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Posterior protrusion of the lumbar intervertebral disks and hypertrophy of the ligamentum flavum

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POSTERIOR PROTRUSION OF THE LUMBAR INTERVERTEBRAL
DISCS AND HYPERTROPHY OF THE LIGAMENTUM FLAVUM

by

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Senior Thesis

Presented to
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I INTRODUCTION

The protrusion of an intervertebral fibrocartilage into the spinal canal with compression of nerve roots is a subject which has been discussed a great deal during the last few years. The great interest in this condition is due to the fact that at last a definite cause and a definite treatment has been found for many cases of low back pain and sciatica which have long been very difficult to explain and very discouraging to treat. Since the syndrome of protruded intervertebral disc has become established, it has been diagnosed more and more frequently. The number of cases diagnosed and treated successfully has grown by leaps and bounds in recent years. Today great numbers of people are being restored to health and usefulness because of the recognition and satisfactory treatment of this condition.

Protruded intervertebral disc may be defined as a pathologic and clinical entity in which a portion of an intervertebral fibrocartilage is extruded posteriorly into the spinal canal causing symptoms of varying degrees of compression of the spinal cord or its nerve roots. This condition may be accompanied by hypertrophy of the ligamentum flavum or the symptoms of compression

of nerve tissue may be due to hypertrophy of the ligamentum flavum without protrusion of the intervertebral disc. Since this phenomenon is seen almost exclusively in the lumbar intervertebral discs with consequent compression of the component nerve roots of the sciatic nerve, the discussion in this paper will be limited to protrusions in the lumbar region.

The protrusion of the intervertebral disc has gone by a number of different names during the short time it has been described in the literature. It has been called an "intervertebral disc chondroma" by Baily and Bucy (6); "ventral extra dural chondroma" by Stookey (51) and Adson (2); "myxochondroma" by Veraguth; "fibrochondroma" by Crouzon; "Schmorl's Nodule" by Klinge (28); "loose cartilage from the intervertebral disc" by Dandy (20); "ecchondrosis" by Elsberg (28); "herniation of the nucleus pulposus" by Peet and Echols (40); "rupture of the intervertebral disc" by Mixter (38); and "protruded intervertebral disc" by Love (35).

II HISTORICAL BACKGROUND

The earliest mention of extrusion of cartilage from an intervertebral disc due to trauma was made by Virchow in 1857 (34).

In 1896 Kocher reported a case of rupture of the intervertebral disc in a man, 26 years old, who fell from a height of 100 feet, landing in the standing position. He died of internal injuries within a short time. At autopsy he was found to have a rupture of the disc between the first and second lumbar vertebrae. The displaced intervertebral disc tissue had apparently caused no cord damage. (7) (28)

In 1911, Middleton and Teacher reported the case of a man, 38 years old, who felt something "snap" in his back while he was lifting a heavy weight and was unable to straighten up. He later developed flaccid paralysis of the lower extremities, with absence of knee and ankle jerks. He had anesthesia to the level of Poupart's Ligament and incontinence of urine and feces. The patient died of urinary infection. Autopsy revealed a mass protruded from the intervertebral disc between the twelfth thoracic and first lumbar vertebrae. There was no injury to the vertebral bodies. (7)

In the same year (1911) Goldthwait reported a

case of a patient suffering from a "right sacro-iliac strain" who developed a flaccid paralysis of the legs following manipulations to "reduce" the subluxation. A laminectomy was performed by Harvey Cushing who found no lesion in the spinal canal. In discussing the case, Goldthwait concluded that posterior displacement of the lumbosacral intervertebral disc with pressure on the cauda equina was the logical explanation. Elsberg, in 1916 mentioned the subject and states that Oppenheim had also observed such a case. Clymer, Mixter, and Mella in 1921 noted a similar case. (45)

In 1923, Ott and Adson reported two such cases and called them fibrochondromata. Again in 1925 (7) Adson reported another case calling it a cervical extradural ventral chondroma.(2)

