CERVICAL SPONDYLOSIS AND NERVE ROOT LESIONS
Incidence at Routine Necropsy

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Cervical spondylosis is a common condition. It is often associated with brachial neuralgia and occasionally it produces spinal cord compression. Although the bony changes may be very obvious on radiographic examination, clinically the disease may not be severe. The real importance of the bony and soft-tissue changes in this condition lies in their effect on adjacent structures. Although the incidence of myelopathy is low there are very many elderly people who suffer from sensory symptoms in the distribution of the brachial plexus.

Most of the pathological studies of cervical spondylosis have dealt with the changes in the intervertebral discs and, although there has been much speculation about the mechanism by which symptoms are produced, the histological appearance of the cervical nerve roots has received little attention. This remarkable omission from the numerous papers on the clinical presentation of brachial neuralgia may possibly be explained by the relative inaccessibility of the nerve roots.

We have attempted, first, to determine both the incidence and distribution of degenerative disc disease and apophysial joint arthritis, and secondly, to see if there is any correlation between the bone disease and the histological lesions in the cervical nerve roots.

CASES STUDIED

This paper is based on a study of 120 cervical spines removed at routine necropsy from elderly patients who had died in a general teaching hospital from a wide variety of causes. Although the age distribution in our series reflects that of the general population, it included fewer of the very old. Selection of cases was, as far as possible, on a random basis and always before it was known whether cervical spondylosis was present or not. There were sixty-one males and fifty-nine females (Table I).

TABLE I

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Number of cases</th>
<th>Expected distribution</th>
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</thead>
<tbody>
<tr>
<td>20–29</td>
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<td>1</td>
</tr>
<tr>
<td>30–39</td>
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<td>2</td>
</tr>
<tr>
<td>40–49</td>
<td>13</td>
<td>5</td>
</tr>
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<td>50–59</td>
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<td>26</td>
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<td>70–79</td>
<td>44</td>
<td>39</td>
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<td>80–89</td>
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<td>90–99</td>
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<td>4</td>
</tr>
<tr>
<td>Unknown</td>
<td>1</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>120</td>
<td>120</td>
</tr>
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TECHNIQUE

A full necropsy was done on all subjects. After the tongue and neck organs had been removed, the arteries at the base of the neck were ligated and a cannula was fastened into the
right common carotid artery. Approximately 15–20 millilitres of a mixture of 45 per cent barium and 20 per cent gelatin dissolved in water and warmed to 37 degrees Centigrade was rapidly injected. In most cases a successful retrograde injection of the vertebral arteries was obtained via the circle of Willis.

The cervical spine was removed intact by sawing through the first thoracic vertebra and disarticulating the atlanto-occipital joints after the ligaments connecting the posterior arch of the atlas to the occipital bone had been divided. The neck was then fixed in 10 per cent formalin for fourteen days, after which it was radiographed in both the antero-posterior and lateral positions.

Decalcification was effected by immersing the necks in 10 per cent formic acid (changed at intervals) for a period of ten to sixteen weeks. The cervical spine was then sectioned transversely with a bacon slicing machine and approximately twenty-five sections each of four millimetres thickness were obtained.

Histological examination of the cervical nerve roots was carried out, most nerves being cut longitudinally to display both nerve roots and ganglion; some nerves were also cut in cross-section. Blocks were embedded for histological examination in paraffin wax and stained routinely by Weigert’s iron haematoxylin and eosin. Masson’s trichrome stain, Methasol fast blue for myelin and by the Glees-Marsland modification of Bielschowsky’s method for neurofibrils. Some frozen sections were stained for free lipid with Oil Red O and by the Marchi method to display altered myelin.

RESULTS

INTERVERTEBRAL DISCS

Disc degeneration was divided into three grades according to the severity of the lesions: Grade I changes were limited to some splitting of the fibrocartilage but without much alteration in the shape or outline of the disc (Fig. 1). Grade II changes consisted of severe

Fig. 1
A cervical spine showing a grade I disc lesion. It has retained its normal shape but there is mild fissuring of the nucleus pulposus. There is osteoarthritis of the left apophysial joint.
Fig. 2
A cervical spine showing a grade II disc lesion. Severe fissuring of the nucleus pulposus is present, with enlargement of the disc and osteophyte formation.

