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Review Article

Cervical Radiculopathy due to Cervical Degenerative Diseases : Anatomy, Diagnosis and Treatment

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A cervical radiculopathy is the most common symptom of cervical degenerative disease and its natural course is generally favorable. With a precise diagnosis using appropriate tools, the majority of patients will respond well to conservative treatment. Cervical radiculopathy with persistent radicular pain after conservative treatment and progressive or profound motor weakness may require surgery. Options for surgical management are extensive. Each technique has strengths and weaknesses, so the choice will depend on the patient's clinical profile and the surgeon's judgment.

KEY WORDS : Cervical radiculopathy · Diagnosis · Surgery.

INTRODUCTION

A cervical radiculopathy is the most common symptom of cervical degenerative disease. Contributing factors may include some combination of disc herniation, osteoarthritis of uncovertebral and facet joints, decreased intervertebral height and spondylolisthesis of cervical vertebrae - collectively known as cervical spondylosis[4].

The natural course of radiculopathy due to degenerative diseases is generally favorable, with spontaneous resolution of symptoms in a majority of patients with time[35,44]. In a cohort study of 51 patients with cervical radiculopathy managed without surgery, 42% were asymptomatic at 10 years, 30% had mild symptoms and 28% moderate symptoms[34]. Patients whose pain does not naturally resolve require some form of intervention. Surgery may be indicated for compressive cervical radiculopathy with persistent radicular pain after conservative treatment and progressive or profound motor weakness[8,49,52].

This article presents the anatomy of the cervical foramen, causes of degenerative cervical radiculopathy, clinical symptoms, and the diagnostic tools and treatments available in cervical radiculopathy.

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ANATOMY

The following is an anatomic description of the lateral area of the cervical canal and the medial cervical foramen, with its contents, from C3 to T1[48]. The lateral portion of the cervical canal is covered by the lateral aspects of a superior and inferior lamina. The ligamentum flavum (LF) attached to anterior two-thirds of the superior lamina, but inferiorly it attached only to the superior margin of the lower lamina. Laterally, the LF ends 1 to 2 mm before the medial limit of the intervertebral foramen. The cervical foramen is bounded anteriorly by the superior and inferior vertebral bodies, and intervertebral disc covered with the posterior longitudinal ligament (PLL), posteriorly by the superior and inferior facets, and cephalad and caudad by pedicles (Fig. 1).

The sensory and motor roots exit the cervical canal within a common dural sleeve, but in the cervical foramen, the dural sleeve divides into a posterosuperior sleeve including the sensory nerve division and an anteroinferior sleeve carrying the motor nerve division. These dural sleeves are once again combined at the region of the sensory ganglion.

CAUSES OF DEGENERATIVE CERVICAL RADICULOPATHY

Two pathological processes, singly or in combination, can cause compression of the nerve root : 1) disc herniation with or without extruded disc fragments, and 2) degenerative

cervical spondylosis.

Disc herniation

As the disc ages, the disc material loses hydration and the annulus weakens, thus increasing the potential for extrusion or herniation. When the disc material protrudes, it is mostly expelled to the lateral side of the spinal canal because of the PLL. This directly compresses the exiting nerve root, which leads to cytokines release and chemical irritation to the nerve tissue[49].

Degenerative cervical spondylosis

Changes characteristic of cervical spondylosis may lead to a cervical radiculpathy. This involves a narrowing of the cervical foramen by osteophytes and bony spurs that develop along the junction of the vertebrae and disc space. Disc degeneration further narrows the foramen by reducing height between the pedicles, which enclose the exit passage of the nerve. Concurrently, buckling of the posterior LF occurs from loss of tension, as well as formation of ostophytes at the disc margins[35]. These combined effects result in circumferential narrowing of the cervical foramen and subsequent neural compression. Approximately 78% of degenerative cervical radiculopathies arise through spondylosis and only 22% from acute disc herniation[44].

DIAGNOSIS

Clinical symptoms of cervical radiculopathy include pain and paresthesias radiating along the distribution of a nerve root, often associated with sensory loss and motor dysfunction. Radiculopathy caused by degenerative disease most often affects the cervical root segments 5 to 8, resulting in well-recognized clinical syndromes (Table 1). However, each dermatome overlaps widely with adjacent dermatomes, so further evaluation is usually required. Radiologic and electrophysiologic studies are commonly used and selective cervical root block is sometimes needed.

