NEURAL COMPLICATIONS OF CERVICAL SPONDYLOSIS: THEIR RESPONSE TO LAMINECTOMY AND FORAMENOTOMY*

WILLIAM L. STOOPS, M.D.,† AND ROBERT B. KING, M.D.

Division of Neurological Surgery, Department of Surgery, State University of New York,
Upstate Medical Center at Syracuse, Syracuse, New York

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Spondylosis of the cervical spine as a cause of nerve-root and spinal-cord compression has been well documented. However, few detailed reports of the course of this disease have appeared in the literature. Many operative procedures have been employed when conservative measures have failed to arrest progression of neurologic deficit. Such reports have emphasized operative technique and observations. Others have reported neurologic or neuropathologic findings without a detailed consideration of changing neurologic deficit and symptoms following operative intervention.

We wish to evaluate the course of this disease in 49 patients before and following cervical decompressive laminectomy and foramenotomy. Our intention is to emphasize the difficulties we have encountered in the management of these patients. By so doing we would wish to be able to identify specific circumstances in which this form of management may require modification.

No patient was able to work prior to surgical intervention. All were severely handicapped by progressive neurologic deficit despite vigorous conservative management. Thirty of these patients are now able to work.

CLINICAL MATERIAL

Sex. Of the 49 patients, 40 were males and 9 were females. There were 29 treated in a

Veterans Administration Hospital;* of these 29 veterans only 2 were females.

Age. The ages of these patients at the onset of symptoms and at the time of operation are shown in Table 1, corroborating earlier reports which have indicated the wide range of ages at which cervical spondylosis may become symptomatic.

TABLE 1

<table>
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<tr>
<th>Age</th>
<th>20–29</th>
<th>30–39</th>
<th>40–49</th>
<th>50–59</th>
<th>60–69</th>
<th>70+</th>
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<tbody>
<tr>
<td>At onset of symptoms</td>
<td>3</td>
<td>9</td>
<td>18</td>
<td>9</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>At time of operation</td>
<td>1</td>
<td>6</td>
<td>17</td>
<td>11</td>
<td>13</td>
<td>1</td>
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Duration of Symptoms. Symptoms persisted prior to operation for 1 to 6 months in 10 patients; 6 to 12 months in 5 patients; 1 to 2 years in 8 patients; 2 to 5 years in 14 patients; 5 to 10 years in 5 patients; and more than 10 years in 7 patients.

Factors Contributing to Onset of Symptoms. Trauma. Of the 49 patients 16 dated the onset of symptoms to a specific single injury. Trauma was an equivocal provocative factor in 5. Of the 16 persons with a clear history of injury followed by persistent symptoms, 11 received blows to the head, neck or shoulder, 4 incurred flexion-extension injuries and 1 person first felt pain in the neck while lifting

* Veterans Administration Hospital, Syracuse, New York.

† Fellow in Neurological Surgery, State University of New York, Upstate Medical Center at Syracuse.
a heavy weight. The role of trauma in cervical spondylosis has been considered by others. Symonds, reported the development of symptoms following trauma in persons with pre-existing cervical spondylosis. Clarke and Robinson reported cases in which acute trauma of the neck was followed by development of spondylotic changes which later caused neurologic deficit. In this circumstance bony changes were more localized and occurred in younger persons. In the present group of patients a history of trauma was associated with a tendency for symptoms to begin at an earlier age than in those without trauma. Injury occurred in 2 of the 3 patients whose symptoms began before the age of 30 years; in 4 of the 9 patients between 30 and 39 years; in 9 of the 18 patients between 40 and 49 years; in 3 of the 9 patients between 50 and 59 years; and in 2 of the 10 patients over 60 years of age.

**Congenital Anomalies.** Six patients were found to have congenital anomalies of the cervical spine. Four had fusion of two vertebral bodies; 3 at the C2-C3 level and 1 at C4-C5 level. In addition to the congenital fusion of the vertebral bodies at C2-C3, 1 person had assimilation of the dorsal arch of the atlas to the occiput, fusion of the dorsal arches of C2 and C3 and platybasia with protrusion of the dens into the foramen magnum. This incidence of congenital anomalies is similar to that in the group of patients reported by Brain et al. The alleged role of the “block-vertebra” anomaly in producing spurring at the joints above and below has been considered by Bradshaw and Brain et al. In 3 of the present 4 cases spondylotic changes occurred at intervertebral levels next to the “block vertebra.” In 1 case, however, the major degree of spondylotic change was at C6-C7, four interspaces away from the “block vertebra” at C2-C3.

The 2 remaining anomalies identified at operation were a smooth prominence of bone from a pedicle (Fig. 6f) compressing a nerve root and a smooth laminar prominence projecting into the spinal canal (Fig. 4a, b).

