HEBERDEN ORATION, 1953

SPONDYLOSIS : THE KNOWN AND THE UNKNOWN

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This Society has always concerned itself with the broad social effects of disease, and degeneration of the intervertebral disks is responsible for a very large amount of pain, suffering, and disability, ranging from episodes which, however painful, are comparatively short-lived though they may be recurrent, to permanent incapacity of the most severe and disabling kind. Moreover, intervertebral disk degeneration is, on the whole, a disorder of the second half of life, occurring particularly in the 5th and 6th decades; hence, as we have an ageing population, the condition is steadily increasing in frequency and in social importance.

My interest in the subject has been primarily concerned with the effects of the disk degeneration upon the nervous system, but the neurological manifestations are, of course, end-results, which often only declare themselves after the disk lesion has been present for many years; so if we are to prevent these most disabling consequences of disk degeneration we must learn far more than we know at present about their aetiology. For, even when the disk degeneration has already occurred and has brought the patient to the doctor on account of pain in the spine or damage to the nerve roots or the spinal cord, we still know far too little about what is really happening, and often have insufficient knowledge upon which to base a rational therapy. Our problem, then, is to correlate the patient's symptoms and signs with the radiological appearance of the affected portion of the spine, and both with the pathological changes responsible for the symptoms. For example, the patient's symptoms may be acute and severe, yet it may be difficult to detect any radiological abnormality. At the other extreme we see patients with gross radiological changes but no symptoms at all. In between fall those patients who seem at first sight the easiest to understand, namely, those who have chronic symptoms associated with chronic changes as shown

by the x rays, but it is equally likely that another patient with x rays which show apparently similar chronic changes will come to the doctor on account of symptoms which are acute. These discrepancies which could easily be multiplied, show how difficult it is in many cases to form an opinion as to the precise nature of the pathological change responsible for the current symptoms; without that knowledge, treatment must be, as we must admit it often is, largely empirical. Hence the differing views about the value of, and indications for, physiotherapy of various kinds, immobilization, traction, manipulation, and operation.

NOMENCLATURE IN RELATION TO PATHOLOGY

I do not propose to deal with those lesions of the intervertebral disks which are produced by their invasion by neoplasms or by infection: I shall confine myself to the changes which have come to be grouped under the term "spondylosis", which, of course, implies that the lesions are degenerative and not inflammatory. This term, however, is itself deceptively simple, if it is taken to mean that we are dealing with a single pathological process: current terminology reflects the confusion in our ideas about the pathogenesis of what is called spondylosis. Sometimes the term "herniation" of the intervertebral disks is used, and sometimes the term "protrusion"; and it is widely believed that the two are synonymous. Frykholm (1951b) points out that

the large amount of data available concerning the thoraco-lumbar disks cannot, however, be used indiscriminately to explain the pathologic condition affecting the cervical disks. The two groups differ too much both anatomically and with regard to the forces to which they are subjected. This is also apparent from the fact that in the cervical region soft nuclear herniations similar to those in the lumbo-sacral region, are relatively infrequent compared to the hard and calcified types.

Nevertheless, I believe that the pathological classification of cervical disk protrusions which Frykholm has himself proposed is equally applicable to intervertebral disk protrusions occurring lower in the spine, provided suitable qualifications as to their pathogenesis are introduced.

In 1948 I suggested (Brain, 1948) a distinction between two main types of intervertebral disk protrusion: nuclear herniations and annular protrusions; and this distinction has been confirmed by Frykholm.

(1) *Nuclear herniation* probably starts with swelling of the nucleus. The annulus, which is encroached upon by the expanding nucleus, undergoes fibrillary degeneration. Its inner fibres merge with the nucleus while its outer fibres disintegrate, as the result of which nuclear material may be extruded into one or other intervertebral foramen, or more dorsally. Bull (1948) has calculated that the total volume of the nucleus pulposus in the cervical region corresponds to that of a red currant. Theoretically, therefore, this would be the maximal size of a complete nuclear herniation. Frykholm points out, however, that the mass always contains fragments of the annulus, and it has, in addition, a tendency to grow in size through a process of metaplasia and the addition of new tissue. The nuclear material is replaced by fibrous and cartilaginous elements and may show evidence of inflammatory reaction. Calcification or ossification may supervene. The mass finally presents the appearance of a well-defined tumour.

