

Clinical anatomy and clinical significance of the cervical intervertebral foramen: a review

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The aim of this paper is to summarise the knowledge about the anatomy of the cervical intervertebral foramen as a whole. Such reviews are rare in the literature. The intervertebral or neural foramen is the opening between the spinal canal and the extraspinal region. It is located between the vertebral pedicles at all spinal levels. A number of structures pass through the foramen: nerves, vessels and ligaments. We describe the bony borders and dimensions of the foramen, the adjacent ligaments, the arteries and veins passing through or neighbouring it, and the neural components. Many procedures are performed in the area of the cervical intervertebral foramen. Knowledge of the anatomy of the foramen is essential in order to operate to the area and to minimize iatrogenic injuries. (Folia Morphol 2016; 75, 2: 143–148)

Key words: intervertebral foramen, neural foramen, cervical, anatomy, review

INTRODUCTION

The intervertebral or neural foramen is the opening between the spinal canal and the extraspinal region. It lies between the vertebral pedicles at all spinal levels [8, 10, 16]. Many studies have evaluated the vertebral body, spinal canal, and spinal cord [15, 26, 35]. However, an extremely limited number of studies have reviewed the complete anatomy of the cervical intervertebral foramen (Table 1) [8, 10, 25, 38, 40, 48]. In fact, there is only one review article describing the anatomy of cervical intervertebral foramen as a whole, which focused on vascularisation. The following review is a thorough anatomic description of the intervertebral foramen, with its contents, from C2 to T1 level.

THE BONY BORDERS OF THE INTERVERTEBRAL FORAMEN

The borders of the intervertebral foramen (Fig. 1) are inferiorly and superiorly the neighbouring pedi-

cles, posteriorly the medial aspect of the facet joint and the adjacent part of the articular column, and anteriorly the posterolateral aspect of the uncovertebral joint, the intervertebral disc, and the inferior part of the suprajacent vertebrae. The nerve root must cross three successive areas to go from the intradural to the extravertebral region [40, 48, 50]. Thus, the intervertebral foramen is divided into three anatomic regions: 1. *A medial area:* It is located within the medial orifice of the intervertebral foramen. 2. *A narrow intermediate area:* Actually, it constitutes the intervertebral foramen. 3. *A lateral area:* The spinal nerve rests in the groove of the transverse process [10].

These three areas create a canal of 20 mm in length. The intervertebral foramen is located anteriorly to the vertebral canal at an angle of 45° relative to the coronal plane [10, 19]. In other words, the intervertebral foramen is located anteriorly to the vertebral canal at an angle of 45° relative to the coronal plane [19]. Therefore, the oblique or axial views have

Table 1. Articles where the anatomy of cervical intervertebral foramen is described as a whole. Quantitative dimensional studies are not included

Article type	Study aim	Material	Date	Authors	Journal	Reference
Review	Anatomy of the foramina in the cervical and lumbar spines and of spinal cord vascularisation	Cadaveric, MRI	2012	Demondion et al.	Diagnostic and Interventional Imaging	[10]
Anatomic study	Correlative anatomic and MRI study of cervical neural foramina	MRI in cadavers and healthy volunteers, cadaver cryomicrotome sections	1988	Czervionke et al.	Radiology	[8]
Anatomic study	The anatomic relations of the foramina, nerve roots, and intradural rootlets	18 cadavers, surgical microscope	2000	Tanaka et al.	Spine	[48]
Surgical technique article	Short description of normal and pathological foraminal anatomy. Description of surgical technique	CT, drawing	2004	Russell et al.	Neurosurgery	[40]
Imaging anatomic study	Correlation of microtomy and CT anatomy	CT of 19 cervical spine specimens	1985	Pech et al.	Radiology	[38]
Imaging anatomic study	Normal spinal anatomy as defined by MRI. A short description of normal anatomy of the cervical neural foramina	MRI	2011	Jindal and Pukenas	Magnetic Resonance Imaging Clinics of North America	[25]

