1 Cervical Anatomy

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Introduction

This chapter provides an overview of the structures that make up the neck. Included among these structures are the cervical vertebrae, soft tissue structures, muscles, and vascular and lymphatic structures. Additionally, a detailed review of the neurological structures of the central nervous system, the peripheral nervous system, and the autonomic nervous system that reside in the neck is provided. The anatomical groundwork that is established in this chapter will allow for an enhanced understanding of the pathological conditions discussed throughout the book.

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Vertebrae

The cervical spine is the most superior portion of the vertebral column, located between the cranium and thoracic spine. There are seven cervical vertebrae referred to as C1–C7. The cervical spine is divided into two major segments: the craniocervical junction (CCJ) and the subaxial spine. The CCJ includes the occiput and the two most cranial cervical vertebrae known as the atlas (C1) and the axis (C2). The subaxial spine contains the remaining cervical vertebrae (C3–C7) [1].

The atlas (C1) is a ring-like, kidney-shaped bone that lacks a spinous process and consists of two lateral masses connected by anterior and posterior arches. Its concave superior articular facets receive the occipital condyles. The axis (C2) contains the dens, also known as the odontoid process, which extends superiorly from the anterior portion of the vertebra. The dens articulates with the anterior arch of C1, forming the atlanto-axial joint. This joint allows for rotation of the head independently of the torso [1].

The average range of motion of the cervical spine consists of: 65 degrees of flexion, 40 degrees of extension, 35 degrees of lateral flexion, and 35 degrees of rotation. Among these numbers, the atlanto-occipital joint is responsible for 20 degrees of flexion, 10 degrees of extension, and 5 degrees of lateral flexion. The atlanto-axial joint is responsible for 35 degrees of rotation [1].

The subaxial spine contains the five most caudal cervical vertebrae (C3–C7). The four typical cervical vertebrae (C3–C6) have the following characteristics [1]:

- The vertebral body is small and longer from side to side than anteroposteriorly; the superior surface is concave, and the inferior surface is convex.
- The vertebral foramen is large and triangular.
- The superior facets of the articular processes are directed superoposteriorly, and the inferior facets are directed inferoposteriorly.

The atypical cervical vertebrae of the subaxial spine, C7, have a singular and very long spinous process. This is the first spinous process that is distinctly palpable through the skin, known as the prominens, which closely resembles the thoracic vertebrae.

The cervical transverse processes consist of an anterior and a posterior bar, which terminate laterally in two small tubercles (anterior and posterior tubercles). These bars encompass the transverse foramen. Injury to this part of the cervical spine can be very severe, as the transverse foramen gives passage to the vertebral artery, vein, and sympathetic plexus to ascend from the C6 to the C1 level (Fig. 1.1).

The cervical spine is responsible for supporting the weight of the cranium, protecting the spinal cord extending from the brain, and cushioning loads while allowing for various movements of

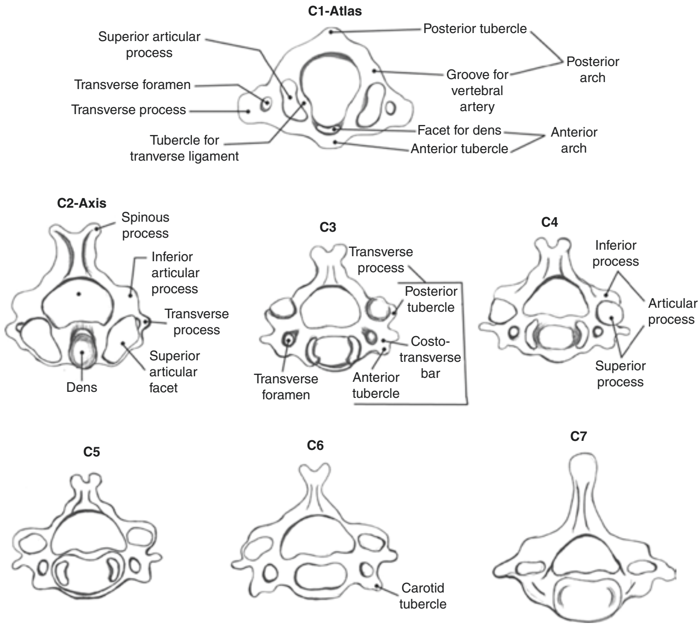

Fig. 1.1 Axial views of cervical vertebrae C1–C7 (From [8])

