Cervical Spondylotic Myelopathy*

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The most common cause of progressive spinal cord and nerve root deterioration is chronic cervical disc degeneration. The first complete delineation of the neurological syndrome of cervical spondylosis was made 15 years ago by Brain et al. The spinal cord is involved in this syndrome only when the vertebral canal is narrow in the sagittal dimension. This crucial factor was demonstrated in surgical observations by Allen, in neuropathological studies by Payne and Spillane, and in radiographic studies by Wolf et al.

Although there is a large body of related literature, questions remain in the practical application of this knowledge. In the natural course of the disease does the impairment reach major proportions? Lees and Turner stated that most of their patients showed symptoms for weeks or months followed by improvement or a static condition. Brain stated that there is a natural tendency for the disease to become arrested, but most of those affected were left with a variable degree of disability. We have had experience with a group in whom the course was not so benign. What are the reliable radiological findings which can be correlated with the neurological picture? This question presents a problem especially when the differential diagnosis includes so-called “degenerative disease” of the central nervous system in older patients with co-existing disc degeneration. What are the relative merits and indications among the surgical approaches available now? This question is complicated by the fact that some part of the disability may be irreversible.

Between 1953 and 1964, 190 patients with a diagnosis of cervical spondylotic myelopathy were admitted to our hospitals for diagnostic investigations. A review of common diagnoses of spinal cord disorders showed spondylotic cervical myelopathy to be the most common single cause (Table 1). Seventy-eight were judged to be of such severity and progressive nature that they were referred for surgical treatment. In this group of patients, we conducted preoperative and postoperative examinations at all stages. Changes in progress were judged by differences in findings. Subjective results from questionnaires were used in only a few patients who had moved to another district. All patients were followed for at least 1 year after operation, the majority longer, to a maximum of 10 years. Sixteen patients were not included in the final assessment because etiologic factors such as concomitant severe trauma or coexistent metabolic diseases clouded the issues. Finally 62 patients, 52 male and 10 female, were intensively investigated.

### Clinical Description

The majority of our patients were middle-aged. Four patients were under 40, 17 were over 60. There were no real differences in clinical manifestations according to the emergence of the disease at different ages nor in the apparent tempo of the process. The onset was frequently insidious. The diagnosis is easiest and the patient comes to examination earliest when pain is a prominent feature. Local pain in the neck, shoulder or subscapular regions, however, was present in less than half of the cases. Cervical nerve root compression, always accompanied by pain

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**Table 1**

<table>
<thead>
<tr>
<th>Prevalent causes of spinal cord disorder</th>
<th>UCLA 1957–1964</th>
<th>VAH 1953–1964</th>
<th>Total</th>
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<tr>
<td>Spondylotic Myelopathy</td>
<td>67</td>
<td>132</td>
<td>199</td>
</tr>
<tr>
<td>Amyotrophic Lateral Sclerosis</td>
<td>68</td>
<td>110</td>
<td>186</td>
</tr>
<tr>
<td>Tubers Dorsalis</td>
<td>10</td>
<td>97</td>
<td>107</td>
</tr>
<tr>
<td>Subacute Combined Degeneration</td>
<td>3</td>
<td>41</td>
<td>44</td>
</tr>
<tr>
<td>Syringomyelia</td>
<td>15</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>Tumors, Cervical Spinal Cord</td>
<td>10</td>
<td>11</td>
<td>21</td>
</tr>
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</table>

UCLA = University of California, Los Angeles, School of Medicine.
VAH = Wadsworth Hospital Veterans Administration Center, Los Angeles.

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FIG. 1. Symptoms and signs in 62 cases of spondylotic cervical myelopathy.

which could be brought on by Spurling's maneuver (oblique extension with vertical compression of the head on the neck), was present in only about one-quarter of myelopathy patients. Seventeen patients experienced shock-like sensations in the trunk or limbs on quick flexion or extension similar to Lhermitte's sign. Other patients experienced ascending numbness of the lower limbs when the neck was in sustained extension even though there was no pain. Nevertheless, a large number of the remaining patients experienced only the signs and symptoms of gradual loss of function of the spinal cord.

