Fişa suspiciunii de plagiat / Sheet of plagiarism's suspicion	Indexat la: 61/07

Opera suspicionată (OS) Suspicious work	Opera autentică (OA) Authentic work

OS	EVA, L. Tratamentul chirurgical în leziunile degenerative ale coloanei cervicale – Hernia de disc cervicală. Teză de doctorat, Universitatea de medicină şi farmacie "Gr.T.Popa", Facultatea de medicină generală, Iaşi, 2010.
OA	HOWARD, S.A. Anatomy of the Cervical Spine. In: HOWARD, S.A. and Simpson, J.M. (Eds) Surgery of the Cervical Spine. Baltimore: Williams&Wilkins. 1994.

Incidența minimă a suspiciunii / Minimum incidence of suspicion	
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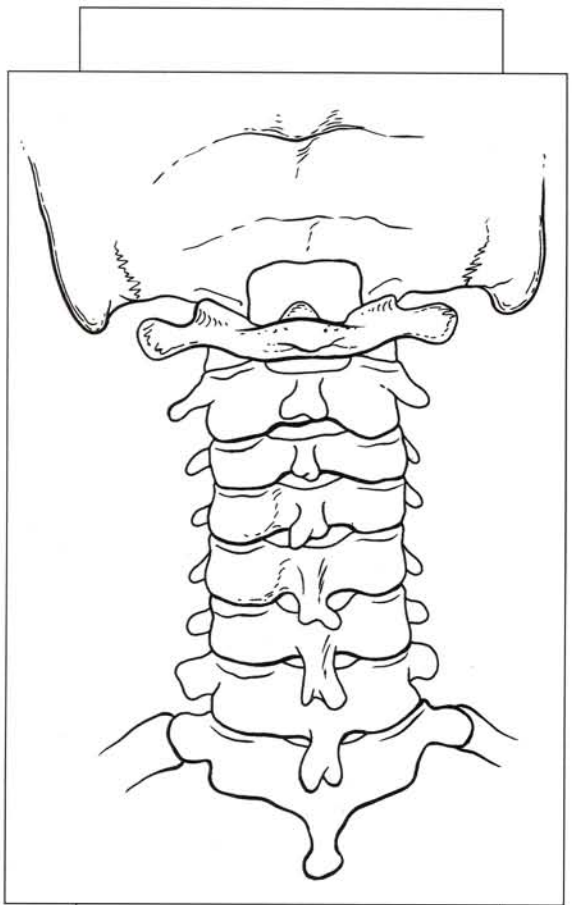
Surgery of the Cervical Spine



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MARTIN DUNITZ

Distributed by Williams & Wilkins, 428 East Preston Street, Baltimore, Maryland 21202, USA, in North America (United States and Canada)

First published in the United Kingdom in 1994 by
Martin Dunitz Ltd, The Livery House, 7–9 Pratt Street, London NW1 0AE

LIbrary of Congress Cataloging in Publication Data
An, Howard S.
Surgery of the cervical spine/Howard S. An, J. Michael Simpson: with illustrations by Carole Hilmer and Anita Hylton.
p. cm.
Includes bibliographical references and index.
ISBN 0–683–00128–0
1. Cervical vertebrae—Surgery. 2. Cervical vertebrae—Diseases. 3. Cervical vertebrae—Wounds and injuries. I. Simpson, J. Michael. II. Title.
[DNLM: 1. Cervical Vertebrae—physiopathology. 2. Cervical vertebrae—surgery. 3. Spinal Diseases—physiology. WE 725 A531s 1994]
RD533.A5 1994
617.3'75—dc20
DNLM/DLC 93–47689
for Library of Congress CIP

Composition by Scribe Design, Gillingham, Kent, UK
Origination by Imago Publishing Ltd
Printed and bound in Singapore by
Toppan Printing Company (S) Pte Ltd