CT — computed tomography; MRI — magnetic resonance imaging

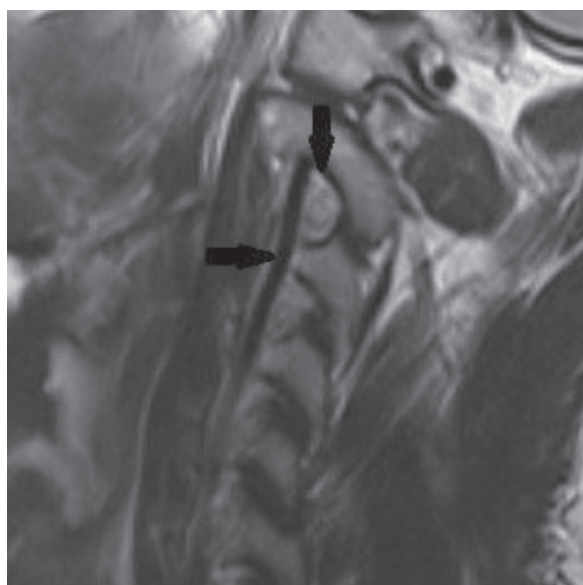


Figure 1. Magnetic resonance imaging of the cervical spine, sagittal T2-weighted image. Arrow pointing down: cervical intervertebral foramen. Arrow pointing right: vertebral artery.

greater confidence rates than the sagittal views, in order to evaluate the presence of foraminal stenosis or of a disc herniation [17, 25, 36, 37, 44].

Other researchers divide the intervertebral foramen into two anatomic zones: *the entrance zone* (medial half of the intervertebral foramen) and *the exit zone* (lateral half of the intervertebral foramen) [48]. The cervical nerve groove is also divided into three zones: a medial zone (pedicle), a middle zone (vertebral artery foramen), and a lateral zone [11]. The first intervertebral space is not a real foramen, because there is not any bone structure posteriorly [5, 31].

Dimensions of the intervertebral foramen

The intervertebral foramen is ovoid in shape [29]. The normal foramen height is 11.08 ± 1.88 mm, width 5.69 ± 1.91 mm, and foramen area 5.61 ± 1.83 mm² [45]. The largest foraminal area is at level C2–C3, and the smallest at C7–T1. The width of the foramina is approximately one half its height [29]. The minimum width of the medial zone of the nerve groove is 1–2 mm for all levels [11].

Cervical intervertebral foramina are larger in healthy than in symptomatic people. Foraminal height changes with age and width decreases with age [23]. Foraminal height and width increase from the upper to the lower intervertebral foramina, except at C2–C3.

Females show larger values for intervertebral foramen width than males [11].

Dimensions and movement

Understanding the effects of cervical position on intervertebral foraminal size is important in the assessment of pathology and injury [53]. Flexion increases the foraminal height width and foraminal area. Extension decreases them [27, 33, 41]. After cervical retraction, dimensions of the cervical neural foramina show no significant change, except at C3–C4 [29]. Cervical traction causes widening of the cervical neural foramina and reduction of the intradiscal pressure [42]. The foraminal area and height are increased [30].

THE LIGAMENTS OF THE INTERVERTEBRAL FORAMEN

The radicular nerves are covered by the radicular sheath. The radicular sheath continues as the perineural investment of the radicular nerve. It blends with the periradicular fibrous tissue from the posterior longitudinal ligament. More laterally, it continues as the fibrous investment of the vertebral artery [48].

The ligamentum flavum

The lateral border of the spinal canal is covered posteriorly by the lateral aspects of a superior and inferior lamina. Anterior to the lamina, the ligamentum flavum is attached to two-thirds of the inferior-surface of the superior lamina, but inferiorly it is attached only to the superior border of the inferior lamina. More lateral, the ligamentum flavum ends 1–2 mm before the medial border of the neural foramen [40].

