or lateral decubitus, the facet joints and the articular pillars form a characteristic sequence of "hills" (facet joints) and "grooves" (articular pillars). The cervical medial branch of the dorsal rami of spinal nerves is located at the waist of the articular pillar and can be visualized with a careful ultrasound examination at the middle surface of the articular pillar between the multifidus and longissimus muscles in longitudinal or axial posterolateral scans with the patient lying in prone or in lateral decubitus. In the axial scan the medial branch appears as a round or ovoid hypoechoic structure (Fig 7).

Spinous processes are small and bifid between C2 and C6 and large and unique at C7 level (Fig 8).

Cervical transverse processes leave the lateral edge of the vertebral bodies and between C2 and C6 are characterized by the presence of anterior and posterior tubercles with a small osseous plate between them which contains the transverse foramen that allows the passage of the vertebral artery and vein. Typically C6 transverse process has a prominent anterior tubercle (Chassignac or carotid tubercle). The C7 transverse process has only a posterior tubercle, given it a unique morphology. The transverse process of C7 can be used as useful osseous landmark for identification of the roots of the brachial plexus by scanning the anterior cervical region in an axial plane.

At ultrasound examination with the patient in supine or lateral decubitus, nerve roots are visualized between the tubercles of the transverse processes as homogeneously hypoechoic structures with a rounded morphology in the axial anterolateral plane and an elongated shape in the longitudinal anterolateral plane. Color Doppler can help in differentiating neural structures from vascular structures. Since vertebral artery passes anteriorly to the posterior tubercle of C7 and enters the transverse foramen of C6, during the ultrasound scan, it can be correctly identify cervical spine level by following the vertebral artery in the caudocranial direction (Fig 9).

Images for this section:
Fig. 1: Superficial anatomical landmarks. Blue line corresponds to C1 and the inferior tip of mastoid process, red line corresponds to C4 and the superior aspect of thyroid cartilage and green line corresponds to C7 spinous process.

Fig. 2: CT reconstruction of a normal cervical vertebrae between C3 and C7.
Fig. 3: Anterior sagittal cervical ultrasound scan and schematic representation of discovertebral joint.

Fig. 4: Up: Posterolateral axial cervical ultrasound scan and schematic representation of the lamina (purple line) between the articular pillar (blue line) and the spinous...
process (green line). Down: Posterolateral sagittal cervical ultrasound scan and schematic representation of vertebrallamina (purple lines) and interlaminar space (blue lines).

**Fig. 5:** Ultrasound scan of cervical neural foramen in anterolateral parasagittal view.

**Fig. 6:** Up: Posterior sagital cervical ultrasound scan and schematic representation of zygapophyseal joints (saw sign). Middle: CT scan showing the zygapophyseal joints in
axial, coronal and sagital planes. Down: CT coronal and sagital reconstructions and schematic representation of zygapophyseal joints.

Fig. 7: Up: Posterolateral sagittal cervical ultrasound scan and schematic representation of the articular pillars (curvilinear purple line; "hills" are the facet joints and "grooves" are the articular pillars) and cervical medial branches of the dorsal rami of spinal nerves (green dots with white peripheral rings). Middle: Lateral axial cervical ultrasound scan and schematic representation of articular pillar (blue and green lines are the spinous process, purple line is the lamina, orange line is the articular pillar and the green line is the posterior tubercule of the transverse process). Down: CT scan showing the facet joints and articular pillars in axial and sagital, and CT coronal reconstruction with schematic representation of facet joints and articular pillars.
**Fig. 8:** Left: Posterior axial interspinous cervical ultrasound scan and schematic representation of vertebral foramen (red line is the posterior wall of the vertebral body, white circle is the cervical spinal cord and the blue circle is the thecal sac). Middle: Posterior sagittal cervical ultrasound scan and schematic representation (green lines) of spinous processes. Right: Posterior axial cervical ultrasound scan and schematic representation (green line) of C4 spinous processes.
**Fig. 9:** Up: Anterolateral axial cervical ultrasound scan and schematic representation of the ventral ramus of the spinal nerve (white ring is the ventral ramus of the spinal nerve, blue line is the anterior wall of the vertebral body and the purple line is the transverse process). Down: Anterolateral sagittal cervical ultrasound scan and schematic representation of the ventral ramus of the spinal nerve (parallels white lines) and transverse process (purple line).
Conclusion

Cervical spine ultrasound is a simple, non-invasive and low cost method to guide interventional procedures. Identifying normal anatomy, variants and adequate scanning technique will assess spinal interventionalists to utilize ultrasound in interventional spine procedures, without exposing patients and personnel to radiation.

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References