Contents

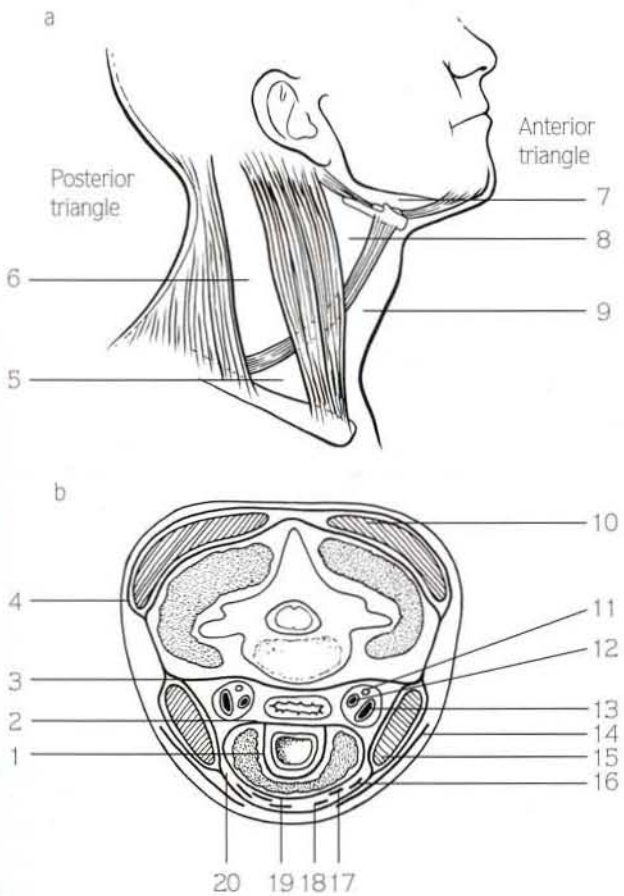


Figure 1.29
(a) Triangles of the neck bordered by muscles. The posterior triangle is formed by the sternocleidomastoid, clavicle, and the trapezius muscles, and the omohyoid muscle divides it into the supraclavicular and the occipital triangles. The anterior triangle is bounded by the midline of the neck anteriorly, the lower border of the mandible superiorly, and the sternocleidomastoid posteriorly. The anterior triangle is subdivided by the submental triangle, the muscular triangle, the digastric triangle, and the carotid triangle. (b) The fascia of the anterior part of the neck invest the muscles and viscera in separate compartments. The superficial fascia contains fat and areolar tissue including the platysma muscle, external jugular vein, and the cutaneous sensory nerves. The structures deep to the superficial fascia are compartmentalized by the deep fascia including the outer investing layer of deep fascia, middle cervical fascia (pre-tracheal fascia), and the prevertebral fascia. The outer layer of the deep fascia extends from the trapezius muscle over the posterior triangle and splits to enclose the sternocleidomastoid muscle. The middle layers of the deep cervical fascia enclose the strap muscles and omohyoid and extend as far laterally as the scapula. The deeper middle layer is the visceral fascia that surrounds the thyroid gland, larynx, trachea, pharynx, and esophagus. The carotid sheath encloses the carotid artery, internal jugular vein, and vagus nerve. The deepest layer of the deep fascia is the prevertebral fascia, which covers the scalenus muscles, longus colli muscles, and the anterior longitudinal ligament

1 Pre-tracheal lamina
2 Prevertebral (middle)
3 Prevertebral (deep)
4 Superficial (investing)
5 Supraclavicular
6 Occipital triangle
7 Digastric triangle
8 Carotid triangle
9 Muscular triangle
10 Trapezius
11 Vagus n.
12 Common carotid a.
13 Jugular v.
14 Platysma m.
15 Sternocleidomastoid m.
16 Omohyoid m.
17 Sternothyroid m.
18 Sternohyoid m.
19 Pre-thyroid lamina
20 Posterior thyroid space

the posterior triangle, and then splits to enclose the sternocleidomastoid muscle. The middle layer of the deep cervical fascia encloses the strap muscles and omohyoid, and extends as far laterally as the scapula. A deeper portion of middle layer is the visceral fascia, which surrounds the thyroid gland, larynx, trachea, pharynx, and esophagus. The alar fascia spreads behind the esophagus and surrounds the carotid sheath structures laterally. The carotid sheath encloses the carotid artery, internal jugular vein, and vagus nerve. The deepest layer of the deep fascia is the prevertebral fascia, which covers the scalenus muscles, longus colli muscles, and the anterior longitudinal ligament.

NEUROVASCULAR STRUCTURES

Neurovascular structures of the cervical spine include the spinal cord, nerve roots, carotid artery, vertebral artery, laryngeal nerves, sympathetic chain, veins, and vessels to the spinal cord. The cervical cord emerges from the foramen magnum as a continuation of the medulla. The cervical cord enlarges from C3 and becomes maximal at C6 with a circumference of 38 mm.[16] This enlargement results from the increased nerve supply to the upper limbs. The spinal cord includes the outer white matter and the inner gray matter, which can be distinguished by magnetic

Figure 1.30
An axial freezing microtome section of the cervical spine showing the white (w) and gray matter (g) of the spinal cord, dorsal root (arrow), and ligamentum flavum (l)