the head and neck. There are eight pairs of cervical nerves that emerge from the spinal cord superior to their corresponding vertebrae, except for C8 that exits inferiorly to the C7 vertebra. This is unique compared to the thoracic and lumbar nerves which exit below their corresponding vertebrae [1, 2].

The hyoid bone lies in the anterior part of the neck at the level of the C3 vertebra in the angle between the mandible and the thyroid cartilage. The hyoid is suspended by muscles that connect it to the mandible, styloid processes, thyroid cartilage, manubrium of the sternum, and scapulae. The hyoid is unique among bones for its isolation from the remainder of the skeleton. Functionally, the hyoid provides a movable base for the tongue and attachment for the middle part of the pharynx. The hyoid also maintains the patency of the pharynx, required for swallowing and respiration [1].

Soft Tissue

Structures in the neck are surrounded by a layer of subcutaneous tissue (superficial fascia) and are compartmentalized by layers of deep cervical fascia. The cervical subcutaneous tissue contains cutaneous nerves, blood and lymphatic vessels, superficial lymph nodes, and variable amounts of fat. Anterolaterally, it contains the platysma. The platysma is a broad, thin sheet of muscle in the subcutaneous tissue of the neck that tenses the skin, producing vertical skin ridges and releasing pressure on the superficial veins. It is innervated by the cervical branch of the facial nerve, CN VII. Damage to this branch can cause paralysis of the platysma causing skin to fall away from the neck in slack folds.

The deep cervical fascia supports the cervical viscera (e.g., thyroid gland), muscles, vessels, and deep lymph nodes. The deep cervical fascia surrounds the common carotid arteries, internal jugular veins (IJVs), and vagus nerves to form the carotid sheath. The deep cervical fascia also aligns into natural planes through which tissues may be separated during surgery. In addition, this layer plays a role in limiting the spread of abscesses (collections of pus) resulting from infections to this area [1, 2].

Muscles

The cervical muscles work together with tendons and ligaments to support and move the neck and head. Common muscles involved with neck pain include the sternocleidomastoid, trapezius, levator scapulae, scalenes, deep cervical flexors, erector spinae, and suboccipital muscles.

The sternocleidomastoid muscle (SCM) attaches to the bony mastoid process on the skull and attaches anteriorly to the sternum and collarbone. The SCM helps in head rotation and tilting the chin and protects the inner structures of the neck. The head rotates away from the side of the contracting SCM. It is innervated by cranial nerve XI, known as the spinal accessory nerve, which is the only cranial nerve to both enter and exit the skull. This nerve also innervates the trapezius muscle.

The trapezius is a large surface muscle that attaches to the medial third of superior nuchal line; external occipital protuberance, *nuchal ligament*, and spinous processes of C7–T12 vertebrae. The trapezius is composed of three parts: descending, ascending, and transverse. The descending part of the trapezius muscle supports the arms. The transverse part retracts the scapula, and the ascending part medially rotates or depresses the scapula. Due to its upper attachment to the occiput and lower cervical *vertebra*, it can easily be injured in patients suffering from *whiplash injury* [1, 2].

The levator scapulae muscle attaches to the transverse processes of the first four cervical vertebrae and descends laterally to insert at the superior angle and medial border of the scapula, between the superior angle and base of the spine of the scapula. It is innervated by the anterior rami of spinal nerves C3 and C4. This muscle helps with lifting the shoulder blade, lateral bending of the neck, and rotation of the head [5, 6].