Spasticity was almost invariably present in the common neurological findings (Fig. 1) and was severe at the initial examination of two-thirds of the patients. Spasticity of the hands, especially in the flexor forearm muscles supplied by the lowest cervical cord segment, was often evident in the slow stiff opening and closing of the fists and by inversion of reflexes. A disabling type of sensory pattern significant of spinal cord impairment was bilateral gauntlet anesthesia of the hands. Segmental sensory patterns and ascending sensory deficit were frequently found, as might be expected, with epidural lesions. Painful paresthesias of a burning, fiery nature aggravated by contact were found associated with zones of partial analgesia. The diagnosis of weakness in Fig. 1 refers to patients who had atrophy or fasciculations.

In order to make comparable correlations the patients were grouped into 5 categories of neurological findings according to the predominant spinal cord syndrome. Classification of a patient was based on the initial
examination recognizing that findings could change in time and with progression of disease.

The transverse lesion syndrome applied to 29 patients with neurological evidence of involvement of corticospinal and spinothalamic tracts, and of posterior columns in almost equal severity below the cervical level. Anterior horn cells were segmentally involved in most of these cases. This type was most frequently encountered, and it is possible that this reflects an end-stage of the disease, since the duration of the disease was the longest in this group. Twenty-five of 29 patients (86 per cent) with a transverse cord syndrome noted the onset of serious deficit more than one year prior to surgery and in 9 patients symptoms developed over 5 years prior to surgery. Spasticity of severe degree was present in 71 per cent of those with transverse cord lesions. Sixty-seven per cent of this group had sphincter involvement and 30 per cent a Lhermitte-like phenomenon.

The motor system syndrome applied to 12 patients whose deficit was primarily of corticospinal tracts or anterior horn cells. Sensory deficit was absent or relatively insignificant in this group. These cases resembled primary lateral sclerosis in some features. Spasticity of severe degree was particularly common among the patients with motor syndrome (75 per cent).

A central cord syndrome was predominant in 8 patients with motor and sensory deficit affecting the upper limbs more severely than the lower. Severe acute trauma was apparently not a factor. These patients all had virtually useless hands, and with painful paresthetic dysesthesias and a posterior column sensory deficit. The Lhermitte phenomenon was encountered in one-half of the patients in this group.

<table>
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<th>TABLE 2</th>
<th>X-ray findings in 62 patients</th>
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<tr>
<td></td>
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<tr>
<td>Central bar</td>
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<tr>
<td>Central bar and foraminal osteophyte</td>
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<tr>
<td>Shingling</td>
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<td>Kyphosis</td>
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<tr>
<td>Subluxation</td>
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<td>Congenital block vertebrae</td>
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A Brown-Sequard syndrome characterized 8 patients whose clinical picture was that of a unilateral cord lesion with ipsilateral corticospinal deficit and a contralateral analgesia below the level of the lesion. It appears likely that this is a less advanced form of the disease than that in the other types. Painful paresthetic dysesthesias were present in one-half of these patients.

A brachialgia and cord syndrome occurred in 5 patients with a predominating picture of upper limb pain and some associated long tract involvement, either motor, sensory or both. These patients had radicular pain, a complaint considerably less frequent among other syndromes. Weakness of the lower motor neuron type was seen in every patient in this group including the only patient in the total series without spasticity.

Radiographic Studies

The process of disintegration of the intervertebral disc substance results in a flattened, rigid pad, and bulging ligaments between the vertebrae with the secondary development of many changes of a fibrocartilaginous nature. Among these are the formation of nodular protrusions, foraminal osteophytes of the lateral processes, transverse ridges of fibrocartilage, and calcifications of these ridges.10,11

<table>
<thead>
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<th>TABLE 3</th>
<th>Preoperative clinical features related to the type of operation</th>
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<tr>
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<td>Clinical Syndrome</td>
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<td></td>
<td>Motor Brown Sequard Central Transverse Brachialgia and Cord</td>
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<td>Anterior cervical excisions</td>
<td>4 5 4 13 2</td>
</tr>
<tr>
<td>Laminectomy</td>
<td>6 4 2 18 3</td>
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</table>
The cervical spinal column becomes deformed with narrowing and sclerosis of adjacent vertebrae. The most common deformity is a kyphosis. In some patients there is an associated osteoarthritis of the apophyseal joints with posterior displacement of the articulating processes. This results in a telescoping effect between the vertebrae such that the lower lamina comes to lie beneath the one above. We have termed this "shingling" to indicate dorsal as well as ventral encroachment (Fig. 2a). It results in a curvature of excessive lordosis. Congenital block vertebrae were encountered in 10 per cent, an incidence greater than would be expected in an otherwise healthy population (Fig. 2b). The principal value of studying plain roentgenograms is to bring out the elements responsible for narrowing of the spinal canal or foramina in each patient. Not even foraminal osteophytes are invariably present since 36 patients with spondylotic myelopathy were free of these. On the other hand osteophytes were present in all patients exhibiting the brachialgia and cord syndrome.

