Cervical spondylosis is a term used to describe the degenerative aging process that encompasses a sequence of changes in the intervertebral discs, vertebral bodies, facet joints, and ligaments of the cervical spine. It is a common condition that occurs as a natural consequence of aging in the majority of the adult population. As a result, it is often difficult to distinguish normal physiological degeneration from pathological changes. Anatomic changes should only be considered pathological if they are etiologically related to specific clinical syndromes.

There are three main categories of cervical spondylosis: cervicalgia (non-radiating neck pain), cervical radiculopathy, and cervical myelopathy. This article concerns the pathophysiology, presentation, and clinical evaluation of cervical radiculopathy and the spectrum of radicular syndromes attributable to cervical spine degenerative disease. Cervicalgia and myelopathy, which are commonly associated with radiculopathy and the treatment of cervical radiculopathy, are covered elsewhere in this issue.

Cervical radiculopathy is a pathological process involving the cervical nerve root. It is the result of compression and inflammation of the nerve root or roots at or near the cervical neural foramen (Fig. 1–3). It occurs annually in 85 out of 100,000 people (22). The most common causes for radiculopathy are cervical disc herniation (Fig. 2 and 3) (17), followed by cervical spondylosis (Fig. 1) (1, 35). Cervical radiculopathy is less commonly caused by intraspinal or extraspinal tumors, trauma with nerve root avulsion, synovial cysts, meningeal cysts, dural arteriovenous fistulae (19), or tortuous vertebral arteries (16). Cervical radiculopathy may also occur without an identifiable cause. Other conditions that can mimic cervical radiculopathy, which should be included in the differential diagnosis, are upper extremity nerve entrapment, primary shoulder disease, brachial plexus disorders, and peripheral neuropathies. This article focuses on radiating pain secondary to compression of cervical nerve roots by herniated disc material or pain that is associated with cervical spondylosis.

**PATHOPHYSIOLOGY**

The cervical intervertebral disc is taller ventrally than dorsally, and it is the cervical disc, not the vertebral body, that is responsible for the maintenance of cervical lordosis. The outer portion of the disc is made up of the annulus fibrosus. The latter is crescent-shaped, and, when viewed in the axial plane, it is thicker ventrally than dorsally. Vertrally, it is multilaminated with interweaving fibers of alternating orientation, but dorsally, it is only present as a thin layer of collagen fibers (23). Before the age of 20 years, few morphological changes occur in the cervical spine. Beginning in the third decade of life, a progressive decline in the water content of the intervertebral disc occurs and continues with age. The nucleus pulposus becomes an indistinct fibrocartilaginous mass (29). In patients younger than 30...
years, the water content of the intervertebral disc approaches 90%, and it decreases to less than 70% by the eighth decade of life. The basic structural unit of the nucleus pulposus is glycosaminoglycan protein, which consists of a proteoglycan protein core and bulky, sterically active polysaccharide attachments of chondroitin sulfate and keratin sulfate. Because of their high molecular weight and overall negative charge, glycosaminoglycan proteins have a strong attraction for water molecules. With aging, these large, sterically active glycosaminoglycan proteins gradually diminish in size and number. As a result, the intervertebral disc’s ability to retain water also diminishes. These age-related changes in the chemical composition of the nucleus pulposus and annulus fibrosus cause the degenerated disc to become more compressible and less elastic (3). Consequently, the disc loses height and bulges dorsally into the spinal canal. As the vertebral bodies drift toward one another (i.e., subsidence), the ligamentum flavum and facet joint capsule fold in dorsally, causing a further decrease in the canal and foraminal dimensions. This approximation of adjacent vertebral bodies leads to a reactive process that produces osteophytes around the disc margins and at the uncovertebral and facet joints. However, the degenerative changes of the cervical intervertebral disc differ from those affecting the lumbar disc. In the cervical spine, true disc prolapse and herniation of the nucleus pulposus is uncommon (23).

The neural foramen is bordered ventrally by the uncovertebral joint and dorsally by the superior articular process of the caudal vertebra (2). Compressive radiculopathies occur as a result of mechanical distortion of the nerve root by either the hypertrophied facet joint or uncovertebral joints (Fig. 1), disc protrusion (Fig. 2 and 3), spondylotic spurring of the vertebral body, or a combination of these factors. Pressure on the nerve root may lead to sensory deficits, motor weakness, or radicular pain. Pain is related to mechanical compression and to an inflammatory response.