(2) *Annular protrusion* is produced by a different process. Owing to various factors, of which age is probably the most important, the intervertebral disk becomes dehydrated and loses its elasticity. As a result it collapses and the annulus bulges in all directions. Local bulgings may also occur at some point if the fibres of the annulus are less resistant. The protruded material becomes vascularized and its fibrous elements are increased in the same manner as in the nuclear herniation. Similarly, the added tissue increases the size of the original protrusion, and again calcification or ossification may occur.

So far we have been describing the alterations which occur in the intervertebral disks themselves, but the impairment of their normal functions leads to reactive changes in the bodies of the adjacent vertebrae. These are stimulated to new bone formation, *i.e.* to the production of the osteophytes which tend to fuse with the disk protrusions (Fig. 1). Frykholm distinguishes two types of osteophytes: the one which is produced in the manner just described he calls marginal lipping, which may either be localized or affect the entire circumference of the vertebral margins. Ventral spurs, on the other hand, are anatomically related to the anterior longitudinal

Fig. 1.—Sagittal section of cervical spine showing intervertebral disk degeneration and formation of posterior osteophytes. (Kindly lent by Dr. M. I. P. Wilkinson.)

ligaments and, according to Schmorl (1929), result from increased strain on this ligament, the fibres of which are firmly attached to the vertebral margins. Furthermore, the collapse of a disk also results in subluxation of the corresponding intervertebral joints with secondary osteophyte formation on the articular processes, leading to further narrowing of the intervertebral foramina.

If, as I believe, this account is fundamentally correct, it follows that “intervertebral disk pro-

trusion" is a name applied to two conditions pathologically distinct: one type of protrusion is the product of a nuclear herniation, while the other is not a herniation but an annular protrusion. A nuclear herniation which has occurred acutely and which is observed before it has had time to harden may be relatively soft; later calcification and ossification, together with the reactive bony changes in the adjacent vertebrae, may make it extremely difficult to distinguish from an annular protrusion which has resulted from disk degeneration. But the matter is more complicated than that, because the beginnings of a nuclear protrusion, which goes no further than to tear some of the fibres of the annulus, may interfere with the function of the intervertebral disk in the same way as primary degeneration, and may excite the same reactions from adjacent vertebrae, so that the changes which tend to produce nuclear protrusion are probably one cause of disk degeneration. Finally, be it noted, intervertebral disk degeneration may occur without causing protrusion.

Thus, when we use the term spondylosis, we are describing processes which are not pathologically homogeneous; we are dealing with a spine which manifests the end-results of either or both of two distinct pathological processes, nuclear herniation and annular protrusion. To some extent radiography is responsible for suggesting that spondylosis is a single disorder, since in the late stages it is not, as far as I know, possible to distinguish the one type from the other by means of *x* rays. If we are to study the natural history of what is called spondylosis, however, we cannot confine ourselves to the end-results, but must also take into account the acute nuclear herniation with which one type of spondylosis begins.

PROBLEMS OF AETIOLOGY

We see, therefore, how complex the causation of spondylosis may be. How large a part does trauma play? In our series of cases of cervical spondylosis (Brain, Northfield, and Wilkinson, 1952), two-thirds of our patients gave no history of trauma, and only six out of 45 gave a history of trauma which could possibly have contributed to the causation of the disorder. Nevertheless, the frequency with which disk degeneration is limited to a single disk (*e.g.* in eighteen out of 38 of our cases of cervical spondylosis), and the fact that it is very common in the lumbar spine, suggest that local causes are at least as important as a diffuse degenerative process, and that a minor trauma which may have started the process years previously may easily have been forgotten. The role of trauma in producing acute

disk protrusion in the lumbar region is well recognized, and it may often exacerbate a pre-existing one.

The wear and tear of normal spinal movements may be a contributory factor, especially when disk degeneration has already begun; and congenital abnormalities, especially Klippel-Feil fusion, throw an added strain on adjacent articulations. Undoubtedly the most important causal factor is the biochemical change in the intervertebral disks which occurs with ageing and is associated with loss of water (Collins, 1949). The nature of this change has been studied by Sylvén, Paulson, Hirsch, and Snellman (1951): by means of electron microscopy they have shown that the healthy nucleus pulposus consists of an intercellular matrix, a three-dimensional lattice gel system containing a dense network of poorly differentiated collagenous fibrils and an amorphous interfibrillar substance. In the process of ageing this substance exhibits an irregular disappearance of the amorphous mucoid material which is responsible for the high water-content and water-binding capacity of the tissue. As a result there is a loss of turgescence and diminution in the vertical height of the disk, and this desiccation renders the spinal column more susceptible to both major and minor injuries.