Fig. 3
Cervical spine showing grade III disc lesion. There is enlargement and cavitation of the nucleus pulposus with some haemorrhage.
fissuring and cavitation of the nucleus pulposus, often with reduction in the height of the disc and narrowing of the intervertebral space (Fig. 2). Grade III changes were similar to those found in the previous grade, but were more severe, often with old and recent haemorrhages (Fig. 3).

The more severe degenerative changes (grades II and III) were always accompanied by an increase in the circumference of the disc caused, apparently, by collapse of the nuclear material and by lateral bulging of the weakened fibres of the annulus fibrosus. In some cases, particularly in the lower cervical region, the collapse was so severe that spontaneous fusion of the vertebrae above and below the disc occurred, leaving only small islands of cartilage between the vertebral bodies. These severe changes were usually accompanied by reactive hypertrophy of bone in the adjacent vertebrae, sclerosis of the superior and inferior margins of the vertebral bodies, and the formation of the characteristic osteophytes at the rim of the bodies which tended to blend with the expanded disc material. The cases were classified according to the state of the worst intervertebral disc present (Table II).

The discs of the lower spine were most frequently and most severely affected (Figs. 13 and 14).

Age—Degenerative disc disease was found more often in older subjects and at an earlier age in male subjects; in the decade around the age of sixty, 50 per cent of men and a third of the women had a significant amount of disease. The mean age in cases showing mild (grade I) disc damage was 60-5 years; that in cases showing severe lesions (grades II and III) was seventy-two years. Further statistical analysis of these figures strongly supports the conclusion that the earliest changes in the intervertebral discs usually precede severe degeneration and collapse by about a decade.

Disc degeneration is frequently associated with narrowing of the intervertebral space and osteophyte formation. While osteophytes may develop at any point around the circumference

<table>
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<th>Disc grade</th>
<th>Normal</th>
<th>I</th>
<th>II</th>
<th>III</th>
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<tbody>
<tr>
<td>Number of cases</td>
<td>10</td>
<td>21</td>
<td>43</td>
<td>46</td>
</tr>
</tbody>
</table>

of the intervertebral disc, those forming in the uncovertebral region are of particular importance because of their closeness to the cervical nerve roots and to the vertebral artery. Figure 4 illustrates the severe reduction in the transverse diameter of the intervertebral foramen which may occur. With collapse of the intervertebral disc there may also be loss, or exaggeration,
Figure 5—Lateral radiograph of a cervical spine to show the narrowing of the intervertebral disc spaces and loss of the normal cervical lordosis. Figure 6—Lateral radiograph of a cervical spine to show a kyphosis caused by severe disc degeneration in the lower cervical region.

Figure 7—Lateral radiograph of the cervical spine to show severe disc degeneration which has produced an increase in the normal cervical lordosis. Figure 8—An antero-posterior radiograph of a cervical spine to show the scoliosis produced by severe unilateral disc degeneration.
of the normal cervical lordosis and, occasionally, subluxation of two adjacent vertebrae. In this series it was the anterior part of the disc that was found most often to have degenerated, with loss of the smooth lordotic curve in twenty cases (Fig. 5). A further three showed actual kyphosis (Fig. 6). The reverse position, with changes most marked in the posterior part of the disc, was less common (five cases) (Fig. 7). Scoliosis due to uneven lateral degeneration was found four times (Fig. 8). The change in the height of the intervertebral disc space and the abnormal curving of the cervical spine, particularly in the presence of subluxation, reduce both the vertical and transverse diameter of the intervertebral foramen and may cause compression and distortion of the cervical nerve roots.

