Chapter 1 – Normal Cervical Function
The functional and structural anatomy of the cervical spine is complex, allowing a great range of motion while containing and protecting the enclosed neural structures. It is important, if not mandatory, that the normal functional and structural anatomy be understood to fully understand the variations that translatory forces impose from a whiplash injury.

A specific diagnosis of a whiplash-associated disease (WAD) depends upon finding abnormalities in the normal function of the cervical spine allegedly caused by a whiplash injury.

The symptoms noted by a whiplash patient are rarely, if ever, ascertained by the discovery of abnormal, objective findings. The aim of diagnosing symptoms and findings in WADs is to discover abnormal function. Because there are few objective structural changes, impaired function must be the diagnosis.

In addition, the tissue site must be delineated as the source of nociception with resultant pain through a meaningful physical examination. Although the site is indicated by the patient, it must be confirmed by the examiner. Before discussing the abnormal cervical spine, which causes the alleged symptoms of WAD, the normal functional anatomy of the cervical spine is discussed in this chapter.

FUNCTIONAL ANATOMY OF THE CERVICAL SPINE
The cervical spine is divided into two segments: the upper cranio-cervical segment, which comprises the occiput, C1 (atlas), and C2 (axis) vertebrae; and the lower cervical segments, which comprises the C3 to C7 vertebrae.

Upper Cranio-Cervical Segment
Motion between the occiput and the atlas (C1 vertebra) is approximately 25 degrees of flexion and extension (see Figure 1.1).

Only approximately 5 degrees of lateral flexion and approximately 3 to 8 degrees of rotation are permitted.

Motion between the atlas (C1) and the axis (C2) is essentially rotation about the dens of approximately 40 degrees in either direction.

Approximately 20 degrees of flexion/extension and lateral flexion is allowed, and very little translation is permitted between the occiput, the atlas, and the axis.

The upper cervical segment, which guards against any translatory motion from a whiplash force, is stabilized by the powerful ligaments that connect all components of this upper cervical section.

These ligaments, as well as the articular capsule, protect contained neural tissues including the spinal cord and the emerging nerve roots.

The ligaments, which support the three structures forming the upper cervical segment, prevent injury to the spinal cord as well as the upper cervical nerve roots.

Ligamentous injuries are difficult to diagnose clinically or radiologically.
Magnetic resonance imaging (MRI) studies can reveal injury to ligaments.

Clinically, a specific ligamentous injury is detected by eliciting excessive motion of the two vertebrae connected by the ligaments.

The articulation of the occiput with the atlas (C1) is supported by the vertical branch of the cross ligament and the capsules of the two atlas bodies with the occiput (see Figure 1.2).

**Atlas and Axis**
The atlas bodies have concave superior facets that articulate with the convex prominences of the occiput (see Figure 1.3).

The atlas and the axis form a function unit with the axis, which has a vertical prominence, the dens, that rises from the anterior arch (see Figure 1.4).

The atlas (C1) rotates about the dens and is firmly connected to the anterior arch by the transverse ligament.

The atlas is also firmly supported by accessory ligaments that arise from the anterior arch of the axis to the bodies of the atlas (see Figure 1.5).

These ligaments stabilize the functional units from the occiput to the axis and protect the spinal cord (see Figure 1.6).

The axis articulates with the third cervical vertebra via a disk between the bodies.

A "gutter" protrudes anterior-laterally from this vertebra through which emerges a nerve root.

The axis rotates upon the third cervical vertebra and is mechanically limited by an anterior protruding process (see Figure 1.7).

The ligamentum flavum extends from the posterior arch of the atlas, proceeds down the surface of the lamina of the axis, then down through the entire vertebral column.

The ligamentum nuchae, a firm ligament that attaches from the base of the skull, descends to attach at each posterior superior spine throughout the length of the cervical spine (see Figure 1.8).

**Cervical Nerves**
The upper three cervical nerves emerge from the spinal canal through soft tissues; there are no foramina between the occiput and the third cervical vertebra.

Soft tissue impairment of the first three cervical nerve roots causes involvement of the greater superior occipital nerves with sensory symptoms at the base of the skull and the occiput (see Figures 1.9, 1.10, 1.11).

Clinically, when a patient with a whiplash injury complains of head pain (headache) and hypersensitivity of the skull, the examiner should determine whether the source of these symptoms is the greater superior occipital nerve.
The nerve can be palpated digitally where it exits the sulcus at the base of the skull; this is where the nerve emerges between the trapezius and the sternocleidomastoid muscle insertions upon the skull.