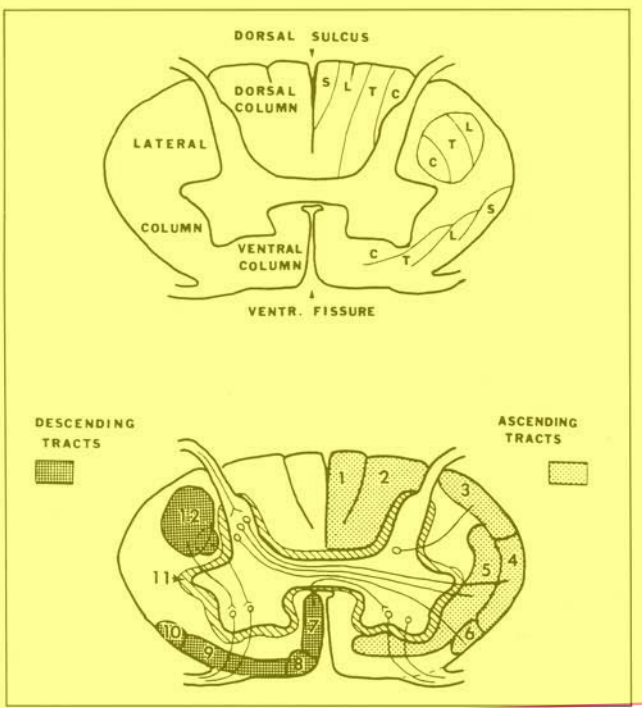
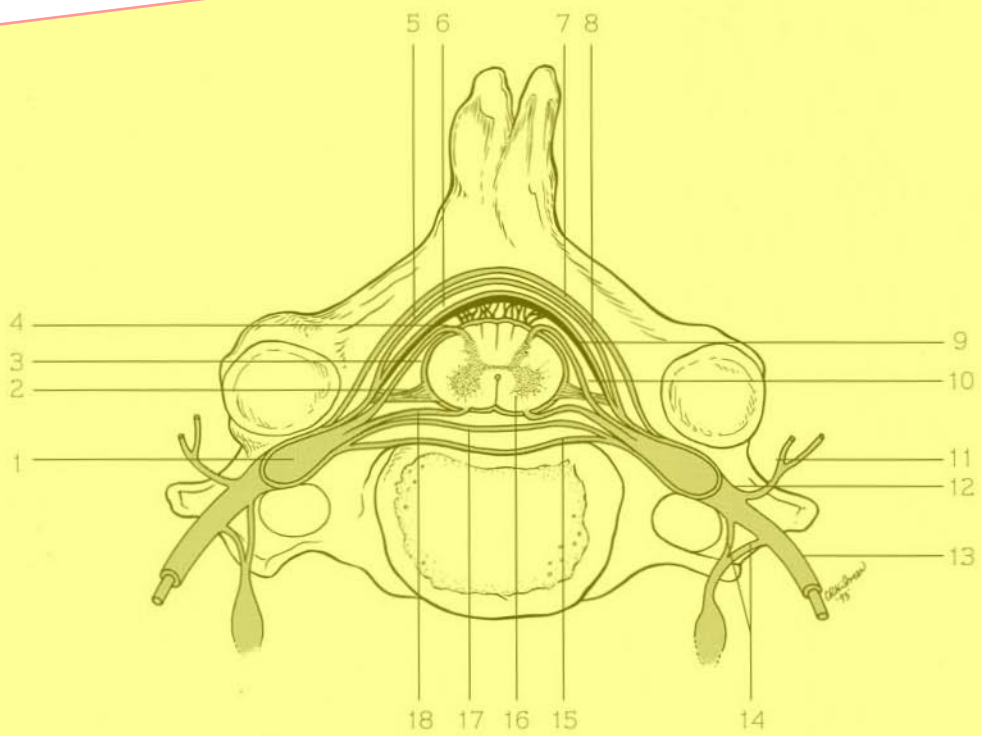


Figure 1.31
Cross-sectional anatomy of the spinal cord at C5 level with columns and tracts of the white matter. Top: columns or funiculi are shown on the left, and segmental arrangement of ascending and descending longitudinal tracts on the right: sacral (S), lumbar (L), thoracic (T), and cervical (C). Bottom: tracts of the spinal cord at C5 level with the ascending tracts on the right and descending tracts on the left: (1) fasciculus gracilis, (2) fasciculus cuneatus, (3) dorsal spinocerebellar tract, (4) ventral spinocerebellar tract, (5) lateral spinothalamic tract, (6) spino-olivary tract, (7) anterior corticospinal tract, (8) tectospinal tract, (9) vestibulospinal tract, (10) olivospinal tract, (11) intersegmental or propriospinal tract, and (12) lateral corticospinal tract. (From Parke WW, Sherk HH: Normal Adult Anatomy. In *Cervical Spine*, 2nd ed., eds. Sherk HH et al., Philadephia: JB Lippincott, 1989: 22.)

resonance imaging (Fig. 1.30).[6] The white matter of the spinal cord contains nerve fibers and glia, and is divided into three columns: posterior, lateral, and anterior. The posterior column includes the fasciculus cuneatus laterally and fasciculus gracilis medially, mediating proprioceptive, vibratory, and tactile sensations (Fig. 1.31). The lateral column contains the descending motor lateral corticospinal and lateral spinothalamic fasciculi, and the anterior funiculus contains the ascending anterior spinothalamic tract and other descending tracts. The lateral spinothalamic tracts cross through the ventral commissure to the contralateral side of the cord, conveying pain and temperature sensations. The anterior spinothalamic tract conveys crude touch sensation.

The gray matter of the spinal cord contains cell bodies of efferent and internuncial neurons. The somatosensory



1 Spinal ganglion
2 Dentate ligament
3 Pia mater
4 Dorsal root of spinal n.
5 Dura mater
6 Subdural space
7 Periosteum
8 Epidural space
9 Arachnoid membrane
10 Subarachnoid space
11 Dorsal ramus
12 Spinal n.
13 Ventral ramus of spinal n.
14 Ramus communicans
15 Periosteum
16 Medulla spinalis
17 Dura mater
18 Ventral root of spinal n.