PATHOLOGY OF THE NERVE ROOTS IN CERVICAL SPONDYLOSIS

We owe much of our knowledge of the structure of the coverings of the nerve roots of the cervical spine, and their relationship to the cervical vertebrae, to the careful studies of Frykholm (1951c). The cervical intervertebral foramina are bounded above and below by the pedicles of the two adjacent vertebrae. The radicular nerves are situated in the foramina, and the dorsal root ganglia lie just outside in the gutter of the transverse process. The posterior wall of the foramen is formed by the superior articular process of the vertebra below, which, in turn, is covered posteriorly by the inferior articular process of the vertebra above. The ventral delimitation of the foramen is effected partly by the two adjacent vertebral bodies and partly by the dorso-lateral rim of the intervertebral disk. This is termed the uncinat process, and there has been some discussion whether between the uncinat process of the lower vertebra and the corresponding facet of the vertebra above there is a true joint, as Luschka (1858) supposed. This has been called the uncovertebral joint and the neurocentral joint, but some, including Frykholm (1951b), believe that what has been regarded as a joint cavity is merely part of the annulus of the intervertebral disk.

Fig. 2.—Principal features of anatomy of cervical nerve-roots and their dural and arachnoidal investments (after Frykholm, 1951c).

The rather complicated structure of the investment of the radicular nerves can be best understood by reference to a diagram (Fig. 2). Opposite each foramen the dural sac has a small infundibular extension, the dural root-pouch, or axillary pouch of some authors. By means of the funnel-like shape of the pouches, each nerve-root is conveyed in a smoothly curved course to the point at which it leaves the dural sac. At the bottom of the root-pouches are two openings, the dural root ostia, one ventral and one dorsal, which are separated by a small dural septum, the inter-radicular septum. Each root ostium leads into an individual root sleeve, of which there are consequently two, one dorsal and one ventral. The root sleeves, which are lateral extensions of the dural sacs, are separated by a small cleft known as the inter-radicular

foramen. Consequently, outside the dural sac, the dorsal and ventral roots pass through individual sheaths which are entirely separated. A tubular extension of the arachnoid membrane encloses each root in its proper root-sleeve. Between the dural sac and the dorsal root ganglion the two roots lie close together and form an anatomical entity referred to as the radicular nerve.

In seeking to interpret the effect of the bony changes of cervical spondylosis upon the radicular nerves, it is of cardinal importance to remember that the radicular nerve normally occupies only one-fifth to one-fourth of the diameter of the foramen, hence if the nerve lay always in the middle considerable narrowing of the foramen could occur without producing any effect upon it. Frykholm (1951c), however, pointed out that the morphology of the lower cervical radicular nerves and their root-pouches is very variable (Fig. 3, overleaf). In early

childhood the dural sac and the radicular nerves are only loosely attached to the bone. As age advances they gradually become relatively well fixed in their definite positions. In most cases the radicular nerves then take a slightly downward course and pass through the centre of their respective foramina. Variations in this arrangement may occur in normal individuals, probably as the result of disproportionate growth of the dural sac and the cord relative to the vertebral column. Displacement of the radicular nerves within the foramina may, however, occur also as the result of cervical disk degeneration, quite independently of the pressure of disk protrusion, since the cord and the dural sac retain their original length while the spine is shortened owing to osteoporosis and disk degeneration. The lower cervical radicular nerves thus tend to be displaced

Fig. 3.—Dissection of cervical nerve-roots in their passage through the intervertebral foramina, showing variations in shape of the dural root-pouches (Dr. R. J. Harrison).

towards the lower part of their foramina and hence become more upwardly directed. The displacement downwards also tends to distort the root-pouches, which results in sharp angulation of the nerve roots, and at this point of angulation the roots are subjected to undue strain and increased friction with the dural lining. Frykholm points out that in

Fig. 4.—Principal types of disk protrusion (after Frykholm, 1951b):
(i) dorso-medial, producing bilateral cord compression,
(ii) dorso-lateral, producing radicular compression intraspinally,
(iii) intraforaminal, producing radicular compression with the intervertebral foramen.

consequence the segmental level of such a lesion does not necessarily correspond to a level of a disk degeneration.