**SYMPTOMS**

The neurologic symptoms and physical signs in persons with cervical spondylosis are determined by the sites of compression of neural structures. They may be caused by spinal-cord compression, nerve-root compression or a combination of cord and root compression. Spasm of paravertebral muscles and tenderness and the “silver-dollar” sign may reflect ligamentous strain. The role of compression of the anterior spinal and vertebral artery in the production of the clinical syndrome of cervical spondylosis has been noted.

Pain in the neck and upper limbs was the most common presenting complaint in this group of patients (Fig. 1). Pain was the principal complaint of 26 patients. Weakness was the chief complaint of 12 patients, disturbance of gait of 7 patients, and upper-limb paresthesias of 5 patients. Eight persons had other presenting complaints. In the records of 5 persons the chief complaint was not stated clearly. Several persons had multiple chief complaints accounting for the total exceeding 49.

The first symptom noted by 25 patients was pain. Paresthesias were present initially in 14, and weakness was present in 8. Six persons had other initial symptoms (Fig. 1).

Pain in the neck and upper limbs and paresthesias in the upper limbs were the most common symptoms, 34 patients complaining of each (Fig. 1). Paresthesias in the lower limbs were noted by 10 persons. Pain in the lumbar region was noted by 3 persons.
Thirty-one patients complained of motor symptoms (weakness, clumsiness) in the upper limbs and 23 had motor symptoms (weakness, disturbance of gait) in the lower limbs. Six persons had sphincteric disturbances, 5 of whom had accompanying long-tract motor signs. One had had persistent constipation for several years which abated following cervical laminectomy and foramenotomy for cervical-root compression. She had no demonstrable long-tract signs.

Four persons complained of headaches and 3 of a grating sensation in the neck.

Sensory symptoms, such as pain and paresthesias, were the most common symptoms and pain the most common presenting complaint. On the other hand, those symptoms that the physician must evaluate when considering the need for operative intervention may be overlooked by the patient. Thus, while weakness in the lower limbs and disturbance of gait were present in 23 patients, these were the presenting complaints of only 4 persons. A history indicative of sphincteric disturbance secondary to spinal-cord compression was elicited from 6 patients, yet this was the chief complaint of none.

PHYSICAL SIGNS

Five of the 49 patients had signs of spinal-cord compression alone. There were 23 who had signs of nerve-root compression alone, and 21 who had signs of compression of root and cord (Fig. 2).

Twenty-three patients had abnormal findings in the neck consisting of decreased mobility, spasm of muscles, tenderness and malalignment.

Twenty persons had disturbance of gait. Weakness, spasticity or both occurred in the lower extremities of 15 patients. Dysfunction of the posterior column was demonstrated in only 6.

Twenty persons had atrophy of muscles. Atrophy in the upper limbs was limited to specific groups of muscles corresponding with the level of root compression. Two patients had "spindle" lower extremities but no evidence of localized atrophy.

Weakness was present in 42 of the 49 patients. It varied in extent and degree from mild paesis of muscles of one upper limb to quadripareisis. Two persons had weakness of the lower limb alone, 29 had weakness of the upper limb only and 11 had weakness of upper and lower limbs.

Spasticity, manifested in gait, increased muscle tone or clonus, was present in 13. Spasticity in the upper limbs was noted in 3.

Twelve persons had fasciculations preoperatively. Three of the 12 had fasciculations in their lower limbs as well as in their upper limbs.*

An extensor response to plantar stimulation was elicited bilaterally in 6 and unilaterally in 3 patients. There was no evident basis for the absence of an extensor toe sign in 3 with other signs of cervical myelopathy.¹²

Changes in deep tendon reflexes in the upper extremities reflected involvement of the root alone in 6 persons, of the spinal cord in 13, and of combined upper and lower motor neurone in 9. In only 2 patients, however, did a hypoactive reflex in an upper limb reflect involvement of the root caudal to the level of involvement of the cord. In the lower extremities 24 persons had hyperactive patellar jerks and 17 had increased ankle jerks. In 3 patients the only evidence of spinal-cord compression was marked hyperreflexia in the legs. The jaw jerk was hyperactive in 2 persons before operation.

Hypalgesia was noted in 19 persons. In 4 it was present in the lower limbs. This contrasts with 25 persons who described subjective numbness. Hypalgesia was demon-

* These patients will be described in detail in a subsequent report.
strated in 33 patients. In 26 persons the hypalgesia was present in a radicular pattern. In 11 it suggested long-tract involvement, and in 4 long-tract and root involvement were combined. Diminished vibratory sensation (128 c./sec.) was present in the lower extremities in 11 persons and 6 had diminished sense of position.