The C5–6 interspace was most frequently involved. Involvement of 2 intervertebral levels was the most common and always included C5–6 interspace (Fig. 3). Only one patient had 4 interspaces involved from C3–4

**Fig. 2.** A. Subluxation or "shingling" between C3 and C4 vertebrae. B. Failure of segmentation, including C6 and C7 vertebrae. Note that the maximum degenerative change is between C3 and C4 vertebrae.

**Fig. 3.** Levels of single and multiple posterior osteophytes in spondylotic myelopathy. The C5–6 interspace is most commonly involved.
to C6–7. Involvement of more than one level did not increase the incidence of a manometric block. C4–5 interspace changes were particularly frequent in Brown-Sequard syndromes whereas C5–6 involvement was associated with a large number of cases in the transverse cord syndrome and the brachialgia and cord syndrome.

The sagittal dimension of the cervical spine is of definite significance in cervical spondylosis and our findings confirm the importance of this factor at all interspace levels (Fig. 4).

Myelography is essential to confirm the diagnosis. Some degenerative changes are not revealed in plain x-rays. Moreover other lesions of the foramen magnum or cervical spinal canal must be excluded. We agree with McGinnis and Eisenbrey that a deformity due to neoplasm need not be confused with disc protrusions or spondylosis. Myelography using Pantopaque (Winthrop Laboratories—ethylidophenylundecylete) has often been unsatisfactory in cervical spondylosis. The irregular nature of the spinal canal floor and the frequent deformity of kyphosis does not permit “pooling” of the contrast medium. There is difficulty in retaining the medium in the head down position because forced hyperextension of the head on the neck is often painful and incomplete and in a few instances has increased the neurological deficit. The density of Pantopaque creates 2 difficulties. A small central disc protrusion may be obscured in the lateral view when both lateral gutters of the spinal canal floor are filled. The density of the medium does not permit sharp definition of the spinal cord shadow. In some Pantopaque studies a widening of the cord shadow in the anteroposterior view and a flattening in the cross-table lateral view can be seen over the transverse bars of the interspace. In nodular protrusions this is not as evident. All too often, however, the filling is inadequate or the image is poor because of globules or escape of the medium.

Oxygen myelography has been used with increasing satisfaction. The technique and results have been reported. The outline of the spinal cord can be defined and our experience indicates at the level of significant encroachment there is a ventral indentation of the spinal cord as well as some indication of cord atrophy below the level. In most cases there is a remarkable obliteration of the dorsal and ventral subarachnoid spaces and the cord changes correlate with the level of involvement. Three examples may be seen in Figs. 2a, 5a, and b. It is also possible to study the changes in vertebral and spinal cord position under flexion and extension. In instances in which the differential diagnosis includes various degenerative diseases we have observed posterior protrusions of spondylosis projecting into the ventral subarachnoid spaces without any observable impingement on the spinal cord. Therefore it seems important to direct attention to the spinal cord shadow in the laminagrams. The test may be applicable only to special cases because there are disadvantages to a suboccipital puncture, the necessity of special equipment, and the additional discomfort to the patient for 24 hours. However, it does offer an alternative for the patient with iodine sensitivity.

Other Etiological Factors

Cerebrospinal fluid examinations showed 72 per cent of the patients had abnormally elevated protein values. A partial manomet-
ric block existed in 26 or 47 patients; a complete block in only 1. Partial block was more commonly noted with the neck in hyperextension. Multiple levels or longstanding myelopathy did not seem to increase the likelihood of a block.

 Patients under the age of 40 were most likely to have had a history of remote but possibly significant trauma (12 per cent). Only 3 per cent of patients having no history of trauma were under the age of 40. Thus spondylotic myelopathy appears to be a disease of the middle-aged and elderly, except in instances of trauma. Also in the traumatic group there was a greater number of Brown-Sequard syndromes.

