Atlas of Neurosurgical Techniques

Spine and Peripheral Nerves

Richard G. Fessler
Laligam N. Sekhar

Second Edition

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Spine and Peripheral Nerves

Second Edition

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This book is dedicated to the memory of my mentors, Dr. Sean Mullan and Dr. Albert Rhoton, Jr. Their patience and commitment to teaching created generations of thoughtful and skilled surgeons. Perhaps more importantly, observing their kindness to patients, colleagues, and families, instilled in us the gift of being compassionate physicians.

R.G.F.

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A. Anterior Approach

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This technique is done through a regular anterior Smith-Robinson approach. One major difference between the surgical access for an anterior cervical diskectomy and fusion (ACDF) and the tunnel technique is that in the latter, exposure of only the target disk and proximal vertebral body is required, without the exposure of the inferior vertebral body. The level is confirmed at this stage, and an operating microscope is brought into the field. Before drilling is begun, indigo-carmine dye is injected in the affected disk to facilitate the orientation of disk space while drilling. The position of the drill hole is 4 to 6 mm above the lower border of the proximal vertebra, at the level of the medial border of the longus coli muscle. Drilling is done using a 4-mm diamond bur initially and a 3-mm bur later. At approximately one-third depth of the drilling, we can see the bluish discoloration of the stained disk and we can safely continue to drill further, keeping the blue-stained material in the center of the hole so as to maintain the direction of the trajectory.

After the desired depth is achieved, a blunt probe is used to palpate the base of the tunnel so that the thin ivory-white shell of the posterior vertebral wall can be carefully lifted with a fine bone punch or curette. The posterior longitudinal ligament still acts as a protective barrier between the instruments and the neural structures. Bone wax can be used to stop the bleeding from the spongy bone, and epidural bleeds can be managed with thrombin-soaked Gelfoam or FloSeal. The use of bipolar coagulation is strongly discouraged at this step.

The adequacy of the decompression can be confirmed by observing the bulging nerve root with cerebrospinal fluid (CSF) flow and palpating the superior and inferior pedicles along the course of the nerve root using a root probe.

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The procedure is based on neurophysiological recordings. Ventral root stimulation identifies the radicular level (anatomic mapping). Dorsal root stimulation evaluates its implication in the hyperactive segmental circuits (physiological testing), helping quantify the percentage of rootlets to be cut.

Keyhole interlaminar dorsal rhizotomy (KIDr) offers direct intradural access to each of the ventral/dorsal roots, thus maximizing the reliability of anatomic mapping and enabling individual physiological testing of all targeted roots. The interlaminar (enlarged) approach minimizes invasiveness by respecting the posterior spine structures.

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Foreword

It is indeed a pleasure to write a foreword for this magnificent second edition of the *Atlas of Neurosurgical Techniques: Spine and Peripheral Nerves*, edited by Dr. Richard G. Fessler and Dr. Laligam N. Sekhar. The book is a true compendium of information designed for both the seasoned spine and peripheral nerve surgeon and the novice. Virtually all conceivable spine operations are covered, resulting in an encyclopedic volume that serves as a refresher guide, a reference for hard-to-find information, and an aide to mastering the art of spine surgery.

During their distinguished careers in neurosurgery, Dr. Fessler and Dr. Sekhar developed many new techniques and procedures and trained thousands of residents and clinicians around the globe in these and other techniques. The effort they have put into editing the *Atlas of Neurosurgical Techniques: Spine and Peripheral Nerves* is commendable. Their commitment to driving our specialty forward is an example to those of us who practice spine and peripheral nerve surgery.

I offer the following recommendation to all spine and peripheral nerve surgeons: Keep this book at your bedside and read from it every night. When finished, start over and read it again.

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Preface

In the preface to the first edition of the *Atlas of Neurosurgical Techniques: Spine and Peripheral Nerves,* I commented on the value of updating the seminal text *Operative Neurosurgery* by Dr. Ludwig Kempi. His step-by-step illustrations of neurosurgical operations offered a brilliant introduction to teaching the necessary sequence of individual surgical procedures, and we wanted to emulate his approach. But I also noted that such a task was relatively overwhelming due to the broad expansion in the variety of neurosurgical procedures since his text was published.

