2 Cervical Spine

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Summary
The subaxial cervical spinal anatomy is critical to understand to safely navigate the neurovascular and bony anatomy during surgery. This is a common area for trauma and degenerative spinal disease, in particular. Fixation options must consider not only the bony structures and neural elements, but also the vertebral arteries. Additionally, the brachial plexus is intimately associated with the cervical spine.

Keywords: cervical spine, vertebral artery, brachial plexus

2.1 Key Points

- The subaxial cervical spine includes C3 to C7.
- The cervical spine, like the lumbar spine, normally demonstrates lordotic curvature (**Fig. 2.1**).
- Posterior instrumentation often uses lateral mass screws because the pedicles are narrower than in the thoracic and lumbar spine, increasing the risk of neurovascular injury.
- The size and volume of lateral masses decrease from the upper to lower subaxial cervical spine.
- The primary blood supply to the cervical spine is via the anterior spinal artery (ASA) and two posterior spinal arteries (PSA).

2.2 Bony Anatomy

2.2.1 Bony Landmarks

- Radiographic landmarks[1]: C3 is at the hyoid, C4 is at the thyroid cartilage, and C6 is at the cricoid cartilage.
- Palpable landmark: The anterior tubercle of the C6 transverse process (Chassaignac tubercle) is palpable.

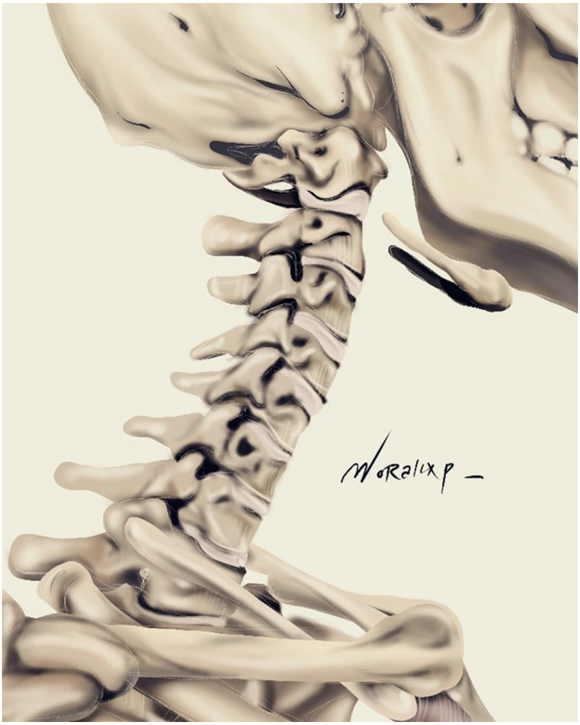

Fig. 2.1 A lateral view of the cervical spine demonstrating a lordotic curvature. (Copyright of Chiang Mai.)

2.2.2 Vertebrae Anatomy

- In the coronal plane, uncovertebral joints are noted at the anterolateral aspect of the vertebral body (**Fig. 2.2**), formed by uncinate processes of the vertebral bodies.
- Lateral masses of the subaxial spine are composed of the superior and inferior articulating processes (the facet joint).
- A lateral mass begins lateral to where the lamina and pedicle meet, helping to form the intervertebral foramen with the uncovertebral joint.
- Cervical foraminal stenosis and concurrent radiculopathy are frequently caused by degeneration of the facet or uncovertebral joints and their proximity to intervertebral foramina.
- The transverse foramen is lateral to the vertebral body and anterior to the nerve root groove.
- Anterior and posterior tubercles are noted along the transverse process.

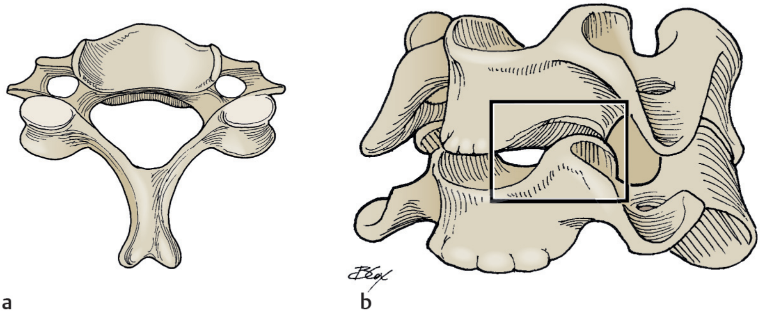

Fig. 2.2 Cervical vertebrae: **(a)** superior and **(b)** oblique views.