Neurological surgeons have recognized for many years that there was a small cartilaginous extradural tumor arising from the intervertebral disc which may cause pressure on the cord or cauda equina. The conception of these lesions as posterior protrusions of the nucleus pulposus was initiated by the researches of Schmorl and Andrai in 1926.(28)

Veraguth reported, in 1928, a case similar to that of Adson, calling it a myxochondroma.(7)

Stokey, in 1928, described seven cases of

compression of the cervical portion of the spinal cord resulting from protrusion of cervical intervertebral discs.(51)

In 1929, Dandy reported two cases of "loose cartilage" which was detached from the intervertebral disc and caused pressure on the spinal cord. In each instance the spinal cord was completely blocked, as shown by iodized oil injection. The lesion was a completely detached fragment of cartilage from a lumbar intervertebral disc. He concluded that the lesion was of traumatic origin.(20)

Probably the first to use the term "rupture of the nucleus pulposus" were Alajouanine and Petit-Dutailis who reported two cases in 1930.(40)

Bucy and Bailey in 1939, and Bucy in the same year, reported the case of a "chondroma" composed of fibro-cartilage on the intervertebral disc between the third and fourth lumbar vertebrae which compressed the cauda equina. They believed the tumor to be a true new growth from the disc or, as von Pechy choose to call it, an "ecchondrosis".(6)(10)

Von Pechy (1929), Klinge (1930) and Kortzebarn (1930), familiar with Schmorl's work, have each reported a case of Schmorl's nodule (Knorpelknotchen) on the posterior aspect of a disc, causing spinal cord pressure.(7)

Three cases of fibroma or of a fibro-cartilaginous nodule arising from an intervertebral disc and causing cauda equina pressure are reported in the French literature: Two by Alajouanine and Petit-Dutaillis (1930) and one by Crouzon, Petit-Dutaillis and Christophe (1931). The etiology was considered traumatic.(7)

Galland and Clave and Galland in 1930 described two instances of paraplegia in cases with severe thoracic kyphosis which they attributed to retropulsion of the nucleus pulposus. (7)

Elsberg, in 1931, reported fifteen cases in which operation was performed. He concluded that the tumor was benign and that "chondroma" or "ecchondrosis" best described it. (7)

Mauric, in 1933, published a monograph on the intervertebral disc in which he reviewed the literature to date.(7)

In the same year (1933) Alpers, Grant and Yaskin reported a case and concluded that the lesion was neoplastic outgrowths from the annulus fibrosis rather than from the nucleus pulposus, probably in response to trauma.(4)

Peet and Echols reported, in 1934, two cases of "herniation of the nucleus pulposus". In both cases there were signs of pressure on the spinal cord which were

relieved by operation. (40)

In the same year, Mixter and Barr reported nineteen proved cases of rupture of the intervertebral disc with involvement of the spinal canal.(7) Mixter with Ayers, in 1935, reported results on 34 cases they had done up to that time and reviewed the location of all 81 cases reported in the literature to that date.(38)

With the clearer recognition of the true nature of this lesion, together with the finding that such herniations are the major cause of sciatica, case reports and studies have appeared in increasing numbers in the literature from this time. (43) Since 1936 the literature on protruded intervertebral discs has become voluminous. There have been reported a great many cases and many clinics have diagnosed the condition with much greater frequency. Today this lesion is considered one of the prominent causes of sciatica and low back pain.

Hypertrophy of the ligamentum flavum with compression of the cauda equina was first described by Elsberg in 1913. He reported a single case in which the hypertrophy followed direct injury to the fourth and fifth lumbar vertebrae. (47)

In 1916, Elsberg reported two more cases of enlargement of the ligament flava. (9)

Since Elsberg's original description of the lesion there had been but six cases recorded until 1937.