**Pathological Changes in the Spinal Cord Observed at Laminectomy**

The spinal cord was sometimes found to be displaced posteriorly by osteophytic bars along the ventral wall of the spinal canal (10 patients). In these cases the dorsal aspect of the cord presented an undulating shape over either single or multiple interspace lesions. This displacement was associated with thinning of the cord in the anteroposterior diameter (9 patients). On a number of occasions measurements of the spinal cord were taken. In several cases the cord measured only 8.0 to 9.0 mm. in anteroposterior diameter opposite an osteophytic bar, and in one case a measurement of 4.0 mm. was recorded. It was almost impossible to make thorough observations of the ventral aspect of the spinal cord at laminectomy because of the hazards of any retraction. Comparison of the appearance of the spinal cord as visualized during air myelography with that seen later at operation indicates that midline ventral encroachment on the cord can be present even though the dorsal aspect of the cord looks smooth. Therefore the conditions affecting the ventral aspect of the cord cannot be appreciated fully at laminectomy.

Pallor of the cord or some irregularity in the vascular pattern on the dorsal surface of the cord was seen in 6 patients. In every case there was associated atrophy or narrowing of the spinal cord. The observation of these regions of change in circulatory pattern was originally reported by Allen. We also noticed...
slight meningeal thickening, opacity of the arachnoid membrane, and in a few instances, evidence of dorsal grooving of the spinal cord.

Results of Surgical Treatment

Three types of surgical procedure for the treatment of cervical spondylotic myelopathy were conducted by our staff members between 1953 and 1964: laminectomy with the dura unopened or reapproximated (23 patients) which we have termed "laminectomy, dura closed," laminectomy in which the dura was left open, usually with insertion of a dural graft (11 patients), termed "laminectomy, dura open," and anterior cervical disc excision with interbody fusion (28 patients).

Twenty-eight anterior cervical disc excisions and interbody fusions (Cloward technique) have been done since 1958, 18 by senior staff members, and 10 by resident surgeons under supervision. Fourteen patients had 2 interspaces, 6 patients one interspace, and one patient 3 interspaces removed and bone grafted with homologous iliac bone discs. A further measure was the use of a cervical brace for 3 months after operation to prevent settling of the interspace, angulation, or pseudoarthrosis.

Forty-one laminectomies were performed by senior staff and 24 by residents. The procedure was fairly standardized in that removal of the lamina was carried as far laterally as possible without jeopardizing stability of the articular processes. Five laminae were removed in 34 patients and 3 to 4 laminae in 7 patients. These operations were all performed with the patient in upright position. Twenty-seven patients had dentate ligament sections and a few had foraminotomies. The insertion of an elliptical leaf of lyophilized human dura mater to enlarge the dural tube is shown in Fig. 6, and was a method frequently used in those operations termed "laminectomy, dura open." Some of the patients in the laminectomy group had had a longer preoperative duration of disease. Ten laminectomies were done before the initiation of anterior cervical disc excisions but the remainder were distributed equally in time.

Postoperative Results. In evaluating the postoperative results, patients were assessed not only on the basis of the neurological examination but also on the basis of their ability to carry out their normal activities. Patients were considered to have excellent results when their neurological deficit and functional incapacitation disappeared completely. Certain residual effects such as an extensor plantar sign or slightly hyperactive deep tendon reflexes were found to persist in some of these patients but did not constitute any functional impairment. Patients were classified as improved if there was evidence of significant regression in the major areas of neurological deficit and increased ability to carry out their normal work. However, there was often visible persistence of neurological deficit in performance, mostly residual spasticity and weakness. Patients regarded as unchanged included not only those who showed little or no change from their preoperative condition but also those who appeared to be improved in early follow-up but whose condition ultimately stabilized at a level close to the preoperative state. The patients classified as worse were those who developed signs of extension of the spinal cord involvement or increase of pre-existing symptoms either early or late in the postoperative course.