Our approach to the text of the first edition of the *Atlas* included the creation of a uniform and consistent format. In addition to the step-by-step illustrations, each section was organized into two types of chapters: The first several summarized common pathologies found in a specific region of the spine; subsequent chapters each detailed a specific operative technique for that region. The operative chapters emphasized accurate and detailed illustrations and photographs of the specific surgical technique and were accompanied by concise descriptions of the procedures, as well as highlighted tables of the indications/contraindications and advantages/disadvantages of that specific technique. This format was intended to enable the student, resident, or surgeon to rapidly review the surgical technique without "wading through" lengthy discussions of the disease processes, etiologies, differential diagnoses, and so on, while still providing that information in the introductory chapters to each section for study when desired. Where numerous procedures utilized the same initial and concluding surgical techniques, redundancy was minimized by detailing them only once and referencing the reader back to the appropriate correlated chapter.

Our efforts on the text were rewarded. In addition to the many positive comments we received from colleagues, the first edition of the *Atlas* was awarded the Association of American Publishers Best Book in Clinical Medicine award in 2006. We were humbled by this acknowledgment, but proud that this text did, indeed, accomplish the goal of being a foundational educational tool for our discipline.

We have maintained the same organizational scheme for this second edition of the *Atlas of Neurosurgical Techniques: Spine and Peripheral Nerves*. During the ten years since the first edition was published, neurosurgical techniques and technology have continued to evolve at a staggering pace. For example, the number of spine procedures performed via minimally invasive technique has dramatically increased. Furthermore, the spine pathology treated by neurosurgeons has progressed, particularly in the arena of deformity. Consequently, the chapters included in this edition have also evolved. Several chapters on techniques that are now performed infrequently have been omitted. Chapters on surgery for spinal deformity have been added. (These chapters cover only the fundamentals, since these techniques are the material for books in and of themselves.) Finally, the "open" and "minimally invasive" surgical techniques can be found side-by-side for each specific operation in which either technique is currently utilized.

It is our hope that, once again, this organization will provide the reader with an up-to-date, easy-to-use reference with minimal redundancy that details current surgical technique through clearly focused text and ample drawings as well as immediately accessible indications, contraindications, advantages, and disadvantages, while still providing specific content on pathology etiology and differential diagnosis.

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Section I Occipital-Cervical Junction

A. Pathology

1 Abnormalities of the Craniovertebral Junction

Brian J. Dlouhy, Raheel Ahmed, and Arnold H. Menezes

The craniovertebral junction (CVJ), also known as the craniocervical junction (CCJ), is composed of the occipital bone that surrounds the foramen magnum, the atlas vertebrae, the axis vertebrae, and their associated ligaments and musculature. The CVJ houses the transition of the central nervous system from the intracranial compartment and the neurovascular structures of the brain to the spinal cord, providing motor and sensory function to the body. The musculoskeletal organization of the CVJ is unique and complex, resulting in a wide range of congenital, developmental and acquired pathology.[1] Early anatomic descriptions of CVJ abnormalities date back to the second quarter of the 19th century. However, the clinical significance of radiographic osseous abnormalities was not described until 1939 by Chamberlain[2] and subsequently by Carl List in 1941. It was List who pointed out that cranial skeletal traction could reduce longstanding cervical dislocation.

Up until the mid-1970s, treatment of CVJ abnormalities consisted of posterior decompression and enlargement of the foramen magnum with removal of the posterior arch of the atlas vertebrae with or without occipitocervical or atlantoaxial fusion. However, for patients with irreducible lesions with ventral cervicomedullary compression, there was considerable morbidity and mortality associated with such treatment. It was not until the late 1970s that the senior author (A.H.M.) refined the transoral approach to the ventral CVJ, minimizing complications that previously plagued the approach.[3,4] In Menezes's 1980 report,[4] nine of 17 patients underwent a transoral approach for congenital, developmental, and acquired CVJ pathology.[3] No postoperative infections occurred, and complications were minimal.