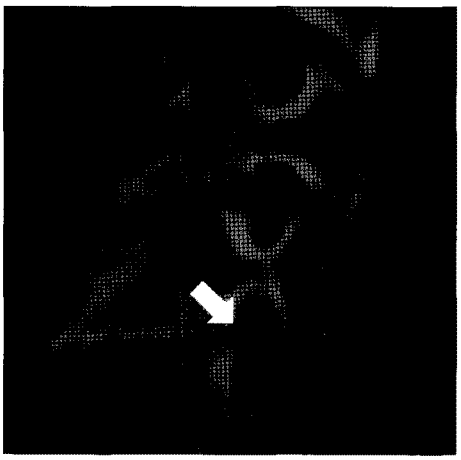

Fig. 1. CT showing anatomical boundaries of the cervical foramen and abnormal bony spurs encroaching (white arrow) on the cervical foramen.

Radiologic studies

Plain radiograph

Plain radiographs can reveal the degree of cervical spondylosis, as well as congenital lesions, calcified lesions, tumorous conditions, deformities and loss of sagittal balance. Dynamic and oblique films can distinguish spinal instabilities and foraminal bony spurs.

Computerized tomography

CT is performed in the axial plane and then reformatted into other planes, including the sagittal, coronal, and curved coronal planes. To ensure minimal degradation in the reformatted images, CT should be performed with the thinnest stacked contiguous sections possible[27]. Using thin sections, the 3D CT performs a very rapid and complete cervical spine examination which with current software may be reformatted into any appropriate plane, as for example, oblique sections through the cervical foramina to assess foraminal stenosis (Fig. 1).

Magnetic resonance imaging

MRI offers a variety of imaging sequences and, of importance, obtains the data directly in any plane without the image degradation produced in CT reformatting. The standard cervical spine screening MRI should include sagittal and axial sequences with T1 and T2 weighted images[27].

Because the degenerative cervical lesions are small, thin sections (2-4 mm) are essential, especially in the axial plane. The standard axial sequence, therefore uses a gradient-echo 3-D volume T2 sequence with 2-mm images and no skip area. However, Van de Kelft and van Vyve[55] showed that an axial MRI view may have low specificity for foraminal lesions. Others find it difficult to delineate disease in the lateral aspects of the spinal canal and foramen on sagittal images because the foramen runs an oblique course with respect to the sagittal

Table 1. Clinical syndromes of cervical radiculopathy

Root	Pain location	Sensory deficit	Motor deficit	Reflex change
C5	Neck, shoulder, anterior arm	Shoulder	Deltoid	Biceps, brachioradialis
C6	Upper arm, thumb, radial forearm	Thumb, index finger, radial forearm	Forearm flexion	Biceps, brachioradialis
C7	Neck, shoulder, dorsum of forearm	Middle finger	Forearm extension (wrist drop)	Triceps
C8	Neck, shoulder, ulnar forearm	Ring, little fingers, hypothenar eminence	Hand intrinsic	Finger jerk

plane[38]. Therefore, the additional acquisition of angled sagittal MR images oriented perpendicular to the true course of the neural foramina clarifies lateral disease by providing a second imaging plane orthogonal to the diseased area. Previous studies show that angled sagittal MRI provides more accurate diagnosis of herniated disc and stenosis in the cervical foramen than conventional MRI (Fig. 2)[38,47,50].

Electrophysiologic studies

Nerve conduction

Patients with pure radiculopathy typically show normal nerve conduction. Although some motor abnormalities may be present, the nerve conduction study can exclude diseases, such as carpal tunnel syndrome, tardy ulnar syndrome, and cubital tunnel syndrome.

Sensory studies provide the most important criteria in the assessment of cervical radiculopathy. The sensory nerve action potential (SNAP) remains normal in lesions proximal to the dorsal root ganglion, so nearly all radiculopathies caused by cervical degenerative disease shows the normal SNAP.

Electromyography

The needle EMG is very useful for evaluation of cervical radiculopathy. Distal, proximal, and paraspinalis muscles are sampled, looking for abnormalities in a myotomal pattern that are beyond the distribution of any one nerve. However, EMG presents the following important limitations : 1) if the lesion is acute, the EMG may be normal; 2) if the radiculopathy is demyelinating without axonal loss, the EMG will be normal; and 3) if the sensory nerve root is predominantly affected, the EMG will be normal[43]. Hence, false-negative results are not uncommon in cervical radiculopathy.

Selective diagnostic nerve root block

In patients with cervical radiculopathy and a multilevel lesion, the main lesion may be difficult to define from the patient's symptoms and radiologic study only. Some patients present radicular pain with an atypical distribution[5] and radiologic findings that do not correlate with clinical symptoms. In particular, the pain distribution in the neck, arm and shoulder is not a reliable determinant of the nerve root origin[2]. SNRB may help to identify the affected root in the symptomatic multi-level degenerative cervical lesions[1,2,54].