CEREBROSPINAL-FLUID STUDIES

The concentration of protein in the cerebrospinal fluid was determined in 42 cases. It was less than 40 mg. per cent in 14 persons (not elevated), 40 to 50 mg. per cent in 10, and greater than 50 mg. per cent in 18. The highest value was 320 mg. per cent in a patient with a partial block of the subarachnoid space. The protein was elevated in 17 patients with signs of spinal-cord compression and in 11 patients with signs of root compression only. Among the 12 patients with evidence of partial block on manometric or myelographic studies 10 had elevated protein in the cerebrospinal fluid.

Manometric studies were performed in 12 patients. There was no block to flow of cerebrospinal fluid in 9. Partial block was noted in 1 patient with the neck flexed and in another with the neck extended. One patient had a complete block in extension.

RADIOLOGICAL STUDIES

Each of the 49 patients was studied by means of plain films of the cervical spine and myelography. The plain films were taken in four projections, anteroposterior, lateral, and right and left posterior oblique. Films were taken with the spine in flexion and extension as needed. For myelography ethyl iodophenylundecylate* was introduced into the lumbar subarachnoid space and the column of oil was examined with the cervical spine in neutral, flexed and extended positions from the foramen magnum to the upper thoracic region. Films were taken in the anteroposterior and lateral planes. Oblique views of specific defects were obtained when additional information seemed desirable. In the plain films intervertebral foraminal encroachment by bony spurs was noted at one or more levels in 27 persons and was the most common radiographic abnormality. Narrowed intervertebral-disc spaces were present in the films of 20 patients. Twelve persons showed straightening of the normal cervical lordosis, in some cases extending to kyphosis. Subluxation of one cervical vertebra upon another was noted in 5 persons. Congenital anomalies of the cervical spine were demonstrated radiographically in 4 patients; a fifth patient had a cervical rib on the side opposite her radicular symptoms. Films of the cervical spine of 1 patient were normal in all regards. This patient was found at operation to have an extrusion of soft disc on the right at C4–C5 and a bony ridge on the right at C5–C6, narrowing that foramen and elevating the root. Although the plain films were normal, myelography revealed both lesions.

Myelography revealed a ventral defect in the column of dye at the level of the intervertebral disc in 34 patients. Indentations of the column of oil posteriorly by ligamenta flava and laminae were present in 7 persons. In 12 patients impairment of flow of the dye was noted. In 5 patients this block was complete in one or more positions of the cervical spine. Root-sleeve encroachment was noted at one or more levels in only 14 patients, and in each instance abnormal physical findings were attributable to the root that appeared abnormal on myelography.

During myelography 1 patient had a brief syncopal episode upon resuming an erect posture after removal of 6 cc. of cerebrospinal fluid. During the next several hours there developed bilateral hypalgesia up to his low thoracic region, extensor toe signs, and hyperreflexia in all 4 limbs. No other untoward responses to myelography occurred.

Others* have noted that abnormal roentgen-ray findings commonly are more extensive than is suggested by demonstrable neurologic deficit.

TREATMENT

Nonoperative treatment, with immobilization, exercises, traction, limitation of activ-

* Pantopaque—General Electric Company.
ity, and analgesics, was employed in all but 1 of the patients for periods ranging from weeks to years. This form of management afforded no relief in some and complete relief of symptoms for varying periods of time in many. Eventually in all cases these measures were considered inadequate as neurologic deficit progressed or pain increased. We do not wish to imply that all persons with this disorder require operative intervention. Most patients' symptoms and signs are controlled adequately by nonoperative measures. (These measures were not used in 1 of our patients with rapidly progressing quadripare-sis.)

Criteria for Operation. Patients were selected for operation when severe radicular pain or disabling weakness increased despite conservative measures or when evidence of spinal-cord compression was not relieved promptly by conservative measures. Radicular pain severe enough to require narcotics for relief and to preclude employment in spite of maximum conservative treatment was considered a criterion for operation. However, radicular pain, in the absence of motor deficit, warranted operation in only 4 patients. Localized atrophy, for reasons to be mentioned later, came to be a strong indication for early operation. All patients in this series with these indications underwent a decompressive operative procedure. None was excluded from the study on the basis of age, severity of symptoms or other disease. No patient refused to be operated upon after surgery was recommended.

Operative Technique. Several operative procedures have been employed in an attempt to relieve the signs and symptoms of progressive radiculopathy and myelopathy associated with cervical spondylosis, 1,9-11,16,20,21,24,26

When neurologic deficit has increased after these procedures, it often has been subsequent to removal of ventral bars or large ventral spurs from beneath the cord. Occasionally when the dura mater is opened for transdural exploration similar difficulties have been reported.