PRESENTATION

Radiculopathy can be divided into acute, subacute, and chronic. Acute cervical radiculopathy occurs in relatively young patients in the setting of a tear in the annulus fibrosus and subsequent prolapse of the nucleus pulposus. Subacute radiculopathy occurs in patients with pre-existing cervical spondylosis, without persistent symptoms except for occasional neck pain. Patients develop insidious symptoms, which are often polyradicular in nature. Chronic radiculopathies materialize from acute or subacute radiculopathies that have failed to respond to treatment.

Pain is most prominent in acute cervical radiculopathy and diminishes as the condition becomes more chronic. It may be described as sharp, achy, or burning and may be located in the neck, shoulder, arm, or chest, depending on the nerve root involved. Classically, an acute radiculopathy presents with pain radiating in a myotomal distribution. For example, patients with a C7 radiculopathy often experience pain in the triceps region rather than the distal dermatomal region. Sensory symptoms, predominantly parasthesias and numbness, are more common than motor loss and diminished reflexes. The clinician should keep in mind that the sensory symptoms frequently do not match the dermatomes illustrated in medical textbooks. Henderson et al. (13) reviewed the clinical presentations of cervical radiculopathy in more than 800 patients and found arm pain in 99.4%, sensory deficits in 85.2%, neck pain in 79.7%, reflex deficits in 71.2%, motor deficits in 68%, scapular pain in 52.5%, anterior chest pain in 17.8%, headaches in 9.7%, anterior chest and arm pain in 5.9%, and left-sided chest and arm pain in 1.3%.

Radicular pain is often accentuated by maneuvers that stretch the involved nerve root, such as coughing, sneezing, Valsalva, and certain cervical movements and positions. Several clinical signs suggestive of radiculopathy have been described. Davidson et al. (9) described the “shoulder abduction sign” in

FIGURE 1. Axial T2 MRI image (A) and CT scan (B) in a patient with a left C6 radiculopathy. There is a left-sided C5 to C6 osteophyte causing neural foraminal stenosis and C6 nerve root compression.

FIGURE 2. A, parasagittal reformat of CT myelogram and axial CT myelogram (B) demonstrating a left-sided C6–C7 disc herniation in a patient who was unable to have an MRI scan due to prior aneurysm clip placement.

FIGURE 3. Axial T2 MRI demonstrating C7–T1 disc herniation in a patient with a left-sided C8 radiculopathy. The patient was referred after unsuccessful attempted dorsal resection of the disc.
which the patient experiences significant relief of arm pain with shoulder abduction. The patient holds the arm over the head and typically rests the wrist or forearm on the top of the head. The Spurling test is a maneuver that provokes the patient’s arm pain with induced narrowing of the neural foramen. It is performed by extending the neck and rotating the head to the side of the pain and then applying downward pressure on the head. The test is thought to cause a narrowing of the intervertebral foramina and is considered positive if the limb pain or paresthesia is provoked with the maneuver. This test has been found to be specific, but not sensitive, for cervical radiculopathy (33).

The type and location of the radicular symptoms are determined by the level at which the cervical nerve root compression occurs (Table 1). Radiculopathy of the third cervical nerve root results from pathologic changes between the C2 and C3 vertebrae and is not common. Patients may experience pain in the suboccipital region, often extending to the back of the ear, and in the dorsal or lateral aspect of the neck. This pain is often difficult to distinguish from other causes of headache. Numbness may be present along the occiput and in the distribution of the great auricular and lesser occipital nerves. Although the third cervical nerve root supplies, in part, the suboccipital muscles, the trapezius, the levator scapulae, the sternocleidomastoid, and the strap muscles, an isolated motor deficit generally cannot be detected clinically.

Radiculopathy of the fourth cervical nerve root results from pathologic changes between the C3 and C4 vertebrae and is more common than a C3 radiculopathy. It may be a cause of unexplained pain along the base of the neck that radiates to the superior aspect of the shoulder and posteriorly to the scapula. The rhomboid, trapezius, and levator scapulae muscles are supplied, in part, by the fourth nerve root, but a motor deficit may be hard to detect. A sensory deficit may be present over the anterolateral aspect of the neck, along the distribution of the transverse cervical and supracleavicular nerves. The C3, C4, and C5 nerve roots innervate the diaphragm. Involvement of these three nerve roots may lead to diaphragmatic weakness (6, 7).