The scalene muscles are three pairs of lateral neck muscles that connect the mid and lower cervical spine with the top of the rib cage. The anterior and middle scalene muscles attach to the first rib, while the posterior scalene attaches to the second rib. The scalene muscles help with neck flexion and side bending. These muscles are innervated by the anterior branches of the cervical spinal nerves from C3 to C8 (Fig. 1.2).

The deep cervical flexor muscles of the anterior neck consist of the longus colli and longus capitis. These muscles help flex the neck forward as well as stabilize the cervical spine. The longus colli muscle is innervated by the anterior rami of the C2–C6 spinal nerves. The longus capitis muscle is innervated by the anterior rami of the C1–C3 spinal nerves.

The erector spinae are a group of many muscles that attach along the back of the spine. The three main muscles of this group include: spinalis, longissimus, and iliocostalis. In the cervical spine, the erector spinae muscles play key roles in posture, rotation of the neck, and neck extension. These muscles are innervated by the dorsal rami of the first cervical nerve (C1) through the fifth lumbar nerve (L5) [1, 2].

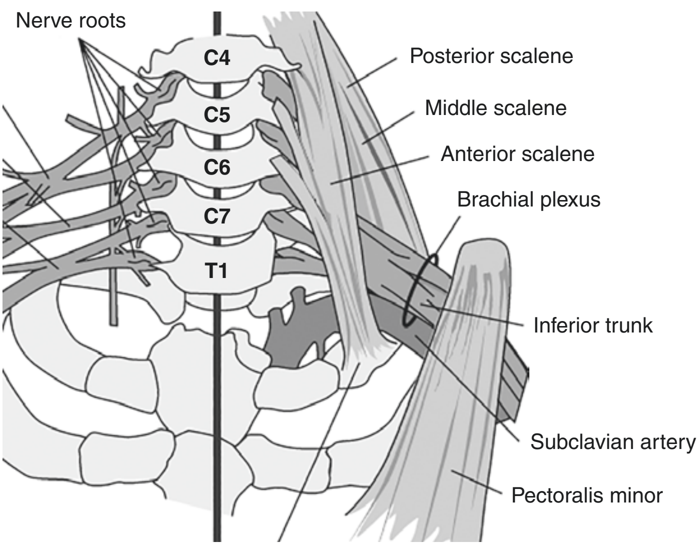

Fig. 1.2 Cervical nerve roots and scalene muscles. (From [8])

The suboccipital muscles are four pairs of small muscles that connect the top of the cervical spine with the base of the skull. These four muscles include the rectus capitis posterior major, rectus capitis posterior minor, obliquus capitis superior, and obliquus capitis inferior. The suboccipitals are needed for head extension and rotation. These muscles are innervated by the suboccipital nerve, also known as the dorsal ramus of the first cervical nerve, which arises from the posterior ramus of the C1 nerve [1, 2].

Spinal Cord

The spinal cord is one of the major neurologic structures of the cervical spine. It emerges from the foramen magnum at the base of the skull and travels to approximately L2. In the cervical spinal cord, the maximum cord circumference is located at C6 and is about 38 mm; this is to accommodate the increased neurologic structures to the upper extremity from the brachial plexus [2]. The spinal cord is made up of an inner gray matter and a surrounding layer of white matter (Fig. 1.3).

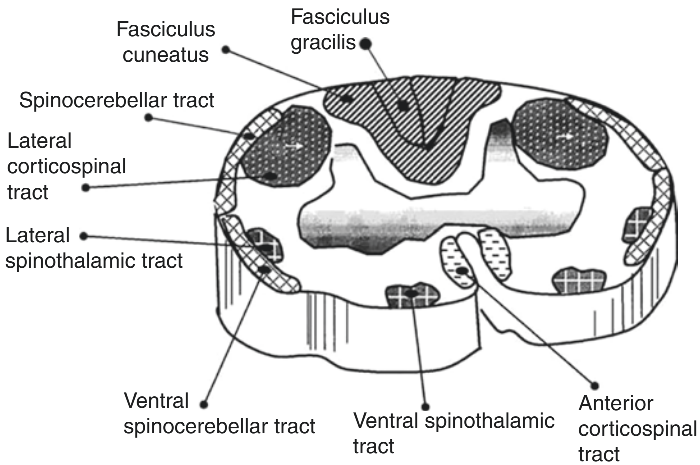

Fig. 1.3 Axial view of the spinal cord. (From [8])