Now let us consider the more direct effect of cervical intervertebral disk protrusion and the associated vertebral changes upon the nerve roots and radicular nerves. In this connexion I shall not concern myself with acute nuclear herniation, but with the end-results of disk protrusion, however produced, and disk degeneration in cervical spondylosis. Such disk protrusions have been variously classified according to their position in the circumference of the disk (Figs 4 and 5). One or more of these different types of protrusion may be encountered in the same disk, and they merge into one another. From the

Fig. 5.—Posterior aspect of bodies of cervical vertebrae in spondylosis, showing central, dorso-lateral, and foraminal osteophytes. (Kindly lent by Dr. M. I. P. Wilkinson.)

point of view of the radicular nerves and nerve-roots, however, the only two with which we need concern ourselves are the dorsolateral protrusion, which does not invade the intervertebral foramen but may compress the intrameningeal nerve roots against the vertebral laminae, and the intraforaminal protrusion, which emerges from the uncinat part of the disk and compresses the radicular nerve against the articular processes. The mechanism of root compression, however, depends, not only upon the size and location of the protrusion, but also

upon the angulation of the radicular nerve and its situation in the foramen. Thus, for example, a protrusion restricted to the lower part of the foramen may leave the roots quite intact if the radicular nerve is downwardly directed and situated cranially in the foramen, whereas, if the nerve is caudally situated and outwardly or upwardly directed, there is a much greater chance that it will be implicated. Furthermore, a protrusion which is strictly localized to the lower half of the foramen may produce a selective compression of the ventral root and leave the dorsal root intact, because the ventral root often runs along the caudal border of the dorsal root. Finally, cervical disk degeneration without protrusion may lead to marginal lipping as a result of the increased stress, which falls directly upon the vertebrae when the disk loses its shock-absorbing properties. This may cause some osteophyte formation in the anteromedial part of the intervertebral foramen. At the same time the narrowing of the disk throws an additional strain upon the corresponding intervertebral joints and that leads to secondary osteophyte formation on the articular processes, thus narrowing the foramen posterolaterally.

The pathological effects of these bony changes in the neighbourhood of the intervertebral foramen have been studied by Frykholm (1951a). In their fully developed form they consist of what he calls "root-sleeve fibrosis". This is characterized by:

- (1) thickening and opacity of the dural root-sleeve and adjacent parts of the dural sac (*i.e.* the root pouch);
- (2) narrowing, or complete abolition, of the dural funnel which forms the root pouch;
- (3) sharpening of the upper and lower duroradicular junctions, which sometimes causes a distinct constriction or notching of the radicular nerve;
- (4) thickening of the dura at the root-ostia and occasionally, also, thickening of the inter-radicular septum, resulting in a constricting ring of fibrous tissue around each nerve root;
- (5) thickening and fibrosis of the arachnoid membrane in the neighbourhood of the root-ostia;
- (6) disintegration and hyalinization of the dural tissue involved.

The chronic constriction of the nerve-roots and radicular nerve and the associated ischaemia leads in time to the degeneration of the nerve fibres. Frykholm points out that in many cases root-sleeve fibrosis is observed in the absence of any constriction of the corresponding foramen, though in such cases there is usually radiological evidence of disk degeneration, either at the same segmental level or at one or two levels above that of the radicular lesion. Occasionally also root-sleeve fibrosis may be present, in spite of the fact that x ray of the cervical spine shows no abnormality.

Thus, cervical intervertebral disk degeneration initiates a complex and variable series of changes which may affect the nerve roots and radicular nerve in many different ways needing individual assessment in each case. These changes may be summarized as follows:

(1) Disk degeneration affects the mobility of the cervical spine. The simplest example of this is the effect of degeneration of a single disk. Usually this greatly limits flexion and extension at the intervertebral joints between the two vertebrae separated by the affected disk, since the main movements must now occur above and below, and abnormal stresses may fall not only upon adjacent intervertebral joints but also upon adjacent radicular nerves. Exceptionally, disk degeneration leads to abnormal mobility, in which case, as a rule, the body of the upper vertebra slips forward upon that of the lower on flexion and slips back again on extension, a movement which must obviously tend to produce damage to the radicular nerves in the corresponding foramina.

(2) Narrowing of intervertebral disks shortens the cervical spine and disturbs the relationship between the radicular nerves and their corresponding foramina, the lower ones, particularly, tending to rest upon the lower margins of the foramina and to be kinked over them.

(3) Disk degeneration by itself can produce lipping of the adjacent vertebral bodies and so narrow the inner margins of the intervertebral foramina, whilst increased strain upon the intervertebral articulations produces osteophytic narrowing posteriorly.

(4) All this may occur without intervertebral disk protrusion. In addition, however, a dorsolateral protrusion may compress the nerve roots within the spinal canal, while an intraforaminal protrusion may compress them or the radicular nerve within the foramen.