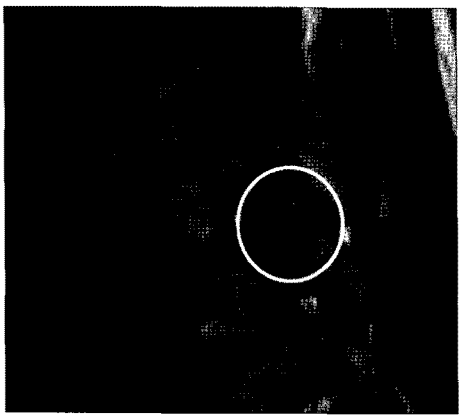

Fig. 2. Angled sagittal MRI showing clearly the foraminal contour and nerve root. The circle indicates the foraminal disc herniation.

TREATMENT

Non-surgical treatment

Conservative treatment

Patients with cervical radiculopathy may find relief in oral analgesics, oral steroids, cervical traction, neck immobilization, physical therapy, behavior modification and various combinations of these. Nonsteroidal anti-inflammatory drugs (NSAIDs) and muscle relaxants are generally used and opiates are added for severe pain. Oral steroid drugs may effectively relieve acute radicular pain[26,49]. However, excessive or long-term steroid use imposes risks for immunosuppression, hyperglycemia, osteoporosis, and adrenal insufficiency[14,20,36].

Cervical traction, neck immobilization, physical therapy and behavior modification have also been used to enlarge the neural foramen and reduce physiologic neck stress[13,56]. However, immobilization must be used with caution, because it may induce neck muscle atrophy.

From 40 to 80% of patients with radicular pain respond to conservative treatment[19,26,49], but conservative treatment should be used in patients with nonprogressive neurological deficits without profound motor deficits.

Epidural steroid injection (transforaminal or interlaminar)

Epidural steroid injection is a rapid and effective mode of treatment[1,7,9,33]. The injection must be monitored by fluoroscopy and the patient should be observed for changes in vital signs for at least 30 minutes after the procedure. Severe complications, although rare, have been reported[7,53,57].

Surgical treatment

For compressive cervical radiculopathy with pain that persists after conservative treatment, and progressive or profound motor weakness, surgery may be effective[8,49,52]. Surgical techniques for cervical radiculopathy and the corresponding outcomes are summarized in Table 2.

Anterior approaches

The anterior approach provides optimal accessibility to the affected lesion without crossing the neural elements. How-

ever, this procedure requires an anterior neck dissection with attendant risks of injury to the vasculature, trachea, esophagus, and laryngeal nerve, as well as compression.

Anterior cervical foraminotomy

In selected patients, the ACF provides therapy while preserving spinal mobility and integrity of the intervertebral disc[22]. The long-term disadvantages, however, include disc degeneration and unilateral removal of an uncoverbral joint[15,25]. Surgical outcomes are generally good[15,23,25,58], but Hacker et al.[15] reported the poor results could arise from poor patient selection, poor surgical technique, or an inherent problem with the produre. Reports emphasize patient selection as the single most important determinant of outcome; patients with unilateral (one- or two-level) symptoms and minimal neck pain show favorable outcomes for this surgery.

Anterior cervical discectomy and fusion

Currently, ACDF is the standard procedure for cervical radiculopathy due to cervical degenerative disease. The ACDF can remove the affected disc as well as augment the cervical foramen, either directly or indirectly[40]. Fusion provides stability and removes the dynamic factors, which may have been the source of neck pain. Multi-level treatment is relatively uncomplicated and surgical outcomes are excellent[17,30,31]. However, this same loss of mobility may promote adjacent segment degeneration (ASD)[18,21].