Kahn 11 introduced the technique of cutting the dentate ligaments to allow the cord to migrate dorsally by releasing the tethering effect of these structures. Frykholm 11 implicated a tethering effect of intradural adhe-sions of cervical nerve roots as they pass through the neural foramina.

A very extensive laminectomy with fora-menotomies has been performed in this series of cases. The dura mater was not opened and dentate ligaments were not cut. No attempt to remove ventral spurs or transverse bars was made. The laminectomy was extended laterally beyond the edge of the dural tube, removing medial elements of the facets bi-laterally when necessary (Fig. 4).

In the lower cervical vertebrae the medial portions of the facets overlie the lateral portion of the spinal canal, that is, they lie medial to the pedicles (Fig. 3). At C3 the facets lie more laterally and no longer overlie the spinal canal. Thus it becomes unnecessary to extend the laminectomy laterally into the facets at C3–C4 in order to decompress adequately the dural tube and nerve roots. However, it is uniformly true in the skeletal specimens and clinical material that we have examined that a partial facetectomy must be accomplished at C6 and C7 if the lateral margins of the spinal canal are to be decompressed adequately.

The cephalocaudad extent of laminectomy initially was carried one vertebral level higher and lower than the most cephalad and caudad bar. We now extend the laminectomy at least two levels beyond the region of compression of the cord.

This procedure was found to allow the entire dural tube to migrate dorsally away from the ventral surface of the spinal canal (Fig. 5). When a narrow bridge of the cephalad edge of a lamina was allowed to remain in place until the laminectomy was completed above and below, the dural tube sometimes could be seen to bulge dorsally as much as 1–1.5 cm. above and below the margins of the intact bony bridge. When that was removed and the ligamentum flavum was incised in the midline the cut edges of the liga-mentum flavum (which under normal circum-stances lie in apposition) separated from
The facets here overlie the spinal canal to a lesser extent but still roof the intervertebral foramina. The facets may migrate dorsally until they overlie the dural tube. The dural tube may then angle sharply as it emerges from beneath an intact lamina into the region of the laminectomy. Additional laminae must then be removed.

Foramenotomies with small curettes was performed at all levels where compression of the root by osteophytic spurs could be correlated with clinical symptoms or signs.

The foramenotomies were extended laterally into the neural foramina until a small dissector could be passed easily into the soft tissue of the neck on the dorsal surface of the root sleeve. The dissector then was passed gently around all sides of the root sheath within the foramen to be sure that the root sleeve was free of tethering adhesions and bony spurs. Occasionally the dural tube would not migrate dorsally until a root sheath had been freed of extradural adhesions in the neural foramen. Clinical signs may not correlate with roots tethering the dural tube in this fashion. We exercise caution during this dissection in an effort to avoid the vertebral artery.

The presumed advantages of this relatively simple procedure stem from not opening the dura mater and avoiding manipulation or displacement of the spinal cord. There is ample realignment of the entire dural tube in a dorsal position away from underlying bony prominences.

Operative Findings. The principal findings at operation are two, namely compression of the dural tube by the bony or ligamentous elements of the vertebral column and compression of nerve-root sheaths in constricted intervertebral foramina. Examples of typical bony lesions resulting in compression of several structures are shown in Fig. 6.

Absence of pulsation of the dural tube upon exposure or after partial decompression was taken as evidence of compression of the dural tube. Local absence of epidural fat and engorged epidural veins sometimes observed at the points of local encroachment of bony structures upon the dural tube. Local-
foramen along the sheath. More commonly there was fibrous scarring immobilizing a root sheath in the intervertebral foramen. Occasionally epidural veins were distended greatly near a narrowed foramen, and following adequate foramenotomy they collapsed.

Pieces of extruded soft discal material were found in 4 patients. In 3, at the level of extrusion of nucleus pulposus, there were bony constrictions of the foramen necessitating foraminal decompression.

One patient had a smooth bony spicule on the ventral surface of the superior edge of a lamina which was compressing the dural tube (Fig. 4). In another patient the C3 lamina was imbricated beneath that of C2, compressing the dural tube.

Evidence of compression of the dural tube without impingement of the root was present in 19 persons. Compression of one or more roots without evident compression of the dural tube occurred in 15 persons. An additional 15 persons had compression of the dural tube plus the root.

The frequency of involvement of the different cervical roots by compression in this group of patients is similar to that reported by Brain et al.5 except for the conspicuous scarcity of involvement of C5 root in the present group. The C4 root was involved once, the C5 root 7 times, the C6 root 22 times, the C7 root 14 times and the C8 root 6 times. Thus 50 foramenotomies were done in 32 patients. In 1 patient 4 foramenotomies were done. Three foramenotomies were done in 2 patients and 2 foramenotomies in 11 patients. A single foramenotomy was done in 18 patients. There was no appreciable difference in the occurrence of tight foramina on one side as compared with the other.