(5) All the above-mentioned processes tend to lead to root-sleeve fibrosis, the characteristic reaction of the investment of the nerve roots and radicular nerve to chronic irritation and compression. These pathological changes, therefore, though most likely to occur in the nerve roots which pass through the intervertebral foramina at the level of the degenerated disk, may be present also at other levels at which there is no evidence of disk degeneration.

(6) The affected nerve-roots and radicular nerves, tethered to the foramina by root-sleeve fibrosis and lacking their normal mobility, are far more susceptible to trauma than the normal nervous tissue.

Consequently, not only may severe and lasting radicular symptoms be set up by head injury in such cases, but it is probable that comparatively slight trauma may be responsible for the acute onset of symptoms in patients with cervical spondylosis, symptoms which may be multiradicular in distribution although the bony pathological changes may be limited to one intervertebral disk and its adjacent vertebrae.

Fig. 6.—Cervical spine, showing results of spondylosis:
(i) narrowing of C5-6 and C6-7 disk-spaces with anterior and posterior osteophytes,
(ii) spondylolisthesis, C4 slipping forward on C5 in flexion.

SIGNIFICANCE AND INSIGNIFICANCE OF RADIOGRAPHIC CHANGES

We are now in a position to assess the value and limitations of radiography in the diagnosis of the radicular lesions accompanying cervical spondylosis, and also, perhaps, to clear up some of the apparent anomalies. In the radiological investigation of a patient suspected of cervical spondylosis, it is usually necessary to take three lateral views in the erect, flexed, and extended positions respectively, as well as an antero-posterior view and right and left oblique views to show the intervertebral foramina. Without the flexed and extended lateral views it may be impossible to detect spondylolisthesis (Fig. 6).

In addition, plain x rays may show a narrowed intervertebral disk space, indicating disk degeneration; posterior osteophytes, in the manifestation of which specially soft films may be helpful; and osteo-

Fig. 7.—Oblique view, showing narrowing of intervertebral foramina C5-6 and C6-7 by osteophytes.

phytic invasion of the intervertebral foramina (Fig. 7).

It is important to bear in mind the following points in the interpretation of the radiological appearances:

(1) A narrowed intervertebral disk space indicates disk degeneration which may or may not be associated with disk protrusion.

(2) The absence of posterior osteophytes, which are radiographically visible, does not necessarily mean the absence of a disk protrusion.

(3) A normal intervertebral foramen does not necessarily mean healthy nerve-roots or radicular nerves, since

(4) The nerve-roots may be compressed in the spinal canal by a dorso-lateral disk protrusion, which does not involve the foramen, or they may be the subject of root-sleeve fibrosis within a normal foramen for one of the reasons mentioned above.

(5) A narrowed intervertebral foramen does not necessarily mean that the corresponding nerve roots or

Fig. 8.—Myelogram, showing compression of the spinal cord by disk protrusions C3-4 and C5-6. Note slightness of narrowing of disks anteriorly and absence of anterior osteophytes.

radicular nerves are compressed, since normally the nerve takes up only a small proportion of the space in the foramen and if it is centrally situated may for a long time avoid damage or even tolerate a considerable degree of compression without giving rise to symptoms.

(6) Myelography may be valuable for the purpose of showing a disk protrusion, which is not visible in the plain x rays (Fig. 8), or a root-sleeve fibrosis, which may be demonstrable by obliteration of the root pouch in the myelogram although the intervertebral foramen may appear normal in plain x rays (Fig. 9, overleaf).

SOME RADICULAR SYNDROMES OF CERVICAL SPONDYLOSIS

I believe that the various clinical pictures described in the past as "brachial neuritis" or "brachial neuralgia" are in most cases caused by the pathological changes described by Frykholm as root-

Fig. 9.—Antero-posterior myelogram in cervical spondylosis, showing filling defects caused by disk protrusions. Note particularly defective filling of root sheaths.

sleeve fibrosis. I shall not now retread the well-worn path of the clinical symptomatology of "brachial neuritis", but shall confine myself to a consideration of some of the less familiar clinical pictures and, in particular, those upon which light is thrown by the newer knowledge of the pathology of the condition.

(1) *Acroparaesthesiae*.—These may be defined as unpleasant tingling sensations affecting some or all of the digits of one or both upper limbs, developing during the night and usually passing off within an hour or so of awakening, which are particularly liable to occur in middle-aged women. Thus defined, they are merely

symptomatic, and it is inherently unlikely that a symptom of irritation of sensory nerve fibres is characteristic of a lesion occurring at only one point in their course. I believe that acroparaesthesiae may occur as a symptom of either

- (i) cervical spondylosis,
- (ii) a costoclavicular syndrome involving particularly perhaps vasomotor elements,
- (iii) compression of the median nerve in the carpal tunnel.