The refinement of the transoral approach enabled the development of the first treatment algorithm by the senior author utilizing a surgical approach for abnormalities of the CVJ.[3,4] The surgical approach is based on an understanding of CVJ dynamics and a determination of the site of encroachment, the type of lesion, and the stability of the CVJ.[5] The pathology of these abnormalities is complex and extensive. There is a wide variety of congenital, developmental, and acquired abnormalities at the CVJ; one or more abnormality can occur in a patient. Since 1977, over 6,000 patients with abnormalities of the CVJ have been evaluated at the University of Iowa Hospitals and Clinics, many undergoing surgical treatment (**Table 1.1**).[6–16]

Table 1.1 Craniovertebral Junction Pathology that Has Required Surgical Treatment at the University of Iowa Hospitals and Clinics from 1977 to 2014

Location	Congenital	Developmental and Acquired	Primary Neoplastic	Secondary Neoplastic
Clivus/foramen magnum	1. Occipital sclerotome segmentation failures 2. Neurenteric cysts 3. Osteopetrosis 4. Foramen magnum stenosis (achondroplasia)	1. Basilar invagination 2. Basilar impression (Paget's, rickets, osteogenesis imperfecta) 3. Cranial settling (rheumatoid arthritis) 4. Paramesial basilar invagination (achondroplasia) 5. Atlanto-occipital dislocation	1. Eosinophilic granuloma 2. Fibrous dysplasia 3. Chordoma 4. Chondroma 5. Chondrosarcoma 6. Plasmacytoma	1. Metastasis 2. Nasopharyngeal malignancy 3. Ectopic pituitary
Atlas vertebra	1. Atlas assimilation with associated segmentation failures 2. Atlas stenosis (achondroplasia)	1. Chronic C1–2 dislocations from Down syndrome, Morquio syndrome, rheumatoid arthritis, and arthropathies 2. Spontaneous and traumatic C1–2 dislocations/ligamentous instability 3. C1–2 rheumatoid pannus 4. C1–2 calcium pyrophosphate deposition disease (CPDD) pannus	1. Chordoma 2. Chondroma 3. Giant cell tumor 4. Osteoid osteoma 5. Osteoblastoma	1. Metastasis 2. Plasmacytoma 3. Local malignancy extensions
Axis vertebra	1. C2–3 segmentation failure 2. Os odontoideum 3. Neurenteric cysts	1. Basilar invagination 2. Basilar impression (Paget's, osteogenesis imperfecta, skeletal dysplasias, hyperparathyroidism, and arthropathies) 3. Cranial settling (rheumatoid arthritis) 4. C2 fractures 5. C1–2 rheumatoid pannus 6. C1–2 CPDD pannus 7. Osteomyelitis	1. Aneurysmal bone cyst 2. Plasmacytoma 3. Chordoma 4. Giant cell tumor 5. Osteoblastoma 6. Chondroma	1. Metastasis 2. Local tumor extension

Classification

The classification of CVJ abnormalities has been divided into the categories of congenital, developmental, and acquired disorders, and further classification can be made based on pathophysiological mechanisms **(Box 1.1)**.

Diagnosis

The most interesting feature of CVJ abnormalities is the diversity of patient presentation. A constellation of symptoms and signs may occur as a result of compromise of the lower brainstem, upper cervical spinal cord, lower cranial nerves, upper cervical nerve roots, and the vascular supply to these structures, as well as resulting from hindbrain herniation and blockage of normal cerebrospinal fluid (CSF) pathways.[7,9] Each of these pathophysiological processes presents with its own characteristic features. A list of the pathological states affecting the CVJ is extensive, and these abnormalities may vary in the magnitude of neurologic dysfunction.

The symptoms of CVJ dysfunction may be insidious and at times may present with false localizing signs. A rapid neurologic progression occurs in rare instances and may be followed by

Box 1.1 Classification of Craniovertebral Junction Abnormalities

I. Congenital abnormalities and malformations of the craniovertebral junction
- A. Malformations of the occipital bone
  - 1. Manifestations of occipital vertebra
    - a. Clivus segmentations
    - b. Foramen magnum remnants
    - c. Atlas variants
    - d. Dens segmentation anomalies
  - 2. Basiocciput hypoplasia
  - 3. Condylar hypoplasia
  - 4. Atlas assimilation (occipitalization of the atlas)
  - 5. Osteopetrosis
  - 6. Foramen magnum stenosis (achondroplasia)
- B. Malformations of the atlanto-occipital junction
  - 1. Atlas assimilation (occipitalization of the atlas)
- C. Malformations of the atlas
  - 1. Atlas assimilation (occipitalization of the atlas)
  - 2. Atlantoaxial fusion
  - 3. Aplasia of atlas arches
- D. Malformations of the atlantoaxial junction
  - 1. Basilar invagination
- E. Malformations of the axis
  - 1. Irregular atlantoaxial segmentation
  - 2. Dens dysplasias
    - a. Persistent ossiculum terminale
    - b. Os odontoideum
    - c. Hypoplasia-aplasia
  - 3. Segmentation failure of C2/C3