The inner, butterfly-shaped gray matter of the spinal cord contains efferent neural cell bodies and interneurons. There are three important structures within the gray matter:

- The **anterior horn** of the gray matter contains somatomotor neurons.
- The **posterior horn** of the gray matter contains somatosensory neurons.
- The **intermediolateral horn** of the gray matter contains the visceral efferent neurons.

The white matter of the spinal cord primarily contains myelinated axons and glia. It is divided into the anterior, lateral, and posterior columns:

- The anterior column contains the anterior spinothalamic tract, which is responsible for deep touch, and other descending tracts.
- The lateral column contains the descending motor lateral corticospinal tract, which controls ipsilateral limb movement, and the lateral spinothalamic tract, which has fibers that cross through the ventral commissure to the contralateral side of the cord to control pain and temperature sensation.
- The posterior column contains the fasciculus gracilis and fasciculus cuneatus, which are responsible for proprioception, vibration, and fine touch.

The central ependymal canal, located in the middle of the spinal cord, is an extension of the ventricular system and allows the presence of a channel of cerebrospinal fluid (CSF) [2].

Meninges

The meninges are made up of three layers and envelop the spinal cord. The three layers include the pia mater, arachnoid mater, and dura mater. The pia mater is the closest layer to the spinal cord, the arachnoid mater is the middle layer, and the dura mater is the outermost layer. The denticulate ligaments are located in between exiting spinal nerves and project laterally from the pia to anchor the spinal cord to the arachnoid and dura. These denticulate ligaments provide cushioning and stability for the spinal cord [2, 3].

The epidural space is located in between the dura mater and the vertebrae. The epidural space is bordered anteriorly by the posterior longitudinal ligament (PLL), laterally by the medial aspect of the pedicles and the intervertebral foramina, and posteriorly by anterior aspect of the laminae and the ligamentum flavum. This space contains epidural fat, the internal vertebral plexus, and lymphatics. The CSF, spinal vasculature, and nerve rootlets are located in the subarachnoid space in between the pia and arachnoid mater [3].

Nerve Roots

At each level of the spinal cord, six to eight nerve rootlets exit laterally, become enveloped by the arachnoid and dura mater, and merge to form the dorsal and ventral roots. The ventral motor rootlets exit the spinal cord at the ventrolateral sulcus to form the ventral root, while the dorsolateral sulcus of the spinal cord is where the dorsal sensory rootlets enter. The dorsal root ganglion (DRG) contains the afferent cell bodies and is seen as an enlargement in the dorsal root in the distal aspect of the intervertebral foramen. The nerve roots travel through the intervertebral foramina and, in the cervical spine, pass above the corresponding level of the pedicle. For example, the C7 nerve root exits through the C6 and C7 intervertebral foramen. The exception to this is the C8 nerve root, which passes below the C7 pedicle. The foramen is generally 9–12 mm in height, 4–6 mm in width, and 4–6 mm in length. The nerve roots occupy about one third of the foramen and are located in the inferior half. The superior half contains fat and small veins [2].

The spinal nerve is formed just distal to the DRG, where the ventral and dorsal roots meet. The spinal nerve then divides into the dorsal and ventral primary rami.

The dorsal rami travel posteriorly and divide into motor and sensory branches that supply the muscles and skin of the back of the neck:

- The dorsal ramus of C1 provides motor fibers to the deep muscles of the suboccipital triangle.
- The dorsal ramus of C2 gives rise to the greater occipital nerve.