(47) Towne and Ruchert in 1932 reported two cases in which there was complete block in circulation of cerebrospinal fluid. Excision of the hypertrophied ligaments relieved the block and other symptoms.(53)

Puusepp, in 1932, reported three cases, two of which trauma might have been a factor. In 1936, Abbott reported one traumatic case with recovery after operation (9)

Spurling, Mayfield and Rogers, in 1937, reported seven cases with relief of symptoms following operation. (47)

With the increasing ability to diagnose prolapsed discs, hypertrophy of the ligamentum flavum is also found more frequently. Today this lesion is being found with increasing frequency as a cause of cord or nerve root compression either alone or in combination with prolapsed intervertebral discs.

III ANATOMY

Before discussing the adult anatomy of the intervertebral disc, a brief review of the embryologic development of the vertebrae and intervertebral discs is in order.

The primitive axial support of all vertebrates is the notochord, but in the higher animals this structure is replaced by a stiffer axial skeleton composed of jointed vertebrae. In the mammals the notochordal rod is a transient supporting structure in the embryo, but at the intervertebral discs it persists as the swollen, mucoid nucleus pulposus in the adult.

The axial skeleton is derived from the pairs of mesodermal segments. From the medial side of the segments the sclerotome migrates toward the notochord. The sclerotomes are destined to form the vertebrae and ribs. The sclerotomic mesenchyme comes to lie in paired segmental masses alongside the notochord, separated from similar masses before and behind by the intersegmental arteries. Each sclerotome differentiates into a caudal compact portion and a cranial less dense portion. The embryonic cartilaginous vertebra is not derived directly from the sclerotome, but is so formed that the caudal part of each sclerotome unites with the

cranial half of the sclerotome directly behind it to form the substance of the definitive vertebrae.

The intervertebral disc corresponds to the center of the sclerotome and holds in its center a portion of the notochord, which, in turn, forms the nucleus pulposus.

In the embryo, the inferior and superior surfaces of the vertebrae are higher at the center than at the edges, in contrast to that of the adult. (11)

As the disc develops there is a gradual change from the hyaline type of cell at the periphery to an almost complete disappearance of the cellular structure within its interior. There is gradual loss of chondromucoid substance with isolated cartilage cells in its lacunae, and in the central portion of the disc remain small clumps of cells which resemble prechondral tissue, the remaining notochord cells. (28)

The anatomy of the surfaces of the bodies of the vertebrae must be understood in order to get a picture of the intervertebral discs.

The shape of the surface of the vertebral bodies are oval in the cervical and lumbar regions and circular in the thoracic region. At the periphery the bone is compact forming a zone about three millimeters in width which is slightly higher than the central

bony tissue. In this zone the fibers of the annulus fibrosus are strongly inserted.

The central portion of the vertebral surface is a bony plate perforated by many holes. At the center there is a zone of smaller holes on which the nucleus pulposus rests and moves. The perforated plate has a cartilaginous covering which does not cover the compact peripheral zone. On its edges this thin cartilaginous plate is continued to the internal limit of the compact peripheral tissue of the annulus fibrosus.

The nutrition of the disc is from the adjacent vertebrae. The bone marrow comes to the level of the holes in the spongy central portion of the vertebra. By diffusion its vessels provide for the nutrition of the external cartilage of the vertebra and for that of the vertebral disc since the disc is devoid of capillary vessels. (11)

Each fibrocartilaginous disc is of a lenticular form and of composite structure. In shape they correspond accurately with the surfaces of the vertebral bodies between which they are placed. Their size is greatest in the lumbar region. The intervertebral discs form about one-fourth of the vertebral column, exclusive of the first and second vertebrae.(3)

In both lumbar and cervical regions, each

disc is thicker anteriorly than posteriorly, thus assisting in producing the anterior convexity which characterizes the vertebral column in these regions. In the thoracic region the reverse occurs due to the anterior concavity.