Radiculopathy of the fifth cervical nerve root results from pathology at the C4–C5 level. Patients often present with numbness and localized shoulder pain that can be confused with a pathologic shoulder condition (Table 2) (2). When it is due to a rotator cuff tear, shoulder disease can present with weakness of abduction and external rotation. However, unlike pain from primary shoulder disease, radicular pain is not significantly affected by motion of the shoulder. The numbness follows the C5 sensory distribution, which is located over the top of the shoulder along its midportion, and extends laterally to the midportion of the arm. The principal motor deficit is supraspinatus and deltoid muscle weakness with impaired shoulder abduction. Weakness of the clavicular head of the pectoralis major, biceps, and infraspinatus muscles can also occur. The pectoralis reflex and the biceps reflex, which are innervated by the fifth and sixth cervical nerve roots, may be decreased.

Compression of the C6 nerve root is the second most common cause of cervical radiculopathy and results from disc herniations or spondylosis at the C5–C6 level. Patients present with pain

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**TABLE 1. The cervical radicular syndromes**

<table>
<thead>
<tr>
<th>Nerve root</th>
<th>Dermatome</th>
<th>Myotome</th>
<th>Reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3</td>
<td>Supraclavicular, suboccipital, and posterior auricular regions</td>
<td>Trapezius, levator scapulae, strap muscles, sternocleidomastoid, diaphragm</td>
<td>None</td>
</tr>
<tr>
<td>C4</td>
<td>Infraclavicular and posterior cervical regions, posterior shoulder</td>
<td>Trapezius, rhomboids, levator scapulae, diaphragm</td>
<td>None</td>
</tr>
<tr>
<td>C5</td>
<td>Superolateral aspect of the arm</td>
<td>Pectoralis major (clavicular head), supraspinatus, infraspinatus, deltoit, biceps, brachialis, brachioradialis, diaphragm</td>
<td>Pectoralis, biceps</td>
</tr>
<tr>
<td>C6</td>
<td>Lateral arm and forearm, thumb and index finger</td>
<td>Biceps, brachialis, brachioradialis, extensor carpi radialis longus, supinator, pronator teres, flexor carpi radialis, triceps</td>
<td>Biceps, brachioradialis</td>
</tr>
<tr>
<td>C7</td>
<td>Posterolateral arm and forearm, middle finger</td>
<td>Triceps, latissimus dorsi, pronator teres, flexor carpi radialis, extensor carpi ulnaris, extensor digitorum, abductor pollicis longus, extensor pollicis brevis and longus, extensor indicis</td>
<td>Triceps</td>
</tr>
<tr>
<td>C8</td>
<td>Medial arm and forearm, fourth and fifth digits</td>
<td>Flexor digitorum superficialis, pronator quadratus, flexor digitorum profundus, flexor pollicis longus, flexor carpi ulnaris, lumbricals 3 and 4</td>
<td>None</td>
</tr>
<tr>
<td>T1</td>
<td>Axillary and pectoral region, medial arm and proximal medial forearm</td>
<td>Adductor pollicis, abductor pollicis brevis, opponens pollicis, flexor pollicis brevis, interossei, lumbricals 1 and 2, Horner’s syndrome may be present</td>
<td>None</td>
</tr>
</tbody>
</table>
and/or numbness radiating from the neck to the lateral aspect of the biceps, the lateral aspect of the forearm, the dorsum of the hand at the web space between the thumb and index finger, and into the tips of those digits. Motor deficits in the wrist extensors and biceps are common. Weakness of the supinator, pronator teres, and triceps muscles may be present. The brachioradialis and biceps reflexes may be decreased or absent. The pain and paresthesias of C6 radiculopathy may mimic carpal tunnel syndrome, which is caused by median nerve entrapment at the wrist by the transverse carpal ligament.