Figure 1.32
Cross-sectional diagram of the cervical spine showing the spinal cord, nerve root, dorsal root ganglion, and spinal nerve. The spinal cord is covered by the pia mater and suspended in the cerebrospinal fluid contained by the arachnoid membrane. The dentate ligament secures the spinal cord within the spinal canal

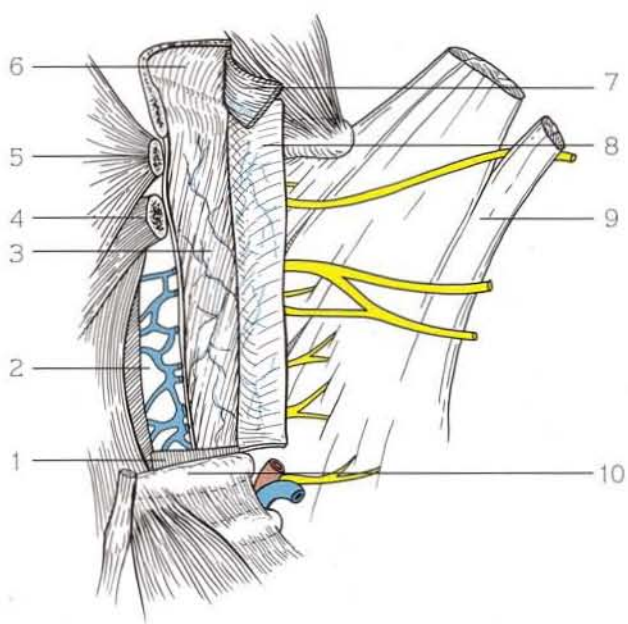


Figure 1.33
The dura mater is the outer covering of the spinal cord, which is continuous at the foramen magnum with the inner layer of the cranial dura. The arachnoid membrane is underneath the dura mater and contains the cerebrospinal fluid

1 Ligamentum flavum
2 Posteroinferior vertebral venous plexus
3 Arachnoid
4 Axis
5 Atlas
6 Cerebellum
7 Dura mater of brain
8 Spinal dura mater
9 Semispinalis capitis m.
10 Vertebral arch C7

Figure 1.34
A coronal freezing microtome section showing the dorsal sensory rootlets entering the cord through the lateral longitudinal sulcus

neurons are located in the posterior horn, and the somatomotor neurons are found in the anterior horn of the gray matter. The visceral center of the gray matter is found in the intermediolateral horn. In the center of the spinal cord is the central ependymal canal for the passage of cerebrospinal fluid.

The spinal cord is covered by the pia mater, which is the outer lining of the cord, and the transparent arachnoid membrane which contains the cerebrospinal fluid (Fig. 1.32). The dura mater is the outer covering of the spinal cord, which is continuous at the foramen magnum with the inner layer of the cranial dura (Fig. 1.33). The cervical cord is anchored to the dura by the dentate ligaments which project laterally from the lateral side of the cord to the arachnoid and dura, at points midway between exiting spinal nerves. By suspending the spinal cord in the cerebrospinal fluid, the dentate ligaments cushion and protect the cord while minimizing movement of the cord during range of motion (Fig. 1.32). The epidural space contains fat, the internal vertebral venous plexus, and loose connective tissue. This venous plexus may be involved in the spreading of infection or neoplasm. There is a potential space between the dura and arachnoid; the subarachnoid space exists between the arachnoid and pia and contains the cerebrospinal fluid, spinal blood vessels, and nerve rootlets from the spinal cord.

The dorsal sensory rootlets enter the cord through the lateral longitudinal sulcus, whereas the ventral motor rootlets exit the cord through the ventral lateral sulcus (Fig. 1.32). The six or eight rootlets at each level leave the spinal cord laterally to lie in the lateral subarachnoid space bathed in the cerebrospinal fluid (Fig. 1.34). The rootlets join to form the dorsal and ventral roots respectively, which together enter a narrow sleeve of arachnoid and pass through the dura to become a nerve root at each level. The cervical nerve roots forming from the ventral and dorsal nerve rootlet complex then extend anterolaterally at a 45° angle to the coronal plane and inferiorly at 10° to the axial plane. The nerve roots enter the intervertebral foramina by passing directly in a lateral direction from the spinal canal adjacent to the corresponding disc and over the top of the corresponding pedicle (Fig. 1.35). The anterior root lies anteroinferiorly adjacent to the uncovertebral joint, whereas the posterior root approximates the superior articular process (Fig. 1.36). The nerve root is positioned at the tip of the superior articular process in the medial aspect of the neural foramen, and then courses more inferiorly to position itself over the pedicle in the lateral aspect of the neural foramen (Figs 1.37 and 1.38).[8] Each cervical spinal nerve root exits over the pedicle bearing the same number, except for the C8 cervical nerve, which lies between the C7 and T1 pedicles (Fig. 1.39).