2.2.3 Geometric Measurements

- The spinal canal is triangular and has a greater lateral than anteroposterior (AP) dimension.
- The AP diameter of the spinal canal decreases caudally[2]: 17 mm at C3, 15 mm at C7.
- The width of vertebral body is usually 17 to 20 mm.
- Pedicles measure 5.1 to 9.5 mm in height and 3.0 to 7.5 mm in width.
- C7 is a transitional vertebra: The lateral mass is thinner and the pedicle wider than in C3 to C6.
- The normal lordotic curvature of the cervical spine is 16 to 25 degrees.[3]

2.2.4 Biomechanics and Mobility

- Biomechanical studies show maximal flexion–extension at C4/C5 and C5/C6 and maximal lateral bending at C2/C3, C3/C4, and C4/C5.
- The least mobile segment is C7/T1.
- Cervical disk herniation occurs most frequently at C5/C6 and C6/C7.

2.3 Neural Anatomy

2.3.1 Geometric Orientation

- C3 to C7 nerve roots exit above their corresponding level (e.g., C7 exits above the C7 pedicle).
- Cervical disk herniation is most frequently posterior–lateral and compresses the nerve associated with that level (e.g., C5–C6 herniation impinges on the C6 nerve).

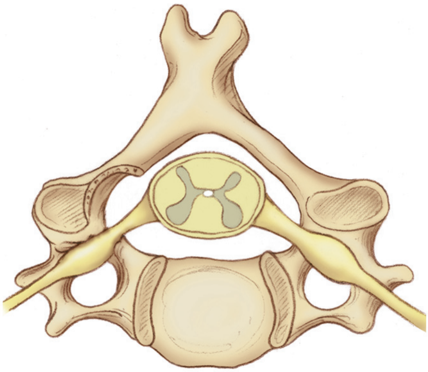

Fig. 2.3 A cervical vertebra with nerve roots exiting anterolaterally to the superior joint facet. (Reproduced with permission from Posterior Cervical Foraminotomy. In: Fessler Procedures. Thieme; 2006.)

- The C8 nerve root exits above the T1 pedicle.
- The cervical spinal cord enlarges caudally and reaches a maximal cross-sectional area at C6.
- Nerve roots enter the intervertebral foramina laterally, occupy approximately a third of the foramina, and are covered by epidural fat and venous plexus above.
- Nerve roots exit the spine at a point anterolateral to the superior joint facet (**Fig. 2.3**).

2.3.2 Cervical Plexus and Phrenic Nerve

- The cervical plexus is formed by the anterior rami of C1 to C4.
- The cervical plexus gives rise to (1) the ansa cervicalis (supplies a branch to the hypoglossal nerve and innervates the strap muscles, except for the thyrohyoid), (2) phrenic nerve (C3 to C5, but mainly C4), and (3) cutaneous nerves of the posterior head and neck.
- The phrenic nerve is formed by the anterior rami of C3 to C5 and innervates the diaphragm.

2.3.3 Brachial Plexus

- The brachial plexus is formed by the anterior rami of C5 to T1 and provides sensory and motor innervation to the upper extremity.[4]
- The brachial plexus gives rise to the (1) axillary nerve (C5 and C6 nerve roots), (2) radial nerve (C5–T1 nerve roots), (3) musculocutaneous nerve (C5–C7 nerve roots), (4) median nerve (C6–T1), and (5) ulnar nerve (C8–T1) (**Fig. 2.4**).