Acroparaesthesiae, however, are so common a symptom of cervical spondylosis that all patients who complain of them should have their necks x-rayed.

(2) *Pain referred to Myotome and Sclerotome*.—A dermatome is the area of skin supplied by a single spinal nerve. The importance of the dermatome in neurological diagnosis has perhaps tended to obscure the fact that a spinal nerve distributes sensory nerve fibres to muscles, bones, joints, and ligaments which have an anatomical distribution ranging widely beyond the cutaneous area innervated by the same segment. The muscles supplied by a single radicular nerve have been termed a myotome, and the bones and joints similarly supplied, a sclerotome. Pain due to irritation of a spinal posterior root or radicular nerve, therefore, may radiate widely, and this may sometimes give rise to difficulties in diagnosis. For example, both the 6th and 7th cervical radicular nerves supply sensory fibres to the posterior cervical muscles, pectoralis major, latissimus dorsi, and serratus magnus, as well as to other muscles of the trunk and upper limbs and the corresponding dermatomes. Irritation of either of these nerves may therefore cause pain referred to the neck, back, and front of the chest, as well as to the upper limb, and, it has been pointed out, may suggest pain of cardiac origin.

(3) *Muscular Wasting*.—This is not usually severe as a result of the radicular lesions of cervical spondylosis, but it may be a prominent symptom and may even occur in the absence of objective sensory abnormalities, when it may lead to an erroneous diagnosis of motor neurone disease. Frykholm points out that such muscular wasting is probably due to a selective damage to the anterior spinal roots by compression arising from the lower part of the foramina. It may affect the muscles supplied from several segments or from one only.

(4) *"The Frozen Shoulder"*.—Pain of radicular distribution due to cervical spondylosis and referred to the shoulder is not infrequently followed by the condition known as "frozen shoulder", in which gross limitation of active and passive movement of the shoulder occurs and any attempt to move the joint causes pain. The possibility that a "frozen shoulder" is a symptom of cervical spondylosis should always be borne in mind.

(5) *Acute or Subacute Multiradicular Symptoms*.—As a rule the radicular symptoms of cervical spondylosis are limited to one, or perhaps two, segments. The older clinical accounts of brachial neuritis, however, usually describe pain radiating down the whole length of the arm to all the digits and associated with some degree of generalized muscular wasting, weakness, diminution of

tendon reflexes, and perhaps very diffuse cutaneous sensory loss. This clinical picture may undoubtedly occur as the result of cervical spondylosis, even when the x-ray changes are limited to one or two intervertebral joints. As I have suggested above, the probable explanation is that in such cases root-sleeve fibrosis is much more widespread than the radiological changes would suggest, and that some change, perhaps a slight trauma or even possibly exposure to cold, has intensified the lesion in most of the roots from which the brachial plexus is derived. An alternative possibility is that an acute lesion of a single root may sometimes cause pain which, owing to the considerable overlap of dermatomes, radiates to a large area of the upper limb and at the same time reflexly interferes with muscular function.

Fig. 10.—Anterior aspect of spinal cord from same case as Fig. 5, showing indentation of cord and roots by osteophytes.
(Kindly lent by Dr. M. I. P. Wilkinson.)

PATHOGENESIS OF MYELOPATHY IN SPONDYLOSIS

Cervical spondylosis damages the spinal cord less often than the nerve roots, but sufficiently often to make spondylotic myelopathy one of the commonest, if not the commonest, disease of the spinal cord during and after middle life. This is illustrated by the fact that 41 patients with cervical spondylosis have been admitted as in-patients to the neurological