OSTEOARTHRITIS OF APOPHYSIAL JOINTS

The apophysial joints are true synovial joints and may be affected by osteoarthritis occurring either alone or with degeneration of the discs. In this investigation three grades of joint disease were defined: *Grade I* in which roughening and irregularity of the articular facets were the only findings (Fig. 9); *Grade II* in which severe erosion and irregularity of cartilage were associated with enlargement of articular facets and hypertrophy of adjacent bony pedicles.
A transverse section of a cervical spine to show grade II osteoarthritis of the left apophysial joint and disc degeneration. There is irregularity of the articular cartilage with enlargement of the articular facets.

A transverse section of a cervical spine to show grade III osteoarthritis of the right apophysial joint with bony ankylosis between the adjacent articular facets.
(Fig. 10); and Grade III with very extensive joint destruction with haemorrhage and occasionally bony ankylosis (Figs. 11 and 12).

The 120 cases were classified according to the state of the worst joint and almost half were found to have serious disease (Table III).

The joints of the mid-cervical and upper cervical regions were most frequently damaged by osteoarthritis (Figs. 15 and 16) and it was found that the severity of the lesions had a similar distribution. This is in agreement with the radiological studies reported by Brain (1963). In five cases apophysial joint arthritis was the only lesion present throughout the cervical spine, which supports the observation of Horwitz (1940) who found that degenerative changes in these joints might sometimes occur even when the intervertebral discs were normal. In the remaining seventy-three cases the joint lesion was associated with disc degeneration at the lower cervical level, thus suggesting that the arthritic changes were usually secondary to alterations in the mechanics of the cervical spine which accompany collapse of the intervertebral discs (Oppenheimer and Turner 1937, Hadley 1938, Wilkinson 1960). This is supported by the result of a comparison between the age of subjects showing early disc damage and those showing early apophysial joint damage, from which it appears that apophysial joint arthritis develops about ten years later than does disc degeneration.

**EFFECTS OF DISC DEGENERATION AND APOPHYSIAL JOINT ARTHRITIS ON THE CERVICAL NERVE ROOTS**

Osteoarthritis of the apophysial joints may alter the size of the intervertebral foramina in two ways. First, the enlarged articular facets may encroach on the posterior part of the canal (Fig. 4), narrowing the transverse diameter; and second, the telescoping which accompanies subluxation may reduce the height.

The importance of narrowing and distortion of the intervertebral foramina is obvious when the anatomical relationship of the nerve roots to the intervertebral foramen is considered, and bony compression of the nerve roots has frequently been thought to be the most important factor producing neurological symptoms in cervical spondylosis.

One of the main purposes of this investigation has been to determine whether or not there is any correlation between bony disease and histological lesions of the cervical nerve roots, and also to try and show if those changes are produced by direct pressure or depend upon other factors, such as vascular disturbance and inflammatory changes.

**Histological changes within the cervical nerve roots**—The cervical nerve roots showed varying degrees of damage, but in all the cases affected the lesions were usually limited to the posterior nerve root, particularly at its junction with the dorsal root ganglion, and to the dorsal root ganglion itself. The anterior nerve roots were rarely damaged and, out of all the 120 cases examined, changes more peripherally within the spinal nerves were seen on only four occasions.
The most obvious and frequent change which could be seen macroscopically as well as on histological examination consisted in a change in the shape of the ganglia and the nerve roots. The normal dorsal root ganglion is oval in transverse section, but when compression occurs its outline becomes elongated, triangular or crescentic. The actual curve of the ganglion reflects the direction of the bony compression and this deformity is frequently associated with flattening and crowding of the neurones, especially along the concave margin.

Changes in the amount and distribution of fibrous tissue within the posterior root ganglia—Lindblom and Rexed (1948) reported that compression of the lumbo-sacral nerve roots was accompanied by an increase in the width of the fine fibrous tissue septa which normally traverse the posterior root ganglion; this finding they considered to be the most sensitive indication of abnormal pressure on a ganglion. In this study, however, it was observed that, although the width of these septa was apparently increased when compression of a ganglion occurred, even in the normal posterior root ganglia the fibrous septa varied in width according to the position of the section, becoming more pronounced as the perineural sheath was approached. Little attention was therefore paid to the width of the septa when assessing neurological damage, and more importance was attached to a diffuse increase in the fibrous tissue of the endoneurium.
Figure 17—A scarred dorsal root ganglion. There is a great increase in the fibrous tissue of the endoneurium which forms a dense network surrounding and separating the individual neurones and their axis cylinders. (Haematoxylin and eosin, x 150.) Figure 18—The axis cylinders are normal and appear as thin black threads of uniform thickness. (Gros-Bielschowsky, x 460.)