Complications. One patient died on the 13th postoperative day. On the 11th day after operation his laminectomy wound dehisced and the following day he became critically ill with a gram-negative bacteremia. During the 2 months prior to operation this man had had two transurethral prostatic resections. Urography at that time revealed a bifid left kidney with double ureter. Preoperatively there were 8–20 white blood cells
per high-power field in his urine without physical signs of urinary-tract infection. Autopsy disclosed a right ureteral calculus with acute pyelonephritis.

Seven persons were troubled with urinary infections postoperatively. In 4 of them pyuria followed catheterization. These complications cleared with treatment in 5 persons. One patient died postoperatively with urinary infection (as noted above). In 1 patient, aged 70 and quadriparetic, an atonic urinary bladder developed after operation with continuing urinary infection which persisted until her death 3 months later from cardiac failure. This woman also had peripheral neuropathy of undetermined origin. One patient who previously had no difficulty initiating urination did so for 5 days postoperatively.

Six persons had infections of the wound and 2 had hematomas of the wound. Except in the patient who died, these wounds were superficial and healed by secondary intent without incident.

Three persons had pulmonary complications. Two had reactivated chronic inflammatory processes and in 1 bilateral lower-lobe atelectasis developed. These responded satisfactorily to treatment.

One patient had phlebitis at the site of a venipuncture in the upper limb.

One patient was found to have a hemianopsia 10 days postoperatively. This loss progressed over a period of months to tunnel vision and subsequently normal visual fields returned.

Eight persons had a temperature of 101°F during the first postoperative day only, without apparent cause. Another 5 patients had fevers from 101° to 103°F, on at least one occasion from 2 to 5 days after operation without evidence of infection. Antibiotics were not used routinely in the postoperative period.

RESULTS OF OPERATION

The results of operation are shown in Fig. 7. Of the patients, 36 (74 per cent) are improved, 28 (57 per cent) being markedly or moderately improved and 8 (16 per cent) slightly improved. Four (8 per cent) patients are neither better nor worse than prior to operations. Three (6 per cent) patients have continued to deteriorate. Two (4 per cent) patients are not available for follow-up. Four (8 per cent) have died.

Operative procedures were performed by 3 surgeons. No evident difference in the results can be ascribed to this factor.
Fig. 6. Commonest sites of bony proliferations responsible for encroachment upon neural structures in this group of patients.
(a) Unilateral foraminal encroachment by a proliferative rim of bone ventral and dorsal to the neural foramen.
(b) Ventral proliferation of bone at a neural foramen, in this instance bilaterally, with normal margins of facet.
(c) Midline mound of bone without foraminal encroachment.
(d) Transverse bar extending across the full breadth of the spinal canal ventrally with marked unilateral foraminal encroachment and projection of the proliferative bone laterally to obstruct the foramen transversarium of the vertebral artery.
(e) Proliferation of facet and dorsolateral margin of vertebral body to occlude the neural foramen and foramen transversarium.
(f) An unusual prominence of bone from the pedicle on the right which expands into the neural foramen. We have identified this circumstance in 1 patient and consider it a developmental anomaly.

One patient died of postoperative complications. One patient committed suicide 6 months postoperatively. Two other persons have died since discharge from the hospital; one 3 months after operation of cardiac failure and the other 13 months after operation of cerebral vascular occlusion. Two patients have been lost to follow-up.

The follow-up period for the remaining 43 persons was from 1 year to 3½ years. Physical examination of each was accomplished periodically throughout the postoperative period and within 1 month of the preparation of this report (November 1960).

Of the 43 individuals followed none is totally free of symptoms and signs relating to his preoperative state. However, 30 (61 per cent) persons have such minimal deficits (for example, occasional aches, small areas of hypalgesia, fasciculations about the shoulder girdle in the absence of marked weakness or atrophy) that they function with virtually the same capacity as prior to the onset of disability. Their occupations include light
and heavy labor. All were unable to work preoperatively. Contrary to Clarke and Robinson we feel that the ability to work is an important criterion of success in treatment.

Among the 13 persons who are unable to carry out their duties as they could prior to the onset of disability, this limitation is caused primarily by loss of motor function (weakness, spasticity) in 8 and by pain in the 5 remaining. This is not to say that these patients are worse than they were preoperatively. Six are better in some appreciable degree yet still have considerable handicap.

Four persons function about as well as before operation and 3 less well, but all 7 are unable to perform duties in keeping with their capacity prior to the onset of symptoms.