Unlike cervical radiculopathy, upper limb nerve entrapments, such as carpal tunnel syndrome, are characterized by pain, paresthesia, and weakness in multiple nerve root distributions. Referred pain with entrapment neuropathy, however, is common and pain can radiate proximally to the site of entrapment. Compression of the median nerve at the wrist, for example, may cause referred pain to the arm and even to the neck. Carpal tunnel syndrome is characterized by nocturnal dysesthesias, weakness, and, occasionally, thenar atrophy. The thenar and first two lumbral muscles are innervated via the median nerve by the C8 and T1 nerve roots. The symptoms of carpal tunnel syndrome are often reproduced with Phalen’s test, and Tinel’s sign may be present at the wrist.

Electrodiagnostic studies may be necessary to evaluate peripheral nerve function to differentiate entrapment syndromes from cervical radiculopathies.

To complicate matters, entrapment syndromes may coexist with cervical radiculopathy. This is known as the “double crush” phenomenon and was first described by Upton and McComas (32) in 1973. According to this hypothesis, a proximal injury along an axon, such as a cervical root lesion, causes impaired axoplasmic flow, which predisposes affected axons to injury at a more distal site. Upton and McComas found that in 81 out of 115 cases of carpal tunnel syndrome, there was an associated cervical radiculopathy as well. However, more recently, Morgan and Wilbourn (26) retrospectively studied 12,736 cases of carpal tunnel syndrome and ulnar neuropathy at the elbow and found that 435 of these cases (3.4%) had a coexisting cervical root lesion. However, in only 98 (0.8%) of these cases were the lesions on the same nerve.

Most studies that employ clinical examination to diagnose cervical radiculopathy have demonstrated the seventh cervical nerve root to be the most frequently involved in cervical radiculopathy (12, 15, 30). It is caused by degenerative changes at the C6–C7 level. The patient may present with pain and/or numbness radiating across the back of the shoulder, over the triceps, the dorsolateral aspect of the forearm, and over the dorsum of the long finger. Triceps weakness can be significant, but may not be noticed by the patient until it becomes severe.

<table>
<thead>
<tr>
<th>Nerve root</th>
<th>Entity mimicking radiculopathy</th>
<th>Differentiating factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>C5</td>
<td>Rotator cuff tear</td>
<td>Both present with weakness of abduction, but the rotator cuff tear is not associated with weakness of other C5 innervated muscles. C5 radiculopathy not associated with painful shoulder movement or significant tenderness</td>
</tr>
<tr>
<td>C5</td>
<td>Suprascapular nerve entrapment</td>
<td>Suprascapular nerve entrapment is not associated with weakness of other C5 innervated muscles, such as the deltoid, biceps, and pectoralis major</td>
</tr>
<tr>
<td>C6 or C7</td>
<td>Carpal tunnel syndrome</td>
<td>Carpal tunnel syndrome is associated with nocturnal dysesthesias, and the hypoesthesia is present distally, over the palmar side of the hand and over the first three to three and one-half digits. There can be weakness and atrophy of the thenar and first two lumbral muscles, which are innervated by C8 and T1. Phalen’s test may be positive, and Tinel’s sign may be present</td>
</tr>
<tr>
<td>C7</td>
<td>Posterior interosseus nerve compression</td>
<td>Posterior interosseus nerve compression is not associated with sensory findings and does not affect the triceps, pronator teres, and flexor carpi radialis</td>
</tr>
<tr>
<td>C8</td>
<td>Anterior interosseus nerve entrapment</td>
<td>Anterior interosseus nerve entrapment usually presents with pain over the proximal forearm and may have a positive “pinch sign” because of weakness of flexion at the interphalangeal thumb joint and at the distal interphalangeal joint of the index. There is no sensory loss with anterior interosseus nerve compression</td>
</tr>
<tr>
<td>C8</td>
<td>Ulnar entrapment at the elbow</td>
<td>Entrapment at the level of the elbow may cause clinical tenderness along the medial aspect of the elbow; may have positive Tinel’s sign. C8 radiculopathy is associated with weakness of the pronator quadratus and flexor digitorum superficialis and of the first two flexor digitorum profundus muscles, which are innervated by the median nerve. Sensory change does not extend proximal to the wrist in ulnar nerve entrapment</td>
</tr>
</tbody>
</table>

TABLE 2. Conditions that can mimic specific cervical radicular syndromes
perhaps because gravity aids in extension of the forearm. The latissimus dorsi muscle, wrist flexors, and finger extensors may also be involved. The motor symptoms of C7 radiculopathy may be confused with entrapment of the posterior interosseous nerve, which may present with weakness in the extensor digitorum, extensor pollicis longus, brevis, and extensor carpi ulnaris muscles. Notably, entrapment of the posterior interosseus nerve does not cause sensory changes, and the triceps and wrist flexors are not affected. In C7 radiculopathy, the triceps reflex may be diminished or absent.