Each disc consists essentially of two parts. The circumferential portion is formed by oblique and spirally arranged fibers passing from one vertebra to the other. In section, this portion is arranged in a series of concentric lamellae and is called annulus lamellosus or fibrosus. For practical purposes this may be regarded as equivalent to the capsule of the joint. (39)

The annulus is formed by numerous fibers solidly and tightly interwoven, which are inserted deeply in continuity with Sharpey's fibers into the compact bony zone forming the outside of the vertebral surfaces. This fibrous ring has few cartilaginous cells. In the small peripheral zone, a fine fibrous netting, not so tightly woven, is found, forming a sort of matting, loosely connected to the vertebral surfaces.

The nucleus pulposus, situated at the center, is a gelatinous mass under pressure, is of a flattened bean shape, is formed of very loose fibrous tissue saturated with liquid and a few cartilaginous cells

and contains some remnants of the primitive notochord.(11)

This soft, elastic pulpy center is of peculiar functional significance. In the healthy disc it possesses considerable inherent turgor and elasticity so that it serves to distribute pressure over the vertebral body. It can most nearly be described as an elastic ball bearing changing in shape and position under functional demands and so distributing and absorbing the mechanical shocks to which the spine is continually subjected.(32)

The nucleus pulposus is yellowish colored, highly elastic fibrocartilage containing some bands of connective tissue. When the disc is divided horizontally, the nucleus rises considerably above the surrounding level. This pulpy substance, which is especially well developed in the lumbar region, according to Luschka, contains a small synovial cavity in its center. (3)

At various ages the nucleus pulposus is variable in structure, as was brought out by Beadle in England. Generally speaking, the younger the individual the higher the water content of the nucleus and the more elasticity of the nucleus pulposus.(46)

The intervertebral disc is supported anteriorly by the anterior longitudinal ligament and posteriorly by the posterior longitudinal ligament. The anterior longitudinal ligament is a wide, well defined structure

exhibiting expansions at the level of the discs. On the other hand, the posterior longitudinal ligament is a poor, ill-defined structure supporting the disc only in the mid-line and often displaying deficiencies where it is related to the disc. It is important to note that posterolaterally on either side where the disc comes in relationship with the intervertebral foramen, it is unsupported by any extrinsic ligamentous structure. In these regions the disc frequently bulges backward to occupy a considerable portion of the lower half of this foramen. (39)

The spinal cord in the lumbar region, as in all other regions, occupies the vertebral canal. It is surrounded by its protective membranes, the dura mater, a thick fibrous membrane; the arachnoid, a membrane having the tenacity of a spider web; and the pia mater, a highly vascular membrane immediately surrounding the cord.

The spinal cord has a cone-shaped termination, the conus medullaris, which ends at the level of the first lumbar vertebra. From the end of this structure the filum terminale is prolonged to the posterior surface of the coccyx. This terminal filament descends in the middle line surrounded by the roots of the lumbar and sacral nerves, to the caudal end of the dural sac at the level of the second sacral vertebra.

The nerve roots are given off from the spinal cord in pairs segmentally. However, since the cord ends at the level of the lower border of the first lumbar vertebra, the roots of the lumbar, sacral and coccygeal nerves, in order to reach their proper intervertebral foramina, descend vertically in the canal around the conus medullaris and filum terminale. In this way there is formed a large bundle which is composed of the roots of all the spinal nerves below the first lumbar and has been given the name cauda equina.

The spinal nerves leave the vertebral canal through their respective intervertebral foramen. The bony foramen is the shape of an inverted pear. Its upper boundary, formed by the pedicle and more anteriorly by the lower part of the vertebral body of the upper of the two continuous vertebrae, is deeply notched. The spinal nerve, closely applied to the medial surface of the pedicle, grooves this structure, forming the sulcus nervus spinalis.