II. Developmental and acquired abnormalities of the craniovertebral junction
- A. Foramen magnum/occipital bone associated abnormalities
  - 1. Secondary basilar invagination
    - a. Basilar impression (e.g., Paget's disease, rickets, osteogenesis imperfecta)
    - b. Cranial settling (rheumatoid arthritis)
- B. Atlanto-occipital junction abnormalities
  - 1. Atlanto-occipital dislocation (AOD)
- C. Atlantoaxial instability
  - 1. Basilar invagination (primary)
  - 2. Errors of metabolism (e.g., Morquio's syndrome)
  - 3. Down syndrome
  - 4. Infections (e.g., Grisel's syndrome)
  - 5. Inflammatory (e.g., rheumatoid arthritis)
  - 6. Traumatic atlantoaxial dislocation; os odontoideum
  - 7. Tumors (e.g., neurofibromatosis, syringomyelia)
  - 8. Miscellaneous (e.g., fetal warfarin syndrome, Conradi's syndrome)
- D. C1/C2 pannus formation
  - 1. Rheumatoid arthritis
  - 2. Calcium pyrophosphate deposition disease (CPDD)

sudden death. Often, an antecedent history of minor trauma triggers a pattern of symptoms and signs that may progress at a rapid pace **(Box 1.2)**.

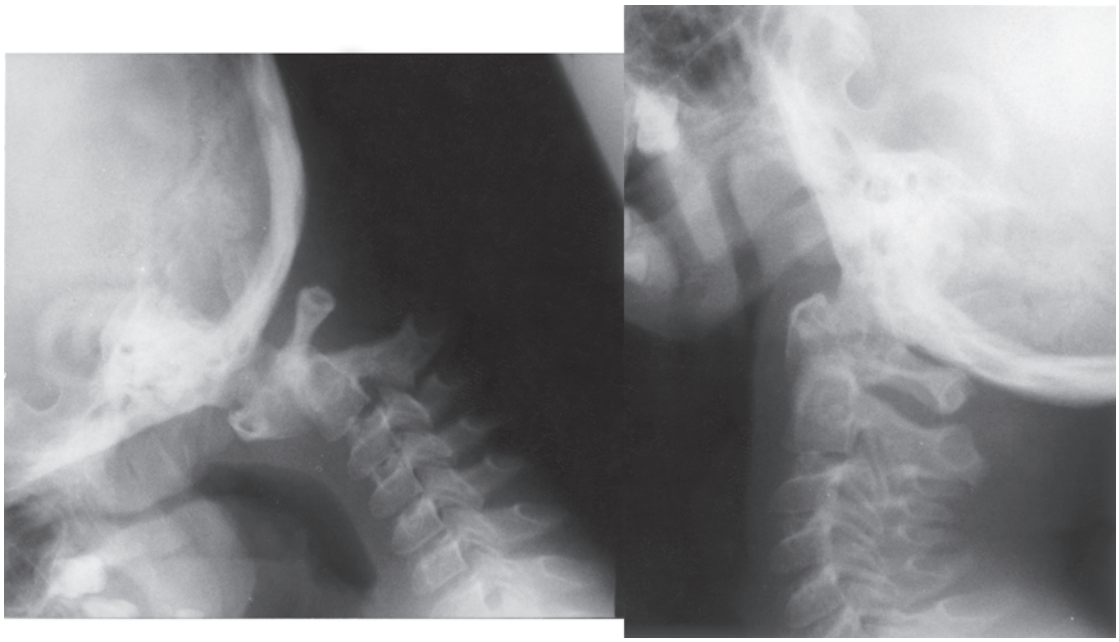
Box 1.2 Signs and Symptoms of Craniovertebral Abnormalities (Insidious or Rapid in Onset)

- Head tilt
- Short neck, low hairline, limitation of neck motion
- Web neck
- Scoliosis
- Features of skeletal dysplasias
- Neck pain and posterior occipital headache
- Basilar migraine
- Hand or foot isolated weakness
- Quadriparesis/paraparesis/monoparesis
- Sensory abnormalities
- Nystagmus—usually downbeat and lateral gaze
- Sleep apnea
- Repeat aspiration pneumonia, dysphagia
- Tinnitus and hearing loss
- Vertigo