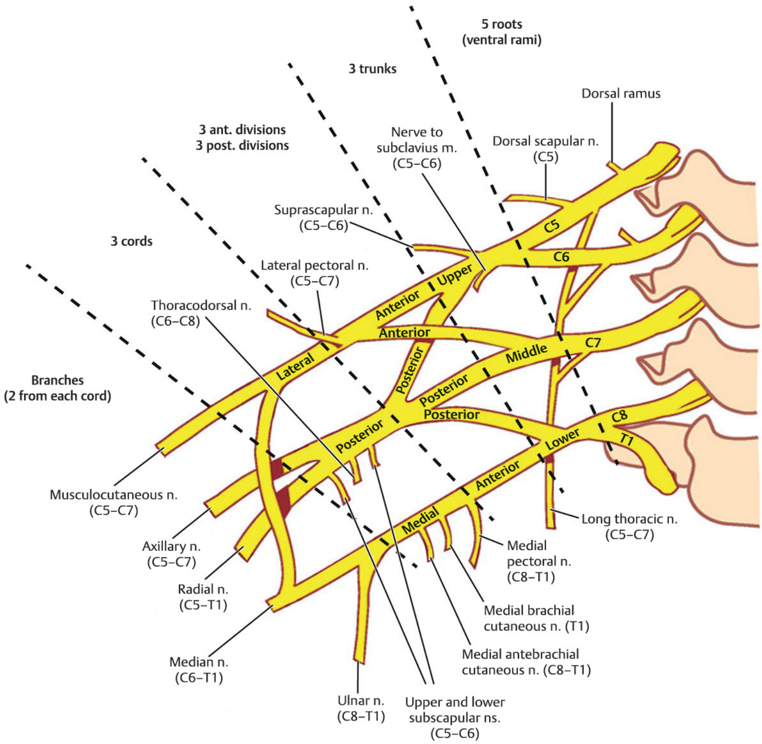

Fig. 2.4 The brachial plexus, demonstrating the relationship between the cervical nerve roots and cervical vertebrae. (Reproduced with permission from Albertstone CD, Benzel EC, Najm IM, Steinmetz M, eds. Anatomic Basis of Neurologic Diagnosis. New York, NY: Thieme; 2009.)

- Sensory and motor neurons from brachial plexus nerve roots correspond to an upper extremity dermatome and myotome respectively.
- Upper, middle, and lower trunks of the brachial plexus exit between the anterior and middle scalene muscles, cephalad and posterior to the subclavian artery as it passes posterior to the first rib.

2.3.4 Sympathetic Ganglia

- Three major sympathetic ganglia rest outside the cervical column, behind the carotid sheath: (1) The superior cervical ganglion lies along the sympathetic trunk from C1 to C4 and carries the sympathetics for the head and neck traversing along the carotid artery. (2) The middle cervical ganglion is located at C5 to C6 (also targeting the head and neck). (3) The stellate ganglion extends from C7 to T1.

2.4 Vascular Anatomy

2.4.1 Vertebral Artery Segments: V1 to V4

- Vertebral artery segments: V1 (preforaminal)—origin to transverse foramen entrance; V2 (foraminal)—C6 to C2; V3—C2 to dura; V4—intradural segment to basilar artery.
- Vertebral arteries usually originate from the subclavian artery and ascend between the anterior scalene and longus colli muscles (V1).[5]
- Vertebral arteries enter the cervical spine at the transverse foramen of C6 (V2) (**Fig. 2.5**) and travel posterior to the longus colli becoming more medial and dorsal as they move cephalad.
- The anterior spinal artery originates from the vertebral arteries just prior to the formation of the basilar artery at the pontomedullary junction (V4).
- The two posterior spinal arteries most commonly originate from the vertebral arteries but can also arise from posterior inferior cerebellar arteries (PICA).
- The anterior spinal artery and the two posterior spinal arteries enter the vertebral canal through the foramen magnum.

2.4.2 Blood Supply to Spinal Cord

- Blood supply to spinal cord includes the anterior spinal artery, the two posterior spinal arteries, and the segmental medullary arteries.
- The anterior spinal artery is found in the ventral median fissure.
- The posterior spinal arteries are found in the posterolateral sulci of the spinal cord.

2.4.3 Venous Drainage

- Venous drainage of the spinal cord includes three anterior and three posterior longitudinally running veins.
- Spinal cord is surrounded by an anterior venous plexus and a posterior venous plexus.
- The anterior venous plexus is most pronounced medial to the pedicles.