Three persons are now worse than before operation. All have had slowly progressive signs of spinal-cord involvement. One of these patients has amyotrophic lateral sclerosis which was recognized in addition to cervical spondylosis preoperatively. A distinct improvement in strength in the right upper limb was noted for 8 months postoperatively at which time weakness became progressive in all limbs. In a second patient additional signs and symptoms of cervical nerve-root compression and sphincteric disturbance have developed although the long-tract sensory and motor deficits have remained relatively stable. Further decompression of additional neural foramina might be expected to alleviate some of his new symp-

toms. The third patient has had slowly progressing long-tract signs and is severely paraparetic. These 2 patients had limited laminectomies early in this series. We would now do a more extensive laminectomy in each circumstance.

Of the 31 individuals who had motor symptoms in the upper limbs before operation 11 are markedly improved in this respect, 12 moderately improved, and 5 unimproved or worse. Two persons have died and 1 has been lost to follow-up.

There were 23 persons who had motor symptoms in the lower limbs preoperatively. Five are markedly improved in this regard, 8 moderately improved and 4 are unimproved or worse. Four of these patients have died and 2 have been lost to follow-up. Of the 4 persons who remain unimproved, 1 was severely quadriparetic, 1 severely paraparetic, 1 severely monoparetic, and 1 moderately paraparetic preoperatively.

Among the 34 patients with pain in the neck and upper limbs prior to operation 12 are free from pain and 14 have minimal or occasional discomfort. Five patients are unimproved in this regard. (Two patients in this group have died and 1 has been lost to follow-up.) Among 5 persons in whom pain remains a major problem there are 4 in whom pain in the neck persists whereas radicular pain, if present initially, has been alleviated uniformly. One person with paraparesis has pain low in the back and hip which is severe.

Of the 34 patients with paresthesias preoperatively, 15 are now totally free of these symptoms, 12 have been partially relieved, and 5 are unchanged. Two of these patients have been lost to follow-up.

Six persons had sphincteric disturbances preoperatively. Three of them now have normal function of bowel and bladder, 1 remains intermittently incontinent of stool and urine, and 2 have died.

Among the 24 patients who had tenderness, decreased mobility, malalignment, or spasm in the cervical region preoperatively, 6 have no residual abnormality in this regard. Twelve persons have persistent signs of lesser degree than prior to operation. Five persons are not improved and 1 has died.

Disturbance of gait was present in 20 patients prior to operation. Six of these persons now have a normal gait, and 1 has partial improvement in his gait. Eight persons have no improvement in their gait; 1 has been lost to follow-up. Four patients have died but did not show improvement in gait prior to death. Those who have shown improvement in gait had less severe disturbances prior to operation than those who failed to improve.
Among the 20 persons with atrophy of muscles prior to operation, it has disappeared in 4 and diminished in 9. In 3 persons whose atrophy was severe preoperatively it has remained so. It has progressed in 1 patient with amyotrophic lateral sclerosis. Two persons have died and another has been lost to follow-up.

Of the 42 persons with weakness prior to operation 15 now have no demonstrable weakness. In 13 there is residual weakness of lesser degree than preoperatively. Nine persons have had no improvement in their weakness. Four patients in this group have died. One has been lost to follow-up. No clear conclusions can be drawn from this group as to whether weakness caused by compression of the spinal cord or of the nerve root clears more favorably after operation.

Spasticity was evident in 13 persons prior to operation. Three persons now have no spasticity and have less than before operation. In 4 persons the spasticity is unchanged. Two patients have died and 1 has been lost to follow-up.

Fasciculations were seen in 12 patients prior to operation. Two no longer have fasciculations, and in 8 persons they are less prominent than before operation. Two persons with fasciculations preoperatively are now dead. In 1 person fasciculations of the lower limb developed 3 days postoperatively, which have since disappeared. The patient with amyotrophic lateral sclerosis has fasciculations in all 4 extremities whereas they were present only in the upper limbs prior to operation. Fasciculations have been noted first in the upper limbs subsequent to operation in 7 persons.

Of the 9 patients with pathological toe signs prior to operation, 2 no longer have them and in 4 they persist. One of this group has died and 2 have been lost to follow-up.

Twenty-five persons had hyperactive knee jerks preoperatively. Six now have normal knee jerks and in 13 they remained hyperactive. Four persons in this group have died and 2 are lost to follow-up. Among the 18 persons with hyperactive ankle jerks prior to operation, 5 now have normal ankle jerks and in 7 they remain hyperactive. Four persons in this group are now dead and 2 have been lost to follow-up.

The 2 persons with hyperactive jaw jerks preoperatively now have normal jaw jerks.

Hypesthesia was noted in 19 persons preoperatively. Of the 16 persons available for follow-up examination, 12 no longer have loss of light tactile sensation and 4 have persistent loss.