Neuroradiological Investigation

The factors that are considered in determining the appropriate treatment of CVJ osseous, ligamentous, and soft tissue lesions are (1) the reducibility of the lesion; (2) the direction and the mechanics of encroachment and compression of neural structures; (3) the etiology of the abnormality; (4) the presence of abnormal ossification centers and anomalous growth and development of the CVJ; and (5) the presence of associated lesions such as vascular abnormalities, Chiari malformation, and syringohydromyelia.[3–5,7,9]

The word *reducible* refers to the ability to achieve normal osseous alignment, thereby relieving compression on neural structures. To achieve this, maneuvers such as flexion, extension, traction, disimpaction, and reduction distraction are utilized **(Fig. 1.1)**. In regard to the direction of encroachment on neural structures, the lesion is either ventral to the cervicomedullary junction or dorsal and may be superior as well as lateral in location to the foramen magnum **(Fig. 1.2)**. Associated neural



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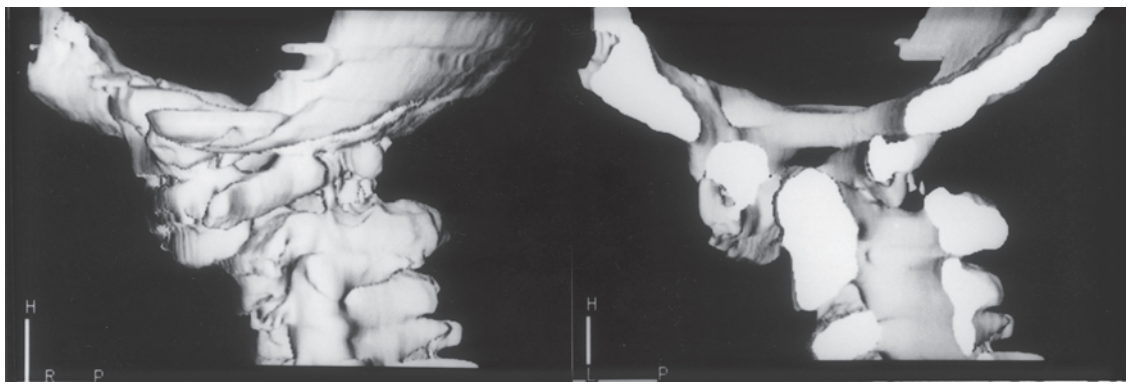

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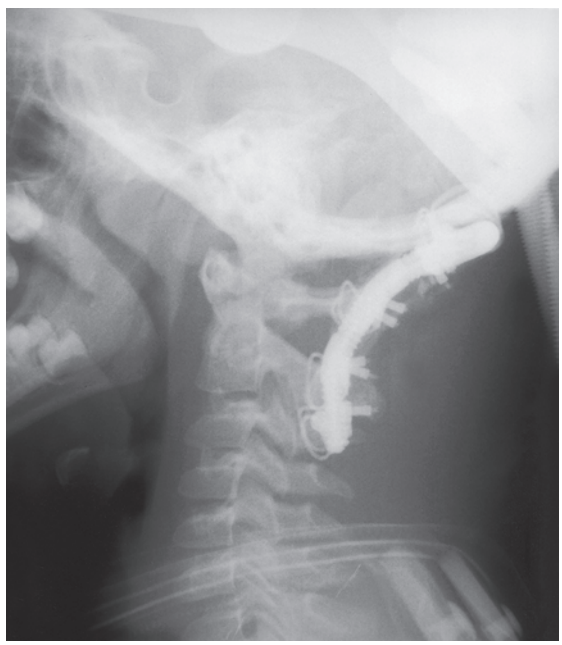

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Fig. 1.1 **(a)** Composite of lateral cervical spine radiograph in the flexed *(left)* and the extended *(right)* position in a 7-year-old child with Down syndrome. Note the atlantoaxial dislocation, possible os odontoideum and the anterior atlantal arch sliding forward in extension. **(b)** Composite of lateral three-dimensional (3D) view of the craniovertebral junction (CVJ) *(left)* and a midsagittal section of the 3D reconstruction *(right)*. There is an atlantoaxial dislocation with bifid anterior and posterior arches to the atlas, as well as an os odontoideum. **(c)** Lateral radiograph taken 3 months following a dorsal occipitocervical fixation utilizing custom contoured threaded titanium loop instrumentation with autologous rib graft. The CVJ alignment is maintained.