department of the London Hospital during the last 2 years, mostly on account of myelopathy. The pathogenesis of the myelopathy, like that of the root-sleeve fibrosis, is complex, and certainly a number of factors are concerned. The most obvious is direct compression of the cord by one or more protruding intervertebral disks (Fig. 10). When the disk protrusion is large, the cord may be compressed between it and the laminae posteriorly, the pressure being sufficient even to cause thinning of the laminae. Greenfield (1953), however, believes that in the majority of cases the areas of demyelination are too limited to be explained as the result of simple compression. He thinks that compression may operate indirectly by interfering with the blood flow through the anterior spinal artery. The blood supply to the spinal cord may be further impaired by narrowing of the intervertebral foramina through which the radicular arteries penetrate. Compression of the anterior spinal veins has also been regarded as a contributory factor. Stretching of the ligamenta denticulata also, in Greenfield's opinion, plays an important part, since these ligaments tend to increase the effects of compression on the anterior spinal vessels by anchoring the spinal cord. Moreover, they exert tension on the lateral aspects of the spinal cord. The neck, however, is not static, but in constant movement throughout waking life, and a considerable amount of movement still occurs in a spine which is the site of severe spondylosis. As already mentioned, movement may be pathological when one body slips forward upon the one immediately below it on flexion of the neck. Root-sleeve fibrosis which is invariably present to a greater or less extent in these cases, tends to anchor the roots in the foramina and, by thus limiting the mobility of the cervical cord, must add to the traumatic effect of repeated movement of the neck when the cord is already compressed by a disk protrusion. All these factors combine to produce a condition which is best described as cervical myelopathy. Moreover, in the presence of cervical spondylosis, even though the spinal cord has so far apparently escaped injury, severe damage may be produced by forcible extension of the neck; such extension may result from a blow upon the front part of the head, or may even occur, as Symonds has recently shown, during the administration of anaesthetic or an operation upon the tonsils.

SYMPTOMATOLOGY OF CERVICAL MYELOPATHY DUE TO SPONDYLOSIS

I do not propose to discuss in detail the symptomatology of cervical myelopathy resulting from spondylosis (Brain, 1948; Brain and others, 1952),

but only to draw attention to the relationship between the pathology described above and the symptomatology, and, in particular, to try to show how the pathology explains the extremely varied clinical picture. To simplify matters, let us consider only the factor of disk protrusion. Since these protrusions may be single or multiple, and may occur at any, or every, level of the intervertebral disks, it is clear that any segment of the cervical cord may be compressed from the 3rd to the 8th, that is, either above or in the course of the cervical enlargement. Furthermore, a disk protrusion into the vertebral canal may be situated either in the mid-line or to one or other side, or may be more or less continuous, and, except in extreme cases, the resulting demyelination does not involve the whole transverse extent of the cord. It is therefore easy to understand how varied is the resulting clinical picture and how many other disorders it may simulate. Since the onset of symptoms is usually insidious, and may be either intermittent or steadily progressive, the disorder will tend to resemble other lesions of the spinal cord which occur in middle life and have these general characteristics. Muscular wasting, fasciculation and weakness in the upper limbs, and spastic weakness of the lower limbs in the absence of sensory loss, may closely simulate motor neurone disease. Weakness, numbness, and clumsiness of the upper limbs, associated with ataxic paraplegia, and perhaps some sensory loss in the lower limbs, present a clinical picture resembling that of disseminated sclerosis. When the damage falls chiefly upon the pyramidal tracts and the posterior columns, with which may be associated some wasting of the hands and sensory loss of glove distribution in the upper limbs, there is a considerable resemblance to sub-acute combined degeneration. Extramedullary tumour, intramedullary tumour, and syringomyelia may all easily be simulated. When the symptoms are those of pure bilateral pyramidal degeneration, a diagnosis of primary lateral sclerosis may be made. In some cases cervical myelopathy may for a long time cause only paraplegia without detectable abnormalities in the upper limbs, and then the cause may be thought to originate in the dorsal region of the spinal cord. Occasionally, as Symonds (1953) has recently pointed out, cervical spondylosis may be the cause of quadriplegia of sudden onset, which may be permanent or, as in one recent patient of my own, brief and intermittent. Finally, to add to the hazards of diagnosis, not only may cervical spondylosis co-exist with a quite independent lesion of the nervous system which is itself responsible for the symptoms, but it may sometimes be associated with

other abnormalities of the spine or spinal cord, particularly of congenital origin, such as congenital fusion of vertebrae, cervical spina bifida, and the Arnold-Chiari malformation, while syringomyelia and tabes may cause a cervical anopathy which is not only difficult to distinguish from spondylosis, but may actually be complicated by it.

THORACIC INTERVERTEBRAL DISK PROTRUSION

I am inclined to include thoracic intervertebral disk protrusions rather among the unknown than among the known facts of spondylosis. They are certainly far less common than disk protrusions at the cervical and lumbar regions, presumably for mechanical reasons. The neurologist and neurosurgeon are familiar with them as rather uncommon causes of extramedullary compression of the spinal cord. I have sometimes suspected one as the cause of an otherwise unexplained root pain, but, apart from those causing compression of the spinal cord, I have never been able to demonstrate one by myelography. This is a field which I am sure would repay research. Apart from the presence of thoracic disk protrusions sufficient to cause symptoms, I have also encountered a good many patients suffering from progressive paraplegia in association with severe thoracic spondylosis. The opportunity for the pathological investigation of such cases rarely occurs. I have suspected that the narrowing of the intervertebral foramina by interfering with the vascular contribution which the radicular arteries make to the vasocorona of the spinal cord may contribute to an ischaemic myelopathy. Here, also, pathological research might prove rewarding.