Hypalgesia was present in 33 persons prior to operation. Ten of them no longer have demonstrable hypalgesia. Twenty persons have persistent hypalgesia, some of lesser extent and degree than preoperatively. Two patients in this group have died and 1 has been lost to follow-up.

One patient in this group was operated upon twice, the second time 8 months after the first, because of recurrent signs of compression of the cord. Myelography prior to the second operation revealed posterior bars opposite anterior bars with consequent marked reduction in the anteroposterior diameter of the spinal canal and encroachment upon the spinal cord two segments below the original site of laminectomy. The dural tube and spinal cord at the level of first laminectomy (C3–C4) had migrated posteriorly and were angulated at the superior margin of the lamina of C5 prior to the second operation. He has improved markedly since the second laminectomy (C5, C6, C7).

In retrospect, among those remaining disabled, 8 had operations which we still would judge to have been adequate in extent. Three of these patients had advanced myelopathy preoperatively; 1 remains unemployed because of psychiatric problems unrelated to his spastic crural monoparesis; 1 responded well to operation until an injury 3 months postoperatively; 1 is incapacitated by pain in the hip and back; 1 remains disabled by pain in the neck; and 1 has had progression of amyotrophic lateral sclerosis. Five persons underwent operative procedures which we now would consider inadequate. Two of these have persistent myelopathy and 3 are disabled by pain. One additional person with persistent pain, though not disabled, underwent a procedure now deemed inadequate in extent.

**DISCUSSION**

Taylor suggested that ligamenta flava bulging anteriorly in cervical extension may cause recurring trauma to the spinal cord raised upon a central herniation of disc or osteophytic bar. Clarke and Little described a case of cervical myelopathy in which the spinal cord was damaged severely by compression between an intervertebral ridge anteriorly and by protruding laminae and ligamenta flava posteriorly at the same level. We have seen 3 patients in whom the dorsal defect related clearly to a portion of the bony lamina rather than to the ligamentum flavum.

Symonds reported 2 cases of sudden paralysis occurring without trauma in pa-
tients with severe cervical spondylosis. One patient in the present group, without antecedent trauma or symptoms, awoke one morning with interscapular pain and weakness and numbness of the upper limbs. Within a few hours quadriplegia became evident after an episode marked by fainting and diaphoresis. Eventually this man was recognized as having a syndrome of the anterior spinal artery. Myelography revealed a partial block in extension from C6–C7 to C3–C4 with transverse ridges at C6–C7 and C4–C5 interspaces. At operation 5 days after the onset of symptoms the laminae of C6, C5, C4 and C3 were removed. The dural tube did not pulsate until after removal of the C3 lamina. Increased pulsation and dorsal movement of the dural tube occurred after excision of the ligamenta flava. Two and one-half years after operation this man has nondermatomal hypalgesia in the left upper and lower limbs but has no pain, weakness, atrophy or long-tract signs other than the hypalgesia. Mair and Druckman in 4 autopsy cases concluded that their findings of degenerative changes in the peripheral distribution of the anterior spinal artery were compatible with compression of that vessel by "prolapsed discs."

Brain referred to "frozen shoulder" as one complication of cervical spondylosis. One patient in the present group had a "frozen shoulder" after the onset of radicular pain. Both the pain and the restriction of the shoulder subsided after laminectomy and foramenotomy, and postoperative physical therapy. We would consider the "frozen shoulder" a secondary manifestation occurring only in association with evidence of radiculopathy.

It may be anticipated that in more of these patients there will be subsequent development of signs of root compression at new levels. Only those roots to which signs or symptoms could be attributed prior to operation were decompressed for signs of radiculopathy. Three patients who have been examined more than 2 years postoperatively now have signs and symptoms referable to a root that was not involved at the time of operation. The preoperative roentgenograms of 2 of these patients showed spurs in the foramina now involved. In 1 of these patients all intervertebral foramina from C4 to T1 were encroached upon by bony spurs preoperatively; he now has root signs and symptoms in both upper limbs whereas prior to operation he had long-tract signs only. His laminectomy was a limited one early in this series. In another patient the new root symptoms were severe but responded to conservative treatment. A third patient has minimal symptoms which have not required treatment.

The differential diagnosis of syndromes resembling that of cervical spondylosis has been discussed by several authors. Bradshaw reported 6 cases among 78 patients with cervical spondylosis in whom all or part of the signs and symptoms were attributable to disease of the spinal cord independent of the spondylosis. One patient in the present group with a history of paresthesias and weakness in the upper limbs on examination displayed atrophy and weakness in the upper limbs and slightly hyperactive reflexes throughout. There was no Babinski's sign and no sensory deficit was detected. Myelography revealed transverse bars at three levels in the cervical region and plain films showed bony encroachment at one foramen on the right side. At operation the dural tube did not pulsate until 2 laminae had been removed. A single foramenotomy was done. Postoperatively the strength in the right upper limb increased. This man was last seen 2 1/2 years after operation. At that time there were marked weakness, atrophy, and fasciculations in all extremities, no hyperreflexia, no subjective or objective sensory loss and the diagnosis of amyotrophic lateral sclerosis was obvious. That his earlier signs and symptoms were the results of concomitant amyotrophic lateral sclerosis and cervical spondylosis was conjectured preoperatively.