Table 2. Surgical outcomes according to the surgical technique

Approach	Author (year)	Symptom	F/U (months)	Result	Complication rate
Anterior foraminotomy	White (2007)	R	10-36	Fully resolve : 67% Mean VAS reduction of arm pain : 6.9	4.8%
	Hacker (2003)	R	Minimum 3	Odom's criteria (good or better) : 52%	30.4% (reoperation)
	Jho (2002)	R	Minimum 24	Good or better : 99%	3.9%
	Johnson (2000)	R	6-36	Oswestry improve : 91%	4.8%
Anterior cervical discectomy and fusion	Korinth (2006)	R	72.1	Odom's criteria (excellent + good) : 93.6%	6.5%
	Heidecke (2000)	R (n=28) M-R (n=78)	48-126	Significantly improvement : R - 92.8%, M-R - 64% Fusion rate (autologous bone) : 96%	1.8% (except donor site complication)
	Kozak (1989)	R	15	Good or better : 83% (non-union group), 87% (union group)	6.4%
Anterior cervical discectomy	Nandoe (2007)	R	84-264	Satisfaction : FU at 6 weeks - 90.1%, Late phone survey FU - 67.6%	10.5%
	Gaetani (1995)	R (n=108) M (n=31)	10-120	Good or better : R - 90.9%, M - 58.1%	5%
Arthroplasty	Garrido (2010)	R	48	Instrument : Bryan NDI (preop → posop) : 51 → 10 Success rate* : arthroplasty (93.3%) vs. arthrodesis (82.4%) VAS of arm (preop → postop) : 78.8 → 10.8	5%
	Beaurain (2009)	R	24	Instrument : Mobi-C NDI : 24.3 points improvement VAS of arm : 46.1 points improvement VAS of neck 41.0 points improvement	13.2% (device or surgery-related, or secondary cervical surgery)
	Kim (2009)	R	6-36 (mean : 29.2)	Instrument : Bryan Odom's criteria (excellent + good) : 90.3%	Not mention
	Park (2008)	R	20	Instrument : Mobi-C NDI (preop → postop) : 23.43 → 8.36 VAS of arm (preop → postop) : 4.85 → 1.9	0%
	Yoon (2006)	R (n=16) M (n=4) M-R (n=6)	2.9-19.5 (mean 11.8)	Instrument : Bryan VAS of arm (preop → postop) : 8.15 → 1.35 VAS of neck (preop → postop) : 6.5 → 3.8	3.8%
Posterior foraminotomy	Kim (2009)	R	24-66	Odom's criteria (excellent + good) : 86.4%	0%
	Korinth (2006)	R	72.1	Odom's criteria (excellent + good) : 85.1%	1.8%
	Jodicke (2003)	R	33.6	Odom's criteria (excellent + good) : 82.1%	7.4%

*Success : NDI improvement is more than 15 points at 48 months postoperatively. R : radiculopathy, M : myelopathy, FU : follow-up, NDI : neck disability index

Anterior cervical discectomy

The ACD allows disectomy without grafting; despite initially good outcome, long-term follow-up reveals increasing patient dissatisfaction[39]. Gaetani et al.[10] report that presentation with pure radicular signs is the most important predictor of good overall outcome[10].

Cervical arthroplasty

Arthroplasty is rapidly emerging in Korea as an alternative to arthrodesis for cervical radiculopathy and myelopathy, and abundant evidence supports superiority of arthroplasty[3,4,6,28,41,60,61]. Unlike arthrodesis, arthroplasty preserves segmental motion, which may theoretically prevent degenerative changes in segments adjacent to a previous fusion. This, however, is a matter of controversy.

Several studies address the natural history of the adjacent intervetebral disc[12,16,51]. Some authors reported no change in the extent of movement in adjacent segments two years after a fusion[45]. Yi et al.[59] reported a 12.5% rate of ASD after arthroplasty, which is higher than in previous studies.

Heterotopic ossification (HO) may also complicate cervical arthroplasty, as it does after total hip arthroplasty[46]. Incidence rates reported for HO range from 0 to 67.1%[28,37,41,42,59,61]. Mehren et al.[37] reported that 49.4% of patients had HO grades 2-3, and that motion preservation after arthroplasty can be assured if spontaneous fusion is prevented. In contrast, Beaurain et al.[4] reported that 67.1% of patients in a study group developed HO (McAfee classification class I, II, III, IV), but that 97% of these had HO class 0, I, and II, with a range of motion > 3°, and that clinical status of the class III and IV groups did not differ from that of other groups overall at 2 years.

Consequently, the role of disc arthroplasty in the treatment of radiculopathy is evolving.

Posterior approaches

Posterior laminoforaminotomy/foraminotomy and/or discectomy

The effectiveness of posterior foraminotomy/discectomy for treating foraminal stenosis and disc herniation is well established[11,24,29,30,32,48]. The advantages of posterior foraminotomy/discectomy include the avoidance of complications associated with anterior approaches to the cervical spine and no need for cervical fusion and instrumentation. The drawbacks of posterior procedures include postoperative muscle atrophy, neck discomfort and limited applicability (e.g., a central disc herniation may be difficult to reach). Kim and Kim[29] reported that tubular retractor-assisted foraminotomy favored reductions in skin incision size, length of hospital stay, duration of analgesics, and postoperative neck pain.

CONCLUSION

Cervical radiculopathy is a prominent symptom of degenerative cervical disease. To effectively treat the condition, we must consider the various causes of the radiculopathy and identify the main lesion among the multiple degenerative lesions that may be present. Although most patients respond well to conservative treatment, persistent radicular pain after con-servative treatment, and progressive or profound motor weakness indicate the need for surgery. The appropriate choice of surgical technique will consider the patient's clinical features and the surgeon's judgment.

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