The roots occupy about one-third of the foraminal space in the normal spine, although this increases in the degenerative spine. Normally, the roots are located in the inferior half of the neural foramen, but when the neck is extended, the nerve roots tend to occupy the more cranial portion of the foramina, whereas the volume of the foramen itself is diminished.[18] The upper half of the neural foramen contains fat and small veins,[11] the whole neural foramen being approximately 9–12 mm in height, 4–6 mm in width, and 4–6 mm in length.[5] It is bounded superiorly and inferiorly by pedicles, anteriorly by the uncinate process, the posterolateral aspect of the intervertebral disc, and the inferior portion of the vertebral body above the disc level, and posteriorly by the facet joint and superior articular process of vertebral body below (Fig. 1.40 and see Fig. 1.16). The nerve root becomes enlarged in the distal aspect of the intervertebral foramen, and the dorsal root ganglion is located just distal to it.[17] The dorsal root ganglion is located between the vertebral artery and a small concavity in the superior articular process (Fig. 1.40). The anterior and

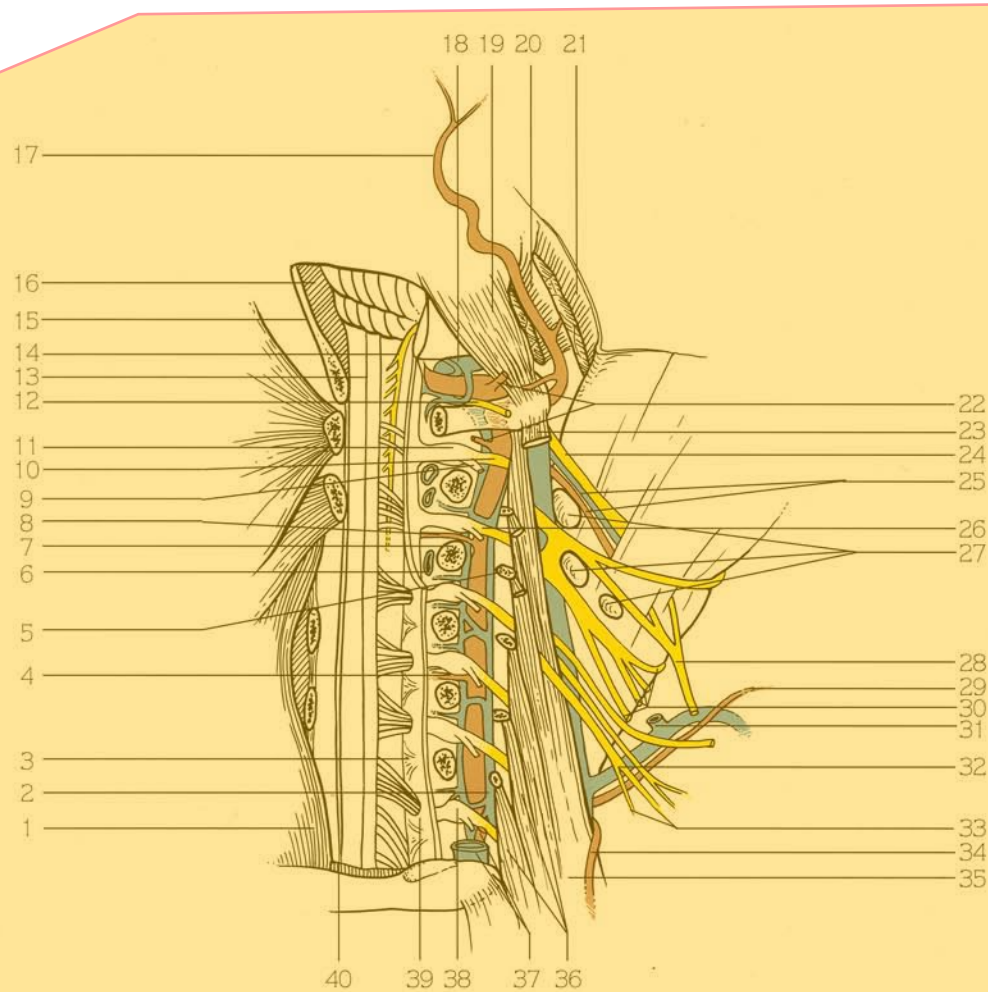


Figure 1.35
Spinal cord and neural structures of the cervical spine showing six or eight rootlets at each level leaving the spinal cord. The rootlets join to form the dorsal and ventral root, which together enter a narrow sleeve of arachnoid and pass through the dura to become a nerve root at each level. The cervical nerve roots that form from the ventral and dorsal nerve rootlet extend anterolaterally at a 45° angle to the coronal plane and inferiorly at about 10° to the axial plane. The nerve roots enter the intervertebral foramina by passing directly laterally from the spinal canal adjacent to the corresponding disc and over the top of the corresponding pedicle

1 Left erector spinae m.
2 Vertebral v.
3 Ligamentum denticulatum
4 Spinal branch of vertebral a.
5 Transverse process C3
6 Vertebral venous plexus
7 Pedicle, vertebral arch C3
8 Spinal branch vertebral a.
9 Posterior primary ramus, C2
10 Anterior primary ramus, C2
11 Spinal gang, C2
12 Suboccipital n.
13 Lateral intermediate sulcus
14 Spinal roots of accessory n.
15 Occipital bone
16 Cerebellomedullary cisterna
17 Occipital a.
18 Vertebral v.
19 Oblique cupitis superior m.
20 Longissimus capitis m.
21 Splenius capitis m.
22 Muscular branches of vertebral a.
23 Levator scapulae m. (first digitation)
24 Accessory n.
25 Sternocleidomastoid a. and v.
26 Anterior primary ramus C3
27 Deep cervical lymph nodes
28 Accessory n.
29 Superior cervical a.
30 Cutaneous branches of cervical plexus
31 External jugular v.
32 Dorsal scapulae n.
33 Branches to trapezius
34 Transverse cervical a. (deep branch)
35 Scalenus medius m.
36 Scalenus posterior m.
37 Deep cervical a, v.
38 Spinal ganglion C7
39 Spinal dura mater
40 Lig. flavum

posterior roots join to form the spinal nerve just distal to the ganglion and outside the intervertebral foramen.