Extraforaminal ligaments of the cervical spinal nerves

Direct ligamentous structures exist between extraforaminal cervical spinal nerves and nearby structures. They are divided into radiating ligaments and transforaminal ligaments [43].

Radiating ligaments consist of a ventral and dorsal part. The ventral and dorsal extraforaminal ligaments also consist of a superior and inferior part. The inferior ventral and dorsal ligaments are attached to each other [28, 43].

Transforaminal ligaments [2, 7] can be found in the cervical spine [1]. They originate from the antero-inferior margin of the superior transverse process and insert into the superior margin of the anterior tubercle of the inferior transverse process. They orientate to the

longitudinal direction of the spinal nerves and cross them ventrally. The posterior side of the transforaminal ligaments is strongly adherent to the spinal nerve sheath. Usually, an intervertebral foramen contains no more than one transforaminal ligament [43].

The posterior longitudinal ligament and the perivascular fibroligamentous tissue

The unciniate process and its covering ligaments are barriers that prevent the nerve root and the vertebral artery against damage [51]. The posterior longitudinal ligament lies posteriorly of the vertebral bodies and has two loosely connected layers named the anterior layer and the posterior layer [6, 20]. It is recognised by surgeons to protect the neural and vascular structures.

The posterior longitudinal ligament also separates into two fibroligamentous parts at the posterior corner of the unciniate process. It is called the perivascular fibroligamentous tissue. It covers the lateral aspect of the unciniate process and the vascular content of the transverse foramen. A venous plexus lies between the two layers of the posterior longitudinal ligament, at the transition from posterior longitudinal ligament to the perivascular fibroligamentous tissue [21, 51, 52].

ARTERIAL VERTEBRAL SYSTEM

The radiculomedullary arteries

The radicular artery divides into an anterior and a posterior radicular artery. The radicular arteries course along the anterior side of the accompanying roots. Only one artery out of eight to ten reaches the spinal cord [10]. From the intervertebral foramina aspect, five radicular arteries (C5, C6, two at C7, C8) enter the foramina, either anteriorly or posteriorly, to supply the anterior and posterior spinal arteries [22].

Vertebral, ascending cervical and deep cervical artery

The vertebral artery (Fig. 1) is the parent vessel for several segmental medullary vessels, which branch from the medial surface of the vessel [4, 18, 19, 24, 47]. If the ascending cervical artery supplies a spinal branch, it occurs at the C3–C4 or C4–C5 foramen, and the spinal branch enters the posterior-inferior aspect of the external intervertebral foraminal opening [24]. The deep cervical artery often gives branches to the roots of the brachial plexus or muscles. In some instances, the vessel forms spinal branches and enters

the posterior aspect of the intervertebral foramen, directly posterior to the exiting ventral ramus. These cervical spinal branches always enter at C5–C6, C6–C7 or C7–T1 level [24].

THE VEINS

The upper half of the intervertebral foramen contains fat and small veins [9, 48]. The abundant epidural veins in the cervical region, communicate with the venous plexuses located around the vertebral artery [10]. Blood is drained by vessels that flows into the perimedullary veins. There are two pathways at these veins [38]. The epidural venous plexuses are in communication with the extravertebral system through the intervertebral foraminal veins, by two veins [6, 10, 12]. The spinal roots are covered by veins, which have a horizontal course to the vertebral vein. The anterior spinal vein is located at the median fissure along the spinal artery and is large at the cervical level [6].

THE NERVES

The nerve roots

The shape of the intervertebral foramina approximates a funnel [48]. As the nerve roots pass through the intervertebral foramen they are found in the lower third of the foramen [10, 19].