This sulcus, in the case of the upper lumbar foramina, extends on the inferior aspect of the pedicle at the apex of the inferior vertebral notch. The fifth lumbar nerve, which has a very oblique anterior and downward inclination, is almost completely overhung by bone and lies close in to the lateral side of the body. The

spinal nerves in the lumbar region occupy only the uppermost portion of their respective intervertebral foramina, closely applied to the inferior aspect of the pedicle.(39)

The lower half of the foramen is bounded below by the shallower superior vertebral notch on the upper aspect of the pedicle below. This portion of the foramen is narrow and bounded anteriorly by the backward protrusion of the intervertebral disc and posteriorly by the forward bulging of the ligamentum flavum. With the soft tissues intact, this portion of the foramen is little more than a slit. In some instances, these structures are in actual contact.

On the medial side of the lower half of the intervertebral foramen, the apposition of the forward protrusion of the ligamentum flavum and backward bulging of the intervertebral disc create a definite sulcus. This sulcus is related to the spinal nerve. The nerve is lying at this point in the sulcus between the intervertebral disc and the ligamentum flavum on the medial aspect of the lower half of the intervertebral foramen above which gives it egress. Furthermore, the nerve is relatively fixed in this region because of its proximity to its point of emergence. The spinal theca in this region is slightly indented by the disc anteriorly and the ligamentum flavum posteriorly with the nerve occupying

the interval. These intimate relationships are of the greatest importance, for in this position the nerve is peculiarly vulnerable to encroachments by either ligamentum flavum or intervertebral disc, or both.(39)

The ligamentum flavum consists predominantly of yellow elastic tissue. It joins the adjacent laminae and articular processes. The medial half is attached to the contiguous laminae.

The thinner lateral half is less wide and tapers off as it extends laterally. It is attached mostly to the articular processes and is related to the joint capsule. The fibers of the medial part are vertical in position; those of the lateral portion run obliquely downward and laterally. (39)

The ligamentum flavum arises from the dorsal and upper margins of each lamina, pass upward beneath the lamina immediately above, and enter the neural canal. They fuse in the midline and laterally have expansions which extend toward the anterolateral aspects of the neural canal and form the posterior margin of the intervertebral foramina. Directly below each ligament lies the intervertebral disc and the very narrow space between them serves as a passage for the nerve root after it emerges from the dural canal. An increase in the size of the ligament or a posterior protrusion of the disc,

or a combination of the two, compresses the nerve root at this point. (9) The ligaments are normally one or two millimeters in thickness.(1)

IV PHYSIOLOGY OF INTERVERTEBRAL DISCS

The intervertebral disc plays an important part in the functional mechanism of the spinal column. Not only does it permit movement to occur between the series of vertebral segments; but it is related to the transmission of body weight, to the absorption and dispersal of the multitudinous shocks to which the column is constantly exposed; and to the maintenance of the spinal curves. (44)

Two forces are in equilibrium so that the vertebral column can return to its original state after forces are applied to it. The forces are equal but act in opposite directions. One force is expansive and tends to separate the vertebral bodies. This depends on the turgor of the intervertebral discs. Petter says that this force is approximately thirty pounds in the individual discs in the lumbar region.

The other force is tensile and resists the separation of the vertebral bodies. It depends upon various ligaments such as the annulus fibrosus, the anterior and posterior longitudinal ligaments, and the other ligaments between vertebrae. The elastic nature of these forces permits spinal movements. These intrinsic forces, together with the curves, give the vertebral column its extraordinary resiliency. Under

functional stress the pressure exerted upon and distributed through the lumbar vertebrae and intervertebral discs must be enormous. Besides carrying the superincumbent body weight, in lifting weights, the lumbar region carries the brunt of the pressure attendant upon use of the spinal column as a lever of the third class. By analysis of force vectors resultant upon the lower lumbar discs in lifting fifty pounds, it has been found that this pressure, under average conditions, amounts to five hundred pounds. Under other conditions, there are fleeting periods during motion in which the pressure is considerably in excess of five hundred pounds.(39)