A local analgesic can be injected into this area to remove pain (see Figure 1.12).

**Musculature of the Head and Neck**

**Lower Cervical Segments**

Motion of the lower cervical segments from C3 to C7 with normal function are dependent upon their specific individual anatomical structures (see Figure 1.13).

These lower cervical segments form a physiological lordosis, which was originally considered to be a perfect sphere, with each functional unit having the same angulation, termed relative rotational angle (RRA), and with great angulation between C4 and C5 and between C5 and C6 (see Figures 1.14, 1.15).

The lordosis of the cervical spine becomes a kyphosis upon flexion.

The foramen (Fr in Figure 1.16) opens when the spine flexes and narrows upon re-extension.

The posterior spinal ligaments mechanically limit the degree of flexion and the intervertebral disks (D) alter their configuration.

On lateral flexion and rotation, the foramen narrow on the concave side and open on the convex side.

This opening and closing are of clinical significance because nerve roots within the foramen are compressed by narrowing (see Figure 1.17).

Movement in all directions, including flexion and extension as well as lateral flexion and rotation, is possible in the lower cervical spine.

Physiological limitation is incurred by the extensibility of the annular fibers, the capsules of the facets, all the ligaments, and the fascia of the muscles.

Movement is greatest at the C4-C5 and C5-C6 intervertebral spaces.

Translation also occurs but cannot be clinically measured, except for kinetic radiological studies.

**Nociceptive Tissue Sites of a Function**

The following tissues within the cervical spine are sites of nociception when inflamed or mechanically compressed (see Figure 1.18):

- Outer layers of the disk annulus
- Posterior longitudinal ligament
- Dural sheath of a nerve root
- Dural root ganglion
- Facet capsules
- Erector spinae muscles
- Ligaments
Length of Spinal Canal
The spinal canal is triangular; its lateral diameter is larger than its anteroposterior diameter at all levels.

The average diameter at levels C3-C6 ranges between 17 and 18 mm and decreases to 15 mm at C7.

The borders of the spinal canal include the pedicles, lamina, zygapophyseal joints, ligamentum flavum, and intervertebral foramina (see Figure 1.19).

Narrowing of either the spinal canal or the foramen imposes a potential mechanical entrapment of the nerve root or the spinal cord.

Anterior-posterior narrowing of the canal in the spinal stenosis limits the area in which the cord can move in the canal away from any encroaching tissue such as a disk protrusion, facet synovitis, and/or degenerative changes of the facets that cause foramenal stenosis.

Upon flexion, the canal lengthens and narrows in width.

Upon extension, the canal lengthens, which simultaneously lengthens the cord and changes the angulation of its nerve roots.

The normal angulation of a nerve root from the cord becomes more acute upon flexion and less acute upon extension.

The angulation conforms to the opening of the foramen through which the roots emerge to become peripheral nerves (see Figures 1.19, 1.20).

These factors influence clinical findings when there is evidence of radiculitis.

Reproduction of radicular symptoms by passive and active neck positions is of clinical significance.

In a whiplash injury in which the superior vertebra glides (translates) forward upon the inferior vertebra, the spinal canal and the intervertebral foramen acutely narrow, compressing any enclosed neural tissue (cord or nerve roots) (see Figure 1.21).

Nerve Roots
The enclosed neural tissues include the spinal cord and the nerve root, which divide into the posterior primary division and the anterior primary division (see Figure 1.22).

The anterior primary division supplies the extremities for sensory function and primarily motor function.

The posterior primary division supplies the muscles (extensor) of the vertebral column, the facet joints, and the posterior ligaments; its function is primarily sensory.

The posterior root is normally three times thicker than the anterior root because it contains more sensory fibers.
Each rootlet is contained within a dural pouch that contains spinal fluid (see Figure 1.23).

The dura is innervated by the recurrent nerve of Luschka.

At the bony level, the dural sac is attached to the bone.

This poses pathological changes when aging causes bony protrusions and spurring of the foramen.

The nerve root is in intimate contact with the facet joint and the outer annular layers of the disk.

Because the roots occupy only one fourth to one third of the foramen, they have room for movement without encroachment.

**FUNCTIONAL ANATOMY OF THE VERTEBRAL ARTERIES**

Vertebral arteries are the major blood supply to the cervical spine and the spinal cord.

They are the first branches of the subclavian artery arising medially to the scalenus anterior (see Figure 1.24).

The vertebral arteries ascend via the foramena transversarum of each cervical vertebra to enter the skull through the foramen magnum.