The cervical nerves result from the junction of an anterior and a posterior root (Fig. 2). The anterior (motor) root is thin, and consists of four to seven rootlets from the anterior collateral sulcus of the spinal cord. It has close connections with the vertebral uncus anteriorly and with the pedicle of the vertebra inferiorly. The posterior (sensory) root, is three times larger than the anterior root, and is composed of four to ten rootlets that penetrate the posterior collateral sulcus. It is located posteriorly and superiorly to the anterior root [38]. The cervical nerve roots extend anterolaterally at a 45° angle to the coronal plane and inferiorly at about 10° to the axial plane [9]. The radicular nerve occupies one fourth to one third of the intervertebral foramen diameter [48]. The dorsal and ventral roots of the C3–C7 nerves are situated in a groove described above [11, 48].

Each of the C5–C8 ventral root contains 14 to 23 bundles of rootlets, and each dorsal root consists of eight to 12 bundles rootlets. The ventral and dorsal rootlets disconnect from the spinal cord approximately one disc level higher than the corresponding intervertebral foramen [48].

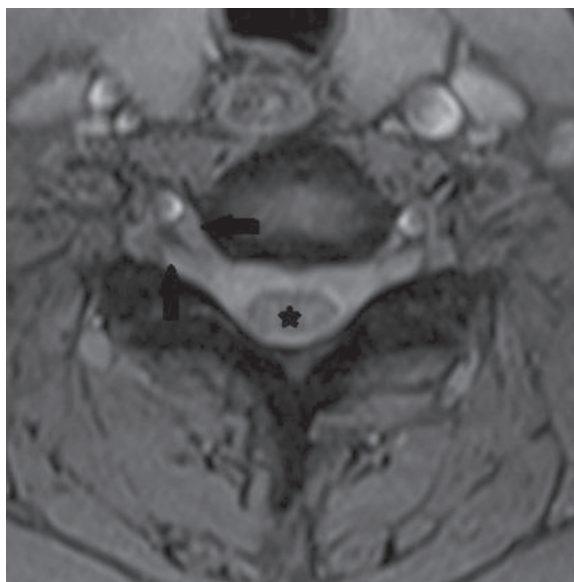


Figure 2. Magnetic resonance imaging of the cervical spine, axial T2-weighted image. Arrow pointing left: anterior nerve root. Arrow pointing up: posterior nerve root and ganglion. Star: spinal cord.

Nerve and meningeal relations

The neural structures and their surrounding connective tissue fill 35% to 50% of the cross-sectional area of the intervertebral foramen. Only the fourth, fifth, and sixth cervical spinal nerves have a strong attachment to the vertebral column, and this is to the gutter of the vertebral transverse process [13, 46, 49].

Each pair of ventral and dorsal nerve roots invaginate the arachnoid and the dura to form a funnel-shaped depression in the wall of the dural sac. Some nerve roots first descend intradurally to up to 8 mm below the centre of the foramen. At this level, they perforate the arachnoid and dura [13, 14, 32]. The nerve roots are angulated at the site at which they pass through the dura [49].

The dorsal root ganglion

The spinal ganglion is a spindle-shaped swelling that each posterior root carries, and contains the cell bodies of the sensory neurons. It lies outside the neural foramen between the vertebral artery and a small concavity in the superior articular process [5, 9, 10, 31, 39, 49].

CONCLUSIONS

Many procedures are performed in the area of the cervical intervertebral foramen. Cervical foraminotomy and placing lateral mass screws are performed

for frequently. However, anatomic reviews have not described the anatomy of the foramen thoroughly [3, 11, 48]. Knowledge of the anatomy of the foramen is also essential to all radiologists performing interventional procedures in order to avoid iatrogenic risks. The cervical intervertebral foramina are the most frequent sites of injections performed by radiologists [10, 21, 24]. Dimensions of intervertebral foramina are clinically important in the diagnosis of foraminal stenosis and radiculopathy [11, 34].

In conclusion, surgeons have to fully understand the three-dimensional anatomy of the cervical intervertebral foramen in order to conduct an optimal surgical procedure [40].

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