The spinal nerve divides into dorsal primary rami and ventral primary rami branches (see Fig. 1.32). The gray rami from the sympathetic cervical ganglion join the ventral primary rami. There are interconnections between gray rami, the perivascular plexus around the vertebral artery, and the sympathetic trunk, all of which give contributions to the ventral nerve plexus to innervate the anterior longitudinal ligament, outer annulus fibrosis, and the anterior vertebral body (Fig. 1.41).[3,13] The dorsal nerve plexus receives contributions from the sinovertebral nerves. The sinovertebral nerve originate from the gray rami and perivascular plexus of the vertebral artery. The dorsal nerve

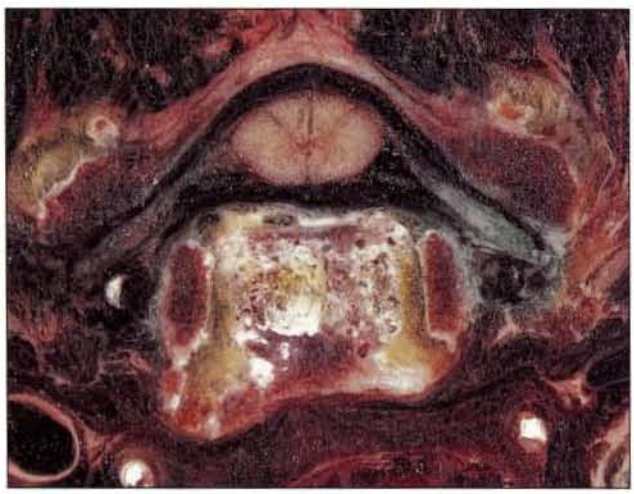


Figure 1.40
An axial freezing microtome section showing the spinal cord and nerve root exiting in the neural foramen that is bound anteriorly by the uncinate process, the posterolateral aspect of the intervertebral disc, and inferior portion of the vertebral body above the disc level, and posteriorly by the facet joint and superior articular process of the vertebral body below

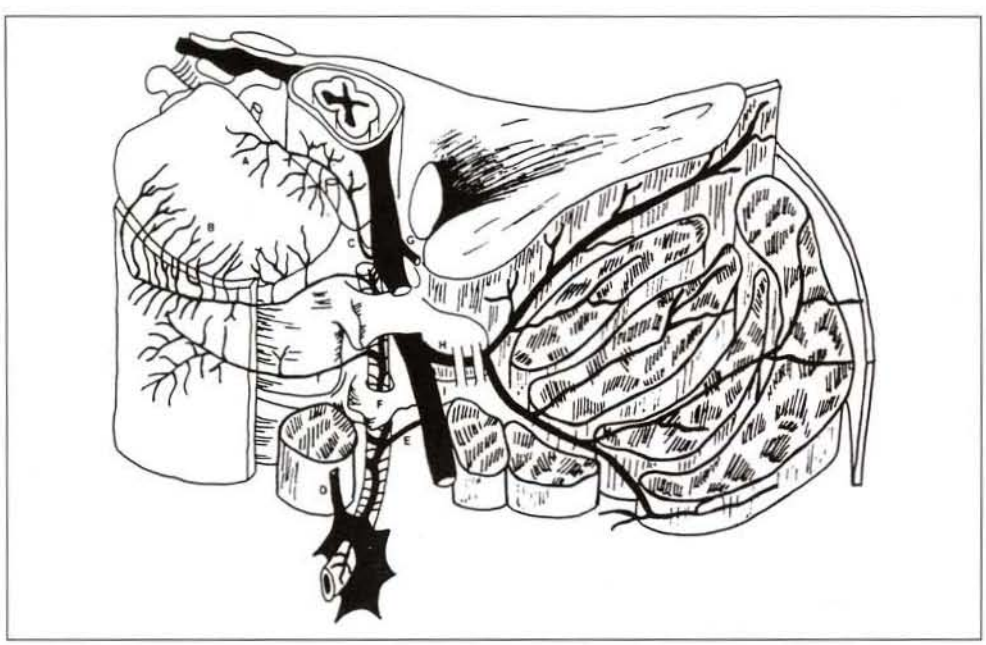


Figure 1.41
Innervation of the cervical spine: (a) dorsal nerve plexus, (b) ventral nerve plexus, (c) sinovertebral nerve, (d) sympathetic trunk, (e) gray ramus communicantes, (f) vertebral perivascular plexus, (g) dorsal root ganglion, (h) dorsal ramus, and (i) ventral ramus. (From Young PA, Young PH: Surgical anatomy of the cervical spine surrounding structures. In *Microsurgery of the Cervical Spine*. Young PH, ed., New York: Raven Press, 1991: 33.)

plexus innervates the posterior longitudinal ligament, whereas the sinovertebral nerves supply branches to the posterior part of the annulus and the ventral portion of the dura. The sinovertebral nerves also innervate two or more discs or motion segments.