From the results of this study neither a patient's age nor the duration of his symptoms per se appears to determine the outcome of operative treatment. However, profound
quadriplegia and severe atrophy in the upper limb, particularly in the deltoid muscle, have not responded well.

Persistent pain in the neck and between the scapulae after operation has been a problem. In 4 persons it has prevented their return to work. In most this pain has disappeared shortly after operation. During operations under local anesthesia Semmes and Murphey demonstrated that pain along the medial border of the scapula, the occiput and the anterior wall of the chest could be produced by stimulating the posterior longitudinal ligament or the annulus fibrosus. Frykholm produced a deep boring pain in the neck, shoulder and arm upon weak mechanical stimulation of compressed ventral roots. Smith and Robinson have observed the disappearance of this type of pain after interbody fusion of the cervical vertebrae at the involved level. Our 4 patients with this type of pain may yet benefit from interbody vertebral fusion or unsheathing of nerve roots. These symptoms, however, are relieved currently by proper bracing and may subside without fusion.

Profound atrophy was encountered in the upper extremities of 3 patients. Although laminectomy and foraminotomy were accomplished and measures of physical therapy were applied vigorously, the restoration of mass of muscles and strength in these individuals has been negligible. In 1 of these patients it has become clear that the original laminectomy was not extensive enough and that another foramenotomy now is necessary. The desirability of operating before atrophy becomes irreversible is obvious. The possibility exists that if ventral roots were constricted by root-sleeve fibrosis additional unsheathing of the nerve roots might have allowed greater return of function for these 3 patients.

Postoperative roentgenograms of the cervical spine were taken routinely. No evidence of instability has been seen to result from bilateral partial facetectomy. The postoperative pain in the neck which has incapacitated 4 persons may be interpreted as evidence of instability of the cervical spine. In these 4 patients, however, unilateral foramenotomy was done at a single level in 3 patients and at 2 levels in 1 patient. In none of these patients is the pain worse than before operation; in 2 it is less. None showed roentgen-ray changes suggesting instability of the cervical spine.

Postoperative pain in the neck, shoulder and between the scapulae subsided so promptly in the majority of these patients after foramenotomy that we are inclined to consider that such pain is not in fact referable to instability of the cervical spine but perhaps to inadequate decompression of root sleeves when it persists postoperatively as in these 4 patients.

Brain et al. and Northfield have observed that no person operated upon for the relief of neurologic complications of spondylosis had been restored to a normal state. The same observation is derived from the present group of patients. However, the improvement in signs and symptoms exhibited by 3 of these patients and the restoration to virtually full functional capacity in 30 is encouraging. The adoption of additional operative measures, such as anterior interbody fusion (4 patients) or more extensive laminectomy and foramenotomy (2 patients) may improve further the circumstance of some of our patients.

**SUMMARY**

1. The neurologic manifestations of cervical spondylosis in 49 patients who underwent operative treatment have been presented.

2. The criterion for operation in this series was signs of progressive neurologic deficit caused by compression of the cervical spinal cord or nerve root.

3. An operative procedure has been described. Laminectomy was performed widely (with partial bilateral facetectomy when necessary) allowing the dural tube to migrate dorsally. The dura mater was not opened. Foramenotomy was done when indicated.

4. The results of operation have been presented. Of the patients, 36 (74 per cent) have improved, 4 (8 per cent) have remained unchanged, 3 (6 per cent) have become worse because of progression of disease, 4 (8 per cent) have died and 2 (4 per cent) have been lost to follow-up. Thirty patients (61 per
cent) have improved sufficiently to allow their return to work without physical limitations.

5. Persisting signs and symptoms after operation have been discussed with considerations to as possible means of improving residual difficulties in 6 patients.

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ADDITIONAL

Since completion of the data for this report 32 additional patients have undergone similar operative procedures for relief of neural complications of cervical spondylolysis. The cephalocaudad extent of the laminectomy was greater than in some of the earlier cases.

The results of operation among these 32 patients are similar to those presented. Neurologic deficit has not progressed post-operatively in any. Very advanced myelopathy (nonambulatory quadriparesis) has improved but slightly while less severe deficit caused by myelopathy and radiculopathy has improved appreciably. No new complications have been observed. There have been no deaths.

REFERENCES