The ventral rami travel laterally and pass between the scalene muscles to give rise to the following:

- The ventral rami of C1–C4 form the **cervical plexus**, which is located anterolateral to the levator scapulae and middle scalene muscles. The cervical plexus contributes to innervation of the rectus capitis anterior and lateralis, longus capitis and cervicis, levator scapulae, middle scalenes, sternocleidomastoid, and trapezius muscles.
- The ventral rami of C5–T1 form the **brachial plexus**, which provides motor and sensory innervation to the upper extremity [2].

Vagus Nerves

Each vagus nerve exits from the jugular foramen and passes inferiorly within the carotid sheath in between the internal jugular vein and the common carotid artery. The right vagus nerve passes anterior to the subclavian artery and posterior to the brachiocephalic vein, subsequently entering the thorax. The left vagus nerve travels inferiorly between the left common carotid and left subclavian arteries to then enter the thorax.

The recurrent laryngeal nerves arise from the vagus nerves in the inferior part of the neck. The right recurrent laryngeal nerve loops inferior to the right subclavian artery, and the left recurrent laryngeal nerve loops inferior to the arch of the aorta. After looping, the recurrent laryngeal nerves ascend to the posteromedial aspect of the thyroid gland, then ascend in the tracheo-esophageal groove to supply the trachea, esophagus, and all the intrinsic muscles of the larynx except the cricothyroid [2, 6, 7].

Phrenic Nerves

The phrenic nerves arise from the C3, C4, and C5 nerve roots and are formed at the lateral borders of the anterior scalene muscles. They descend under the internal jugular veins and sternocleidomastoid muscles, then pass under the prevertebral layer of the deep cervical fascia, between the subclavian arteries and veins, subsequently traveling to the thorax to supply the diaphragm [2, 6, 7].

Sympathetic Trunks

In the cervical spine, the sympathetic trunks are located anterolateral to the vertebral column and extend superiorly to the level of C1. There are three cervical sympathetic ganglia in the cervical sympathetic trunks, which receive presynaptic fibers from the superior thoracic spinal nerves and their associated white rami communicantes. These cervical sympathetic ganglia then send fibers to the cervical spinal nerves, the thoracic viscera, and the viscera of the head and neck. The three cervical sympathetic ganglia are described as follows:

- The **superior cervical ganglion** is located at the level of C1–C2 vertebrae and is large in size. Postsynaptic fibers from this ganglion form the internal carotid sympathetic plexus, and this ganglion also sends fibers to the external carotid artery and the anterior rami of the superior four cervical nerves.
- The **middle cervical ganglion** is the smallest of the three ganglia and is located on the anterior aspect of the inferior thyroid artery at the level of the C6 vertebra. Postsynaptic fibers from this ganglion travel to the anterior rami of the C5 and C6 spinal nerves, as well as to the heart and thyroid gland. This ganglion is occasionally absent.
- The **inferior cervical ganglion**, in a majority of people, fuses with the first thoracic ganglion to form the cervicothoracic ganglion (**stellate ganglion**). This stellate ganglion is located anterior to the transverse process of C7. Postsynaptic fibers

from this ganglion travel to the anterior rami of the C7 and C8 spinal nerves, the heart, and contribute to a nerve plexus around the vertebral artery [2].

Vasculature

Subclavian Arteries

The subclavian arteries supply the upper extremities and send branches to the neck and brain. The right subclavian artery arises from the brachiocephalic trunk, and the left subclavian artery arises from the arch of the aorta. The branches of the subclavian arteries are important in the blood supply of the neck and include the vertebral arteries, the internal thoracic arteries, the thyrocervical trunks, the costocervical trunks, and the dorsal scapular arteries. The internal thoracic arteries travel inferomedially on both sides into the thorax, and the dorsal scapular arteries supply the levator scapulae, the rhomboids, and the trapezius muscles. The other three branches are described in more detail below [6].