The results of the operations are shown in Fig. 7. Anterior cervical disc excision and interbody fusion gave a very high proportion of excellent and improved results (71 per cent). The favorable characteristics of the procedure are the removal of the primary
Fig. 7. Changes in spondylotic myelopathy following several types of surgical procedures in 62 patients. The total number of patients in each group is given at the top of each column.

pathological abnormality and a stabilization and alignment of the deformation or subluxation. The posterior protrusions and osteophytes can be removed from the spinal canal floor and foramina with minimal manipulation of the cord or nerve roots. This is reflected in the statistics of complications in which there was no instance of increased signs of spondylotic myelopathy immediately following operation. Additional intradural adhesions developing after this operation were rare. Adhesions are one of the complex factors in the pathogenesis of the disorder. Restoration of the spinal cord and nerve roots from an angulated position to a usual contour would favor vascular channels if this is a pathogenetic factor. The role of a projecting spur in future spine flexion injury has been eliminated. We have come to the conclusion that if preoperative analysis discloses that there is major cord compression at one or two levels from a relatively large amount of fibrocartilaginous material, this is the best operation. When 3 or more levels of
Cervical Spondylotic Myelopathy

Disc protrusion are present, the incidence of complications of anterior cervical disc excision rises since the exposure extends into the upper neck, the operation is longer and the difficulties in achieving good fusion and alignment are increased. If successful there is then a long, rigid segment of cervical spine which may create additional hazards in the event of trauma.

Complications of the anterior cervical approach in our group of myelopathy patients included 1 wound infection at the donor site, 1 tracheotomy, 3 instances of interspace collapse with the later development of increased myelopathy in 1 patient, 1 death in a patient with diaphragmatic hernia and pneumonitis. It has been our experience that concomitant diabetes mellitus is practically a contraindication because of risks of wound infections, poor wound healing, and interference in the processes of bone dowel absorption and replacement. A less obvious complication of this approach is superior laryngeal nerve palsy which occurred in 3 patients and was manifested by postoperative stridor and later by a weak and higher pitched voice. The question of accelerated degeneration of interspaces adjacent to a fusion cannot be answered from our experience although one instance of further disc protrusion and cord involvement occurred 4 years following operation.

Comparison of the two types of laminectomy showed that we had unequivocally greater and faster improvement in laminectomy with the dura open. We now believe that laminectomy with the addition of a dural graft decompression is a useful procedure when multiple interspaces and numerous transverse ridges in a narrow cervical canal are involved. Complications included 8 instances of increased neurological deficit immediately following operation, 5 after laminectomy with the dura closed and 2 after laminectomy with the dura open. Three wound infections occurred, 2 of them associated with cerebrospinal fluid leakage. One patient developed a pseudomeningocele.

![Graph]

**Fig. 8.** Prognosis for improvement of various clinical manifestations of spondylotic myelopathy.
A small number of patients had only minimal improvement following laminectomy, but showed further significant recovery when the anterior procedure was performed soon thereafter.

In considering the entire group of patients with all types of surgical treatment, the changes in individual clinical features are graphed in Fig. 8. A majority had either relief or improvement from pain and spasticity. Only one-quarter of our patients showed any reduction in fasciculations. Among the types of spinal cord syndromes, the Brown-Sequard syndrome was most frequently improved, while least improvement was observed in the motor syndrome type. A history of trauma made a significant difference in the results of surgical therapy. Only 46 per cent of the patients with previous trauma showed excellent or improved results as compared with 67 per cent of patients without trauma.

Haft and Shenkin recently reviewed the results of all published series of operations to 1963. In a total of 203 patients with spinal cord syndrome and cervical arthritis, 42 per cent benefited by surgery, 26 per cent showed fair results, and 32 per cent showed poor results. These operations ranged from laminectomies with and without dente ligament section to extensive laminectomies and foraminotomies. They concluded that laminectomy was unsatisfactory as treatment for midline lesions.

The results of laminectomy and foraminotomy were recently reported by Stoops and King. In their experience, 33 per cent showed marked improvement, 50 per cent definite improvement, 17 per cent were unchanged and none were worse.

Summary

We have analyzed 62 cases of spondylotic cervical myelopathy treated surgically. Five syndromes of spinal cord dysfunction were distinguished, the transverse cord syndrome being the most frequent and possibly representing an end-stage of the disease.

We found oxygen myelography to be a particularly useful diagnostic technique for assessing cord compression and atrophy.

Surgical procedures consisted of laminectomy with dura unopened or reapproximated, laminectomy with insertion of a dural graft and anterior disc excision with interbody fusion. The results were best with the anterior procedure or with laminectomy when a dural graft was inserted; they were poorest when the dura was left intact or was reapproximated.

Spasticity and pain were the symptoms that showed most improvement after surgery.

Acknowledgment

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References