Figure 19—The degenerate axis cylinders are disrupted and swollen and there is some silver staining of the surrounding myelin sheaths. (Gros-Bielschowsky, x 460.) Figure 20—Degenerate changes of the myelin sheaths. They are swollen and irregular in outline. (Methasol fast blue, x 360.)
The endoneurium, or connective tissue sheath of Keyes and Retzius, forms a delicate network which is attached to the neurilemmal sheath of Schwann and separates the individual nerve fibres. A similar sheath of fibrous tissue also surrounds the bipolar neurones of the posterior root ganglion.

Compression of a ganglion and its nerve roots in our cases was usually reflected by a diffuse increase in the fibrous tissue of the endoneurium to form a dense network encircling the individual neurones and separating the axis cylinders (Fig. 17).

These changes were associated with a reduction in the numbers of the axis cylinders and a large proliferation of Schwann cells. The increase in fibrous tissue was usually distributed evenly throughout the posterior root ganglion and the posterior nerve root but in some cases the changes were more patchy and were limited to the compressed margin of the ganglion or were localised to areas of scarring in the posterior nerve roots.

Similar changes were recorded by Bedford, Bosanquet and Ritchie Russell (1952) who examined the cervical nerve roots from a patient with neurological symptoms associated with cervical spondylosis. In their case the posterior nerve roots showed patchy areas of degeneration with an increase in the amount of collagen and considerable proliferation of the Schwann cells. Recent electron microscopy studies reported by Causey (1962) and Barton (1962) have also shown that the collagen content of degenerating nerves is greatly increased, and there is evidence that, under these conditions as in tissue culture, the Schwann cells may be responsible for the production of collagen.

**Changes in the axis cylinders**—Normal axis cylinders stained by the Gros-Bielschowsky method appear as thin black threads of fairly uniform thickness (Fig. 18). Damage to these structures, which is most easily recognised in the larger medullated nerve fibres, causes the formation of irregular globular excrescences in turn caused by swelling of the axon and separation of the neurofibrils (Fig. 19).

The most severe degenerative changes were again seen within the posterior nerve roots and posterior root ganglia. These lesions had a patchy distribution and occurred in association with swelling and fragmentation of the myelin sheaths. In some sections there was an increase in the amount of fibrous tissue separating the damaged fibres. In other examples, however, the degenerative changes were limited entirely to the axis cylinders. An attempt to assess damage to the sympathetic system was abandoned because of the difficulty in staining fine unmedullated fibres reliably.

In cases showing active degenerative changes disintegration and swelling of the myelin occurred, giving the myelin sheath an irregular ballooned appearance which was most marked in the region of the incisurae of Schmidt-Lantermann (Fig. 20). Nerve roots showing these changes often showed degenerative changes in the appropriate axis cylinders: in other cases, however, the changes were limited to the myelin sheaths.

When the Marchi technique was used certain of the sections showed fine black granules of Marchi-positive material, situated within the outline of the swollen myelin sheaths, particularly in the region of the incisurae.

**Degree of nerve root damage**—For purposes of comparison the histological damage to the nerve roots was divided into three grades. In grade I the nerve roots showed variations from the normal pattern. The changes seen included alterations in the shape of the ganglion, slight increases in the amount of fibrous tissue and slight degenerative changes of the nerve fibres. Grade II lesions, although essentially of the same type as those seen in the first grade, were much more severe. Grade III included all cases showing marked diffuse fibrosis throughout the ganglion, with reduction of the number of neurones and obvious degeneration of the nerve fibres. Cases showing obvious areas of scarring and atrophy of the nerve roots were also included.