Nerve root compression at the C7–T1 level causes radiculopathy of the eighth cervical nerve root. This usually manifests with symptoms extending over the medial aspect of the arm and forearm and into the medial hand and the last two digits. Numbness usually involves both the dorsal and volar aspects of the digits and hand and may extend proximal to the wrist over the medial aspect of the forearm. Unlike a T1 radiculopathy, the sensory findings produced by the C8 nerve root syndrome do not extend to the axillary region (25). The C8 nerve root innervates the small muscles of the hand, particularly the interossei, and the flexors and extendors of the wrist and fingers (with the exception of the flexor carpi radialis and extensor carpi radialis muscles). Thus, patients complain of difficulty using their hands for routine daily activities. Compression of the C8 nerve root may initially be difficult to differentiate from ulnar entrapment at the elbow. C8 nerve root compression may affect the function of the flexor digitorum profundus in the index and long fingers, the flexor pollicis longus in the thumb, and the pronator quadratus, but these muscles are not affected by entrapment of the ulnar nerve. Also, the short thenar muscles, except for the adductor pollicis, may be involved with C8 or T1 compression but are spared with ulnar nerve involvement. Furthermore, sensory changes seen with ulnar neuropathies include numbness, tingling, and/or pain in the fourth and fifth fingers and the hand just below these fingers, but not proximal to the wrist (medial antebrachial cutaneous nerve distribution), as may be seen with C8 radiculopathy. Anterior interosseus nerve entrapment may also mimic C8 or T1 radiculopathy but lacks sensory changes, and thenar muscle involvement is absent.

T1 radiculopathy is uncommon but has been reported in association with T1-T2 disc herniations (25). Intrinsic hand muscle weakness is common because the T1 root is the main contributor to the adductor pollicis, the thenar muscles, and to the interossei and first two lumbricals. Axillary numbness is common, and Horner’s syndrome can occur ipsilaterally.

**CLINICAL EVALUATION**

The diagnosis of cervical radiculopathy depends on the correlation of the history and physical examination with radiographic imaging studies. The value of these imaging studies as an adjunct to the diagnosis and treatment of patients with cervical radiculopathy depends on their accuracy associated with demonstrating the precise anatomic features of the nerve root compression.

**Plain Films**

Historically, clinicians have used cervical spine plain films to infer nerve root compression by the presence of degenerative changes; however, it has been shown that degenerative changes within the cervical spine are age-related and present in asymptomatic as well as symptomatic individuals (4, 11, 14, 34). Despite the poor correlation between the clinical symptoms of patients and the degenerative cervical spine, plain films remain an important screening tool in the evaluation of patients presenting with neck and limb symptoms. They are inexpensive, readily available, and provide information regarding sagittal balance, congenital abnormalities, fractures, deformity, and instability. Flexion-extension lateral cervical spine radiographs can disclose occult instability that may be the cause of intermittent or positional symptoms. Because plain films cannot visualize neural structures, either directly or indirectly, other diagnostic modalities, including myelography, computed tomography (CT), and magnetic resonance imaging (MRI), are more commonly used in the evaluation of nerve root compression.

**Myelography**

Neural compression is diagnosed indirectly with myelography by observing changes in the contour of a contrast-filled spinal canal. Today, water-soluble contrast agents are used. These are associated with less toxicity and enable improved visualization of neural structures compared with the original oil-based agents. The major disadvantage of plain myelography is its invasive nature. Because the diagnosis of neural compression is inferred only indirectly, the exact nature of the compression is not always clear. For example, with myelography alone, it can be difficult to distinguish between a “hard disc” with bony osteophytes and a “soft disc” herniation. Because plain myelograms do not rely on the sagittal or coronal reconstruction of an axially acquired image, excellent spatial resolution is achievable with these images.