The first cervical nerve or suboccipital nerve exits from the vertebral canal above the posterior arch of the atlas and posteromedial to the lateral mass, lying between the vertebral artery and the posterior arch (Fig. 1.42). The posterior primary ramus of the first cervical nerve enters the suboccipital triangle and sends motor fibers to the deep muscles (Fig. 1.43). The anterior primary ramus of the first cervical nerve forms a loop with the second anterior primary ramus, and sends fibers to the hypoglossal nerve.

The cervical plexus receives fibers from the anterior primary rami of C1 through C4. The cervical plexus is located opposite C1 through C3, ventral and lateral to the levator scapulae and middle scalene muscles. The cervical plexus has distributions to the skin and muscles, including rectus capitis anterior and lateralis, longus capitis and cervicis, levator scapulae, and middle scalene. The cervical

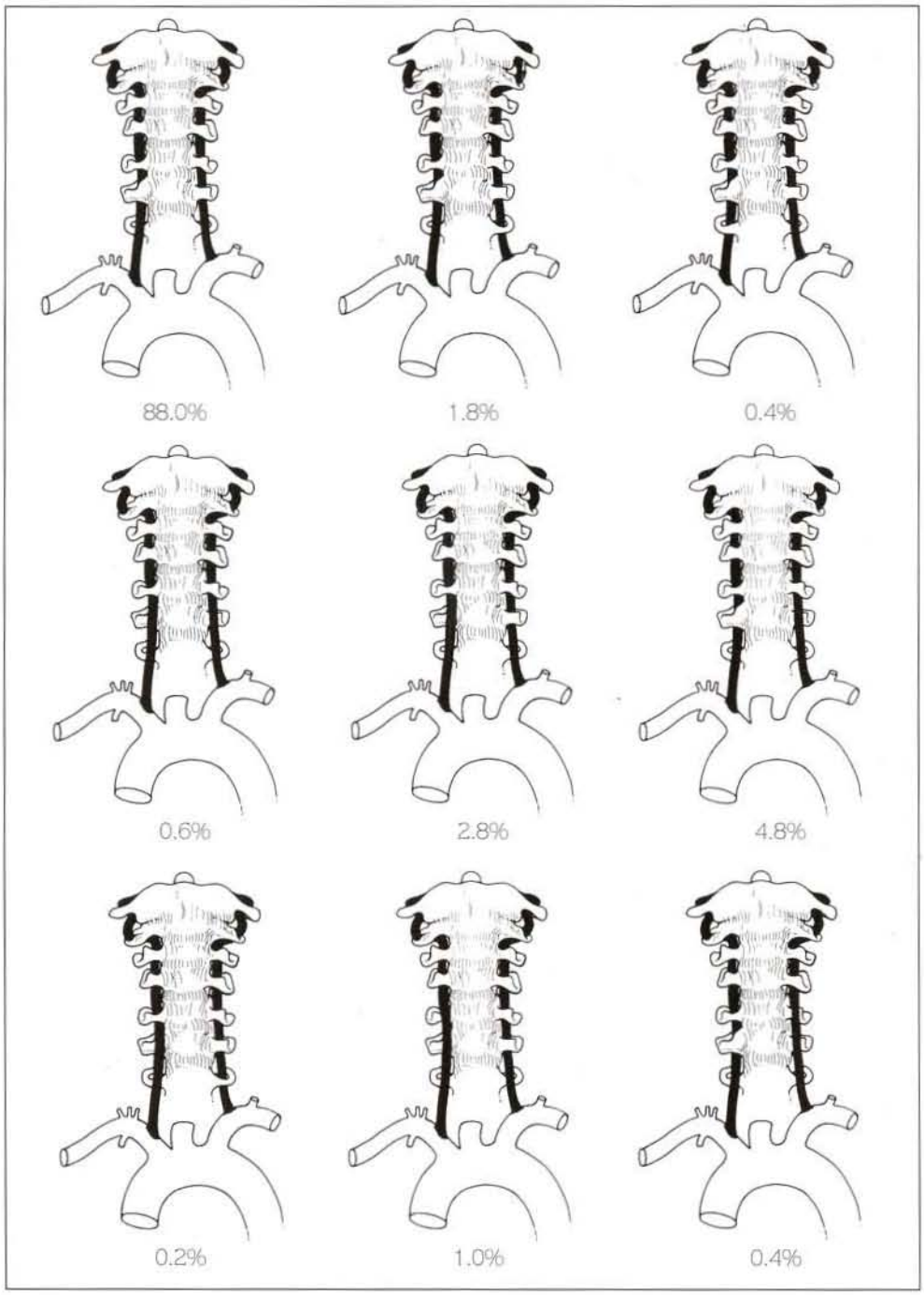


Figure 1.46
Variations of the course of the vertebral artery. (Modified from Rickenbacher J, Landolt AM, Theiler K: *Applied Anatomy of the Back*. Berlin: Springer Verlag, 1982.)

plexus forms loops and branches to supply the sternocleidomastoid and trapezius muscles, and has communications with the hypoglossal nerve from C1 and C2; then it leaves this trunk as the descending branch and unites with the descending cervical nerve (C2 and C3) to form the ansa cervicalis.