**Relationship between disc degeneration and histological damage of the cervical nerve roots**—
Nerve roots from all levels of the cervical spine in cases showing various grades of disc damage
but no evidence of apophysial joint lesions were selected for examination and the histological damage in these nerves was compared with that found in nerve roots obtained from specimens which showed, by contrast, no evidence of skeletal disease (Table IV).

<table>
<thead>
<tr>
<th>Normal discs</th>
<th>Diseased discs</th>
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<tbody>
<tr>
<td>Normal nerve roots</td>
<td>25</td>
</tr>
<tr>
<td>Damaged nerve roots</td>
<td>2</td>
</tr>
</tbody>
</table>

\( \chi^2 = 24.6 \quad P < 0.001 \)

The severity of the disc lesions varies and an attempt has, therefore, been made to assess the relationship between the various degrees of disc and nerve root damage. This has been done for the cervical spine as a whole and also for the upper and lower cervical regions separately. The results of these investigations indicate that there is some positive correlation between the severity of disc degeneration and the degree of nerve root damage, but that this is not absolute, and patients with only slight to moderate disc changes (grades I and II) sometimes show severe nerve damage.

**Effect of co-existent apophysial joint arthritis with disc degeneration in the upper and lower cervical spine**—When apophysial joint arthritis and degenerative disc lesions occur together they may produce considerable narrowing of the intervertebral foramina. Although this may not be sufficient to compress the upper cervical nerves because their foramina are large, in the lower cervical spine, where the nerve roots are large and the intervertebral foramina much smaller, a further reduction in the transverse diameter of this canal may well damage the nerve root. In order to test this supposition, a comparison was made between the nerve roots in the upper and lower cervical regions obtained from spines in which the severity of apophysial joint arthritis (grade II) and disc degeneration (grade II) were similar at both levels (Table V).

<table>
<thead>
<tr>
<th>Disc (grade II) and apophysial joint (grade II)</th>
<th>Nerve root normal</th>
<th>Nerve root diseased</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper cervical region . . . . .</td>
<td>16</td>
<td>11</td>
</tr>
<tr>
<td>Lower cervical region . . . . .</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>

\( \chi^2 = 6.6 \quad 0.02 < P < 0.01 \)

There is a difference between the two cervical levels in that foraminal narrowing produced by a combination of these skeletal lesions is more likely to damage the lower cervical nerve roots.

**Blood supply to the nerve roots**—The vertebral arteries are distorted in their course by the bony changes of cervical spondylosis (Hutchinson and Yates 1956). It is known that, in such patients, movement of the neck may interrupt the flow of blood up the vertebral arteries to the brain stem and cerebellum and produce symptoms (Sheehan, Bauer and Meyer 1960). These vessels are also the main source of blood to the cervical nerve root ganglia, and it was thought possible that atheromatous narrowing combined with distortion of the arteries might...
be a cause of nerve root damage. A detailed analysis of the arterial changes in the 120 subjects will be given elsewhere but it was found that severe narrowing, and even occlusion, of one vertebral artery did not appear to be important in this respect. There are, of course, many alternative collateral channels by which the nerve roots could be supplied from the opposite vertebral artery.

**Cysts in the posterior nerve root**—A surprising finding was the presence of cystic cavities in many of the roots and ganglia. In thirty-six of the 120 cases, at least one root showed such a lesion (Fig. 21) and 5 per cent of all the roots examined were affected. The occurrence of

![Figure 21](image_url)

**Fig. 21**

A transverse section of a cervical spine to show a bilocular cyst lying within the posterior root ganglion.

these cysts has been analysed with the conclusion that they were in themselves a cause of damage to the posterior root ganglia (Holt and Yates 1964). They appear to be formed from diverticula of the subarachnoid space which may arise because of the changes in the cerebrospinal fluid pressure. They may be responsible for the well known clinical phenomenon, perhaps first reported by Déjérine, Leenhardt and Norero (1905), that intensification of nerve root pain is often brought about by coughing and sneezing which abruptly raise the venous pressure and therefore that of the cerebrospinal fluid. We found no causal relationship between cervical spondylosis and the presence of these cysts, which were often present in patients who had no
skeletal disease; they may, however, further embarrass a nerve root already trapped in a narrowed intervertebral canal.