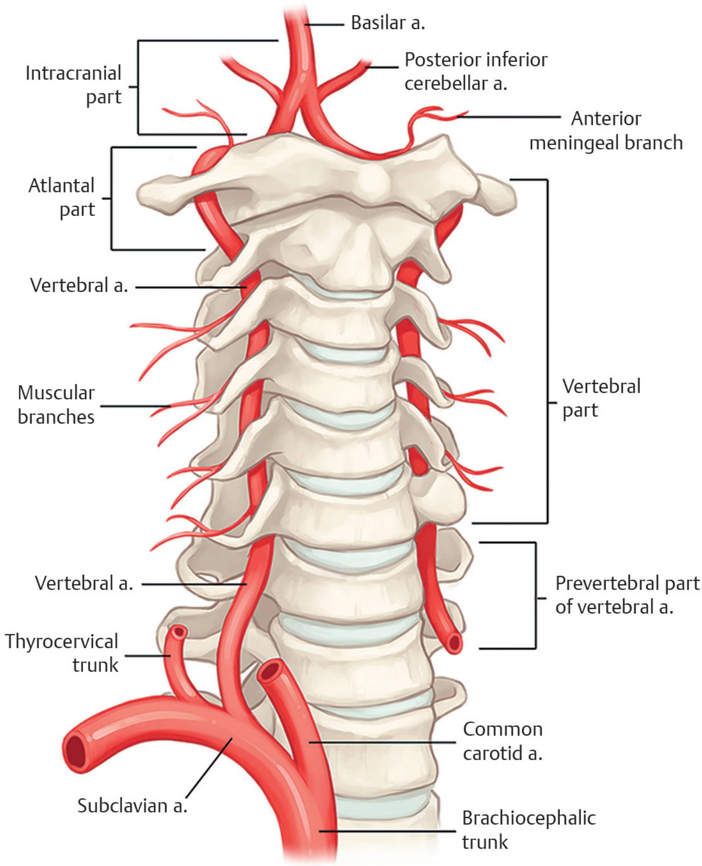

Fig. 2.5 The anatomy of the vertebral artery, emphasizing the relationship to the transverse foramina of the cervical vertebrae. (Reproduced with permission from Singh K, ed. Spine Essentials Handbook: A Bulleted Review of Anatomy, Evaluation, Imaging, Tests, and Procedures. New York, NY: Thieme; 2019.)

2.4.4 Transverse Foramen and the Vertebral Artery

- At C3 to C5, the lateralmost aspect of the transverse foramen is often anteromedial to the midpoint of the lateral mass.
- At C6 to C7, a portion of the transverse foramen is often anterior to the midpoint of the lateral mass.

2.5 Ligamentous and Muscular Anatomy

2.5.1 Ligamentous Anatomy

- The anterior longitudinal ligament covers anterior vertebral bodies, resists hyperextension, and widens as it descends.
- The posterior longitudinal ligament covers posterior vertebral bodies and resists hyperflexion.
- The interspinous and supraspinous ligaments run between adjacent spinous processes and form the ligamentum nuchae.
- The ligamentum nuchae makes up the midline avascular plane.
- The ligamentum flavum runs posteriorly to the spinal canal and connects the lamina of the sub-axial adjacent vertebra.

2.5.2 The Carotid Triangle

- The carotid triangle of the neck is an important surgical landmark for anterior approaches, formed laterally by sternocleidomastoid, superiorly by dorsal portion of the digastric, and anteriorly by omohyoid (**Fig. 2.6**).
- The carotid triangle contains the carotid sheath (common carotid artery, internal jugular vein, and vagus nerve). The artery is anteromedial, the vein is anterolateral, and the nerve runs posteriorly between the artery and vein.
- After bifurcation of the common carotid, the external branch exits the sheath, whereas the internal branch continues within.

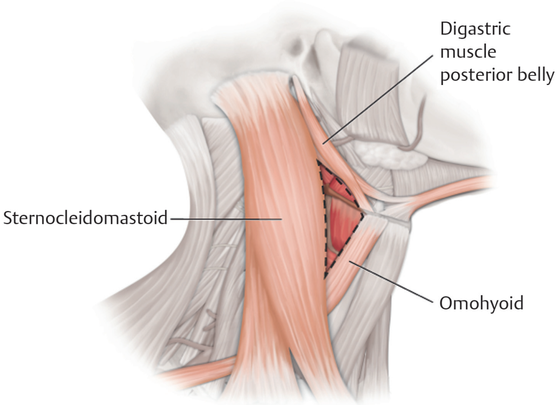

Fig. 2.6 The carotid triangle, with borders depicted. (Reproduced with permission from Kim D, Choi G, Lee S, Fessler R, eds. Endoscopic Spine Surgery, 2nd Edition. New York, NY: Thieme; 2018.)