The posterior primary ramus of the second cervical nerve lies on the lamina of the axis posterior to the lateral mass. The greater occipital nerve is a branch of the C2 posterior primary ramus, and pierces the trapezius about 2 cm below the external occipital protuberance and 2–4 cm from the midline (Fig. 1.43). This is the largest cutaneous nerve of the cervical region. Cutaneous branches of the posterior primary rami of C2–C5 are consistently present in the skin of the nuchal region. The lesser occipital nerve is a branch of the anterior cervical plexus, and runs upwards and lateral to the greater occipital (Fig. 1.44). The posterior primary ramus of C3, or the

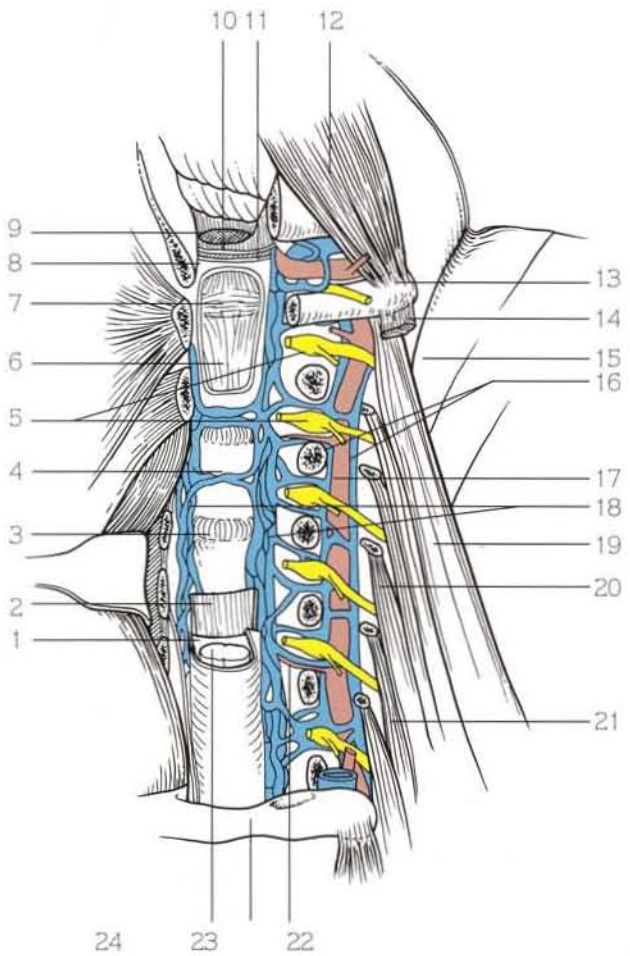


Figure 1.47
The vertebral artery and extensive venous network around the vertebral foramen and spinal canal

1 Spinal dura mater
2 Posterior longitudinal ligament
3 Intervertebral disc C3 and C4
4 Basivertebral v.
5 Spinal ganglia
6 Longitudinal fibers of cruciform ligament of atlas
7 Transverse ligament of atlas
8 Tectorial membrane
9 Medulla
10 Cranial dura mater
11 Posterior longitudinal ligament
12 Oblique capitis m.
13 Transverse process of atlas
14 Levator scapulae m.
15 Semispinalis capitis m.
16 Vertebral v.
17 Vertebral a.
18 Anteroinferior vertebral venous plexus
19 Scalenus medius m.
20 Anterior cervical intertransverse m.
21 Scalenus posterior m.
22 Spinal branch
23 Spinal cord
24 Vertebral arch T1

third occipital nerve, pierces the trapezius more inferiorly and about 1 cm medial from the midline (Fig. 1.44). The posterior primary rami of cervical nerves send motor fibers to the deep muscles and sensory fibers to the skin, but the first cervical nerve has no cutaneous branches. The anterior primary rami of C1–C4 form the cervical plexus, and of C5–T1 form the brachial plexus. Laterally, the musculature and skin are innervated by branches of the cervical plexus such as the accessory nerve, the greater auricular nerve, transcervical nerve, supraclavicular nerves, and lesser occipital nerve (Fig. 1.45).

BLOOD SUPPLY TO THE CERVICAL SPINAL CORD

The major blood supply of the cervical cord and the cervical spine is the vertebral artery, which originates from the subclavian arteries and enters the transverse foramen at C6 in most cases. Variations in the course of the vertebral artery have been reported (Fig. 1.46).[19] The vertebral artery courses cephalad within the transverse foramen of each vertebra and winds around the lateral mass and posterior arch of the atlas, and then passes through the posterior atlanto-occipital membrane into the foramen magnum (Fig. 1.47). The vertebral arteries join together to form the basilar artery beyond the foramen magnum (Fig. 1.48). In the foramen magnum region, the vertebral arteries give branches anteriorly that join together to form the single anterior spinal artery. The posteroinferior cerebellar arteries send branches on the posterolateral aspect of the spinal cord called posterior spinal arteries. These are paired and give rise to plexiform channels which are arranged transversely on the dorsum of the spinal cord. The anterior and posterior spinal arteries are the major blood supplies of the spinal cord (Fig. 1.49).[9] The anterior spinal artery supplies most of the spinal cord except for the posterior columns.