The histological changes in the nerve roots, therefore, appear to depend on four factors: first, the severity of the disc degeneration; second, the arthritic changes within the apophysial joints; third, the level of the cervical spine at which these lesions occur; and last, the presence of arachnoid diverticula or cysts within the posterior root or ganglion.

**DISCUSSION**

**The mechanism of radicular symptoms**—Damage to the nerve roots can be produced by the bony changes associated with disc degeneration or apophysial joint arthritis, or by arachnoid diverticula. Each process is effective when it occurs alone but a combination of any two conditions produces more severe damage. The nerve roots in the mid-cervical and lower cervical regions are more vulnerable than in those situated at a higher level.

When disc disease alone was considered it was found that grade I disc disease was not associated with any significant degree of nerve root damage. The changes in the intervertebral discs in these subjects were mild, consisting mainly of transverse fibrillation of the fibrocartilage and, although this probably increases the mobility between adjacent vertebrae, it does not produce any compression or distortion of the spinal nerve roots. However, with disc disease of grades II and III nerve root damage was found whatever the level; furthermore, an increase in the severity of the disc lesions was accompanied by an increase in the damage found histologically in the nerve roots. Both these grades are associated with collapse of the disc nucleus and an increase in the circumference of the disc, with consequent narrowing of the intervertebral foramen. They may also be accompanied by the formation of osteophytes which, if they occur in the uncovertebral region, project laterally into the intervertebral foramen, compressing and distorting the cervical nerve roots as they emerge from the vertebral canal. The nerve roots are usually displaced backwards and laterally and this may lead either to stretching or to an increase of friction between the nerve roots and the bony protrusions during movements of the head and neck.

The apophysial joints, which form the posterior wall of the intervertebral foramina, are intimately related to the posterior root ganglia, and in specimens where the articular facets are enlarged by osteoarthritis, marked anterior displacement and compression of the cervical nerve roots may be found. Even with mild degrees of osteoarthritis an effusion into the synovial cavity would increase the size of the joint, to cause transient symptoms by displacement of the nerve root.

Studies of the clinical presentation of patients suffering from brachial neuralgia, notably those of Bisgard (1932), Mettler and Capp (1941), Clarke and Robinson (1956) and Bradshaw (1957) demonstrate that it is the lower cervical nerve roots, particularly the posterior nerve roots and their ganglia, which are most severely affected in cervical spondylitis. The patients most commonly complain of sensory disturbances, particularly pain and paraesthesia in the distribution of the lower part of the brachial plexus. Motor symptoms including weakness, wasting and clumsiness of the hands do occur but are less common and are usually found only in severe cases.

These clinical findings correlate with the localisation of the histological damage found in the present study, where the main changes were usually limited to the dorsal nerve root and its ganglion whilst comparatively few lesions were found in the anterior nerve roots or the spinal nerves.

The posterior nerve root is intimately related to the anterior aspect of the apophysial joint and it suffers the greatest degree of distortion when the joint is enlarged by osteoarthritis (Nachlas 1944). The severity of the histological damage within the posterior nerve root is, however, more difficult to explain in subjects in which the predominant change is disc
degeneration, because in the normal cervical spine the anterior nerve root is more intimately related to the intervertebral disc. The most likely explanation of this apparent anomaly was suggested by Payne and Spillane (1957) who found that the anterior nerve root lay at the bottom of the intervertebral foramen and, sliding into the small niche below the deformed uncus, may thus escape damage from a protruding osteophyte.