2.5.3 Muscular Anatomy

- Longus colli muscles lie anterolateral to vertebral bodies and are elevated during anterior spinal procedures.
- Three scalene muscles lie lateral to vertebral bodies and connect vertebrae to the first two ribs.
- The anterior scalene muscle originates from the anterior tubercles of the transverse processes of C3–C6 and elevates the first rib.
- The middle scalene muscle originates between the anterior and posterior tubercles of C2–C7 and elevates the first rib.
- The anterior and middle scalene muscles form the fissure scalenorum for passage of the brachial plexus.
- The posterior scalene muscle originates from the posterior tubercles of the transverse processes of C5–C7 and elevates the second rib.
- The sternocleidomastoid muscle lies superficial to the scalene and longus colli muscles and is innervated by the spinal accessory nerve and the cervical plexus.
- The semispinalis capitis and semispinalis cervicis span the posterior aspect of the cervical spine.

2.6 Variations in Anatomy

- About 28 to 40% of patients have a prefixed brachial plexus, which involves C4–T1. In this population, C4 partially innervates the deltoid.[6]
- About 0.4 to 5% of patients have a post-fixed brachial plexus, which involves C5–T2. In this population, T2 affects hand function.[6]
- About 0.58 to 6.2% of patients have a cervical rib, which is an accessory rib stemming from C7. This may predispose to thoracic outlet syndrome due to compression of the subclavian artery and/or brachial plexus.[7]
- About 4 to 84% of patients have an accessory phrenic nerve. This nerve has variable origins, but usually arises from either the ansa cervicalis (approximately 16.5% of patients), subclavian nerve (approximately 15.8% of patients), or C5/C6 nerve roots (approximately 15.1% of patients).[8]

2.7 Surgical Pearls

- Uncovertebral joints provide several surgical landmarks: They define the lateral borders for corpectomy or diskectomy, and they define the midline for cervical plate placement.
- The Magerl technique for lateral mass screw placement is used to avoid injuring the vertebral artery or nerve root. The drill is placed 1 mm medial to the midpoint of the lateral mass and is angled 25 degrees laterally and 30 degrees superiorly.

- During anterior procedures, instruments are most safely inserted into the lateral aspect of the canal.
- During posterior cervical procedures, the patient can be placed in a slight reverse Trendelenburg position to reduce venous engorgement.
- C7 is a transitional-level vertebra. For a posterior fusion involving C7, some surgeons advocate extending the fusion to T1 to reduce adjacent-level disease.

Common Clinical Questions

1. At what level does cervical disk herniation most often occur?
2. What is the normal curvature of the cervical spine?
3. Which arteries provide the majority of blood circulation to the spinal cord?
4. What are the location and clinical significance of the vascular watershed in the cervical spine?
5. The vertebral artery travels through which transverse foramina?
6. A patient presents with pain in the cervical spine with nonlocalizable, diffuse radiation to the left upper extremity. Examination reveals weakness of left shoulder abduction from 15 to 90 degrees. MRI of the cervical spine demonstrates C3–C4 disk herniation. Why are the examination and imaging findings inconsistent?

Answers to Common Clinical Questions

1. C5/C6 and C6/C7.
2. The cervical spine normally has a lordotic curvature between 16 and 25 degrees.
3. The spinal cord is supplied by the anterior spinal artery (from the vertebral arteries), two posterior spinal arteries (from either the vertebral arteries or PICA), and segmental medullary arteries.
4. The watershed exists between the base and apex of the odontoid process. The limited blood supply between the distributions of the internal carotid artery and vertebral artery may impair healing in fractures of the odontoid process.
5. Typically, the vertebral artery travels through the transverse foramina of C1–C6. In up to 10% of patients, there may be anatomical variation in which the vertebral artery takes an atypical course. A common variation is that the vertebral artery travels through the foramen of C7. Absent, hypoplastic, triple, and open foramen are additional anatomical variations.
6. The patient most likely has a prefixed brachial plexus, an anatomical variation. The C4 nerve partially innervates the deltoid muscle in this patient.

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