Vertebral Arteries

The major blood supply of the cervical spine comes from the vertebral arteries. One vertebral artery branches off each subclavian artery bilaterally. The vertebral artery typically enters the transverse foramen of the C6 vertebrae and travels superiorly until C1. There, it bends around the lateral mass and posterior arch of C1, travels through the vertebral artery groove and into the foramen magnum where it joins the contralateral vertebral artery to become the basilar artery.

The anterior spinal artery branches off the vertebral arteries at the level of the foramen magnum and supplies the anterior portion of the spinal cord. The posterior columns are supplied by two posterior spinal arteries. The posterior spinal arteries arise from the posterior inferior cerebellar arteries, which are branches of the vertebral arteries. The vertebral arteries and ascending cervical arteries also give rise to segmental medullary arteries; they are typically present at each level to supply the spinal cord, vertebrae, and surrounding tissues [6].

Thyrocervical Trunk

The thyrocervical trunk arises near the medial border of the anterior scalene muscle and has four branches. The largest branch is the inferior thyroid artery, which supplies the larynx, trachea, esophagus, thyroid and parathyroid glands, and the adjacent muscles. Other branches include the ascending cervical arteries, suprascapular arteries, and the cervicodorsal trunk. The terminal branches of the thyrocervical trunk are the inferior thyroid and ascending cervical arteries [6].

Costocervical Trunk

The costocervical trunk arises from the posterior aspect of the second part of the subclavian artery. It divides into the superior intercostal artery, which supplies the first two intercostal spaces, and the deep cervical artery, which supplies the posterior deep cervical muscles.

Veins

The major veins of the neck drain the face, brain, and neck. The internal jugular vein arises as a continuation of the sigmoid sinus and travels out through the jugular foramen. It lies in the carotid sheath with the carotid artery and vagus nerve. It joins with the subclavian vein to form the brachiocephalic vein. The subclavian vein arises as the continuation of the axillary vein at the lateral border of the first rib. It receives only one tributary, which is the external jugular vein. The right and left brachiocephalic veins meet behind the lateral border of the manubrium to form the superior vena cava, which then passes inferiorly to enter the right atrium [4].

Lymphatics

The cervical lymphatic system is responsible for the drainage of tissue fluid, plasma protein, and other cellular debris from the head and neck. The deep lymphatic vessels of the cervical region arise from the deep cervical lymph nodes and converge to form the left and right jugular trunks. The right jugular trunk drains the right upper extremity and right side of the head and neck. It empties into the right lymphatic duct. The left jugular trunk drains into the thoracic duct, which is the larger of the two lymph ducts, which is responsible for draining the rest of the body [4, 6].

Conclusion

In this book, pathological conditions of the neck are discussed. These conditions include cervical strains and sprains, facet-mediated neck pain, discogenic neck pain, cervical radiculopathy, cervical myelopathy, traumatic neck injuries, and rheumatologic causes of neck pain. Having a solid grasp of the normal anatomy of the neck allows for an enhanced understanding of the mechanisms behind the pathologies that will be discussed later in the book.

References

1. Agur, AMR, Dalley AF, Moore KL. (2019). Neck. In Moore's essential clinical anatomy. 6th pp. 595–640). Wolters Kluwer.
2. Dodwad SNM, Khan SN, An HS. Cervical spine anatomy. In: Shen F, Samartzis D, Fessler R, editors. Textbook of the cervical spine. 1st ed. Saunders; 2015. p. 3–21.
3. Ellis H. The anatomy of the epidural space. Anaesth Intensive Care Med. 2009;10(11):533–5.
4. Ellis H. The great veins of the neck. Anaesth Intensive Care Med. 2007;8(1):15–6.
5. Henry J. *Anatomy, head and neck, levator scapulae muscles*, https://www.ncbi.nlm.nih.gov/books/NBK553120/, Accessed 11 Nov, 2021.
6. Moore K. *Moore clinically oriented anatomy*; Ch 7–8.

7. Schuenke M, et al. *THIEME atlas of anatomy: general anatomy and musculoskeletal system*; 85–120.
8. Cuccrullo S. Physical medicine and rehabilitation board review. New York: Demos Medical; 2010.