In our study the most severely damaged nerve roots were obtained from the mid-cervical and lower cervical regions. This corresponds with the clinical reports of Gunther and Kerr (1929), Frykholm (1951), and Friedenberg, Broder, Edeiken and Spencer (1960), all of whom stressed that the most commonly affected nerve roots were the sixth and seventh cervical, with pain and paraesthesia radiating along the radial border of the arm into the fingers. The lower cervical nerve roots are particularly vulnerable to compression because they are situated in a region where the most severe degrees of disc degeneration and foraminal narrowing occur and, although they are the largest of the cervical nerve roots, they traverse the smallest intervertebral foramina. Another factor which predisposes them to injury is the great mobility of the middle and lower parts of the cervical spine, for it is in this region that extension and flexion of the neck occur. Many authors, including Turner and Oppenheimer (1936) and Epstein and Davidoff (1951), have observed that the symptoms of cervical spondylosis are aggravated by movements of the head and neck, and Jefferson (1951) reported the remarkable relief of pain which was obtained by the simple expedient of immobilising the neck in a rigid collar. When the main skeletal lesion is disc degeneration with the formation of intraforaminal osteophytes the nerve roots, already displaced, will be further flexed and distorted by flexion of the neck. In other cases, however, pain may be associated with extension of the neck and both Hadley (1949) and Frykholm (1951) have shown that this movement reduces the transverse diameter of the intervertebral foramen, particularly when the canal is already narrowed by a combination of both disc degeneration and apophysial joint arthritis.

Many factors may account for the discrepancies which have been observed between the radiographic appearances of the cervical spine and the presence, severity and distribution of neurological symptoms. Frykholm (1951) pointed out that allowance must be made for the considerable variations which occur in the brachial dermatomes and he drew attention to the fact that pre-fixation and post-fixation of the brachial plexus may occur. He also observed that there may be some difference in the segmental innervation of the two sides of the body. Since we have shown that the distribution of histological lesions within the nerve roots is patchy, it is also likely that the symptoms produced will not affect the whole sensory area supplied by a particular dermatome.

Another factor to be considered is the change in the length of the vertebral column which may accompany degeneration of the intervertebral discs and may be associated with alterations in the position of the nerve roots within the intervertebral foramen. In the adult spine the lower cervical nerve roots pass obliquely downwards and laterally to enter the intervertebral foramen, but when degeneration of the discs occurs the vertebral column may decrease in height, without a corresponding change in the length of the cord. This was commented on both by Frykholm (1951) and by Brain (1956), who said that the altered position of the cervical nerve roots may result in their compression by an otherwise normal intervertebral foramen. The oblique position of the nerve roots, particularly in the lower cervical spine, is also sufficient for at least part of the anterior nerve root to be at one disc level higher than its corresponding intervertebral foramen, so that below the fourth or fifth cervical level a posterior disc protrusion may affect the nerve roots of a lower segment of the cord.

Not infrequently, severe disc degeneration and apophysial joint arthritis are seen in patients who are free from symptoms. This observation is more difficult to explain, but corresponds with the findings in this study that occasionally only slight histological changes were found in subjects with severe bony disease. One possible explanation is that the size of
the cervical nerve roots relative to the intervertebral foramina varies in different people, and a degree of foraminal narrowing which would produce compression in one patient might well be insufficient to do so in another in whom the foramina are larger. Another important consideration is that, in the lower cervical regions, severe disc degeneration may cause fusion of adjacent vertebrae and thus restrict the mobility at this level; the nerve roots at the same level are then enclosed in a rigid tube and may be protected from the compression produced by alteration in shape of the foramen.

SUMMARY

1. One hundred and twenty cervical spines removed at routine necropsy from elderly patients dying in a general hospital have been examined.
2. There was some degree of degeneration of intervertebral discs in 110 cases—in forty-six this was severe.
3. Degenerative disc disease was found at an earlier age in men; mild damage preceded severe degeneration and collapse by about a decade.
4. Discs of the lower spine were most frequently and most severely affected.
5. Alterations of the normal cervical lordosis were produced by disc disease in thirty-two cases.
6. Osteoarthritis of the apophysial joints was found in seventy-eight, and by contrast to disc degeneration was commonest in the mid-cervical and upper cervical regions. In eighteen it was severe.
7. Degeneration and scarring of nerve roots was frequently associated with diseased discs; apophysial joint arthritis was found to be an important additional factor when it occurred in the lower cervical region.
8. No nerve root changes could be attributed to ischaemia resulting from narrowing or distortion of the vertebral arteries.
9. Cystic arachnoidal diverticula which excavate the posterior root ganglia were found in thirty-six cases.

REFERENCES