LUMBAR DISK PROTRUSION AND FORAMINAL PRESSURE NEURITIS

I have left lumbar spondylosis until the last because it has been the subject of research for a much longer period than cervical spondylosis, and because, until recently at least, much more has been known about it. This, however, does not mean that there are not still many important unknown factors. It is desirable to bear in mind that the distinction between nuclear and annular protrusions, which I discussed in connexion with cervical disks, applies equally to those in the lumbar region. There are, however, certain points of difference between the two. In the lumbar region acute nuclear protrusions are a much commoner cause of symptoms than at the cervical level, but it is probable that in the lumbar region pre-existing disk degeneration is a more important predisposing cause of such nuclear protrusion than it is in the neck. At the lumbar level, as at the cervical

a nuclear protrusion, if undisturbed, may provoke an osteophytic reaction from the vertebral bodies, which may in the end be difficult to distinguish from an annular protrusion. In particular, plain x rays may provide no clue whether a narrowed lumbar intervertebral disk space results from simple

disk degeneration, annular protrusion, or nuclear protrusion.

Whereas in the neck, compression of spinal nerve roots by disk protrusion in the vertebral canal is rare compared with compression in the foramina, the reverse is generally thought to be the case at the lumbar level. Nevertheless, in the lumbar spine, exactly as in the cervical, intervertebral disk degeneration can produce damage to the spinal nerve within the foramen, and in precisely the same way, first the narrowing of the intervertebral disk narrows the corresponding foramina by bringing their edges nearer together, and secondly an additional strain is thrown upon the articulation, so leading to osteophyte formation, which in turn narrows the foramina still further.

This cause of sciatic pain was hinted at by Sicard (1921) and elaborated by Putti (1927), but the subsequent discovery of intervertebral disk protrusion has led to its neglect. I believe that the symptoms of lumbar intraforaminal root compression are usually distinguishable from those of intrathecal root compression by disk protrusion. This is only to be expected on anatomical grounds, for intrathecal compression is exerted upon the posterior root of an intact ganglion, whereas intraforaminal compression is exerted upon the ganglion or the spinal nerve. It should be noted, for example, that the fifth lumbar root may be compressed either by a protrusion of the fourth lumbar disk or by narrowing of the fifth lumbar foramen (Fig. 11). Radiologically the fourth disk-space will probably be narrowed in the first instance, and the fifth in the second, with osteophytic invasion of the L5-S1 intervertebral foramen (Figs 12*a* and *b*). Of course, both may be present in the same patient. Lumbar foraminal pressure-radiculitis increases in frequency with age, and is most commonly encountered in the seventh and eighth decades. It is, however, especially common in diabetics, in whom it may occur at an earlier age. It may be uniradicular or multiradicular, unilateral or bilateral. Pain is usually less severe than in the sciatica resulting from disk protrusion, and it is less likely to be exacerbated by coughing or sneezing; it is often, however, influenced

Fig. 11.—Dissection of lumbar nerve-roots (L2-L5). The lowest (5th) can be traced up from the lumbo-sacral disk, to where, intradurally, it passes behind the 4th lumbar disk (Dr. R. J. Harrison).

Fig. 12 (a and b).—Lumbar spondylosis causing narrowing of 5th lumbar disk-space and foramen. Antero-posterior and lateral views. (Kindly lent by Dr. M. Jupe.)

by posture and may be worse when the patient is sitting. On the other hand, there may be no pain, but only dyaesthesiae in the distribution of the dermatomes supplied by the affected root or roots. Cutaneous sensibility is often blunted over these areas. When several roots are involved there may be conspicuous muscular weakness, wasting associated with fasciculation, and diminution or loss of the knee jerks.

Look back for a moment and recall that it is just 20 years since sciatica was first attributed to an intervertebral disk protrusion. Before that it was called sciatic neuritis and put down to various hypothetical toxins. Even then the same view was taken of brachial neuritis, and nothing at all was known of the protean clinical picture of spinal cord compression by disk protrusion, except for a small number of cases gathered by neuro-surgeons in

which the lesion was called a chondroma. How much we have learned since then! But how much still remains to be discovered!

I am grateful to Dr. R. J. Harrison for the dissections illustrated in Figs 3 and 11.

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