Accuracy rates for water-soluble nonionic cervical myelography in the diagnosis of clinical nerve root compression ranges between 67% and 92% when compared with intraoperative findings (8, 24, 31). Myelography was associated with no false-positive results, a 15% false-negative rate, and an overall accuracy rate of 85% in a study of 53 patients who had surgical confirmation of the cervical spine pathology (15).

**Computed Tomography**

Unlike myelography, CT allows for the direct visualization of pathology causing compression of neural structures. Compared to myelography, CT emits less radiation, has improved visualization of lateral pathology, such as foraminal stenosis, has no significant adverse reactions, and can visualize structures above or below myelographic blocks (2). CT also has a high spatial resolution and is especially helpful in visualizing the foraminal region. Another important advantage of CT is that it can distinguish neural compression caused by soft tissue from compression related to bony structures, such as facet hypertrophy. This is a major advantage from a surgical planning per-
Cervical Radiculopathy

The reported accuracy of CT of the cervical spine ranges from 72 to 91% (10). By combining myelography with computed tomography (CT myelogram), the diagnostic accuracy has approached 96% (18, 20). When there is a discrepancy between the findings found via myelography and those found via CT myelography, CT myelography generally has been found to be more accurate (27), although other authors have found the two to be comparably useful (31).

Magnetic Resonance Imaging

Because magnetic resonance imaging (MRI) can detect the neural structures directly and non-invasively, it has become the most common method of imaging the cervical spine to detect significant pathology (22). The accurate assessment of disc herniations and spinal stenosis is due to the intrinsic contrast and good spatial resolution. Brown et al. (5), in a blinded, retrospective review, studied 34 patients who underwent MRI prior to surgery. MRI correctly predicted 88% of the lesions as opposed to 81% for CT myelography, 57% for plain myelography, and 50% for CT. Disc herniations are commonly observed with MRI scans of asymptomatic individuals (22). They may be observed in 10% of asymptomatic people younger than 40 years of age and 5% of those older than 40 years of age. Degenerative disc disease may be observed in 25% of asymptomatic people less than 40 years of age and 60% of those older than 40. Therefore, the imaging findings should be carefully correlated with the neurological examination. In difficult situations, MRI can be used in conjunction with CT or CT myelography to refine the diagnostic accuracy as these studies provide complementary information.

Electrodiagnostic Studies

Electrophysiological studies may play an important adjunctive role in diagnosing cervical radiculopathy by identifying physiological abnormalities of the nerve root and ruling out other neurological causes of the patient’s symptoms. However, in patients with well-defined radiculopathy and good imaging correlation, the pain and added expense of electrodiagnostic studies are usually not justified.

The electrodiagnostic study has two parts: the nerve conduction studies and the needle electrode examination (EMG). Nerve conduction studies are performed to exclude peripheral nerve pathology. The amplitude, distal latency, and conduction velocity can be measured. The amplitude corresponds to the number of intact axons. The distal latency and conduction velocity reflect the degree of myelination. The needle electrode portion of the EMG is performed by analyzing multiple muscles within the same myotome and in adjacent myotomes (28). The presence of fibrillation potentials and positive sharp waves at rest is indicative of denervation, but these changes may not occur until 3 weeks after the onset of neural injury. They are noted in the paraspinal musculature before they become apparent in the appendicular muscles. EMG may be normal in the presence of mild radiculopathy or a predominantly sensory radiculopathy and are less likely to be positive in patients with no demonstrable weakness (28). Nerve conduction studies and EMG have been shown to be useful in diagnosing nerve root dysfunction and distinguishing cervical radiculopathy from other lesions that are unclear on physical examination (22). They have also been found to correlate well with findings on myelography and surgery (35). A reference chart detailing the results of needle electrode examination of upper extremity muscles in patients with surgically proven solitary root lesions has been published (21).

CONCLUSION

Cervical radiculopathy is usually the result of disc herniation or cervical spondylosis and is a common cause of upper extremity symptoms. A thorough history and neurological examination, combined with confirmatory radiographic and electrodiagnostic studies enable accurate localization of the pathology and allow the exclusion of other common causes of upper extremity dysfunction, such as shoulder pathology and entrapment neuropathies.

REFERENCES


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