That the disc can withstand the enormous pressures placed upon it is no doubt related to its high water content. This water content is highest in the newborn and decreases with age. The nucleus contains about eighty percent water. Daily variations in water content occur giving daily oscillations in total height of the individual. These variations amount to about one per cent of the total height, or in the male about two centimeters a day. Patients are taller in the morning and there is a gradual decrease in height during the day. These fluctuations are due to loss of turgor of the intervertebral discs.(44)

The nucleus pulposus is a gelatinous round

mass under pressure inside of the disc at the center of a compact fibrous ring and between two bony vertebrae. Its shape and position can be slightly altered during motion and it acts as a spring to keep the vertebrae apart.

Thus the nucleus is a structure under pressure transforming and modifying the force of strain in the manner of a shock absorber.

The nucleus also acts as a true ball bearing inserted between two adjacent bodies of vertebrae. The nucleus is an axis for the movements of the vertebrae giving the vertebral column unusual flexibility and mobility.(11)

V INCIDENCE AND ETIOLOGY

With the increasing interest in this condition and the voluminous amount of material written about it in the last few years, one may well believe that protruded intervertebral discs and hypertrophy of the ligamentum flavum are major causes of back and sciatic pain. While this phenomenon does account for a great many cases of sciatic and low back pain, actually, these cases form a small percentage of all back and sciatic disabilities. According to Henderson, although 188 cases of protruded intervertebral discs were operated at the Mayo Clinic during 1935, 1936, and 1937, during that three year period the orthopedic consultants were called on to see more than 10,000 patients complaining of back or sciatic pain. Of this group 188, or less than two per cent, were subjected to this operation. (27) Craig and Walsh quote similar figures on the incidence of protruded discs at the Mayo Clinic. (18)

Protruded intervertebral discs occur at any age, but more often in the third, fourth and fifth decades of life. This period is the most active period of life and suggests the etiologic factor of trauma. The average age in most series of cases is forty years. (30) (57)

Men, it would seem, are more unkind to their

backs than women, for in all series of cases in the literature males far outrank the females in numbers of cases. In Love and Walsh's series of 500 cases recently collected at the Mayo Clinic, 358 were males and 142 were females.(36)

This does not mean that the male's back is weaker than that of the so-called weaker sex. It means probably that the discrepancy is due to the etiologic factor, trauma, which has a greater chance to exert itself among men who ordinarily do most of the heavy lifting and straining and who, in industry, are more likely to be injured. (36) (31)

In a series of 40 cases reported by Bair, 87.5% occurred in males and 12.5% were in females.(7) This corresponds roughly to the incidence of "sacroiliac" and "Lumbosacral" strain with sciatica in males and females and suggest strongly that trauma is a major etiological factor. In 77.5% of cases in this series there was elicited a history of trauma which the patient felt was a causative factor.(7)

The type of trauma is extremely varied, the most common being lifting a heavy weight. Falls from a height and twisting strains are much less frequent. These facts suggest that abnormal pressure on a disc can produce a sudden rupture of the annulus fibrosus with

immediate posterior prolapse of sufficient disc tissue to produce pressure on the cauda equina.(7)

It is possible in other cases there has been in the past some unremembered trauma which produced a slight weakening or tear in the annulus fibrosus. The ordinary stresses of weight bearing were then sufficient to produce a slowly enlarging prolapse of disc tissue over a period of time.(7)

Schmorl in 1932 advanced the idea that in some cases degenerative changes in the annulus fibrosus which have been due to trauma or possibly to constitutional factors may predispose to the protrusion of the nucleus pulposus as a result of further trauma.(34)

There can be little doubt that an apparently normal disc may be ruptured in a few instances, but a great deal may be said for the view that the rupture occurs from the effects of trauma acting upon a disc already weakened by degeneration. This is indicated by the fact that the majority of cases occur in patients in the fourth and fifth decades when, as Schmorl has shown, degenerative phenomena are common.(43)

One would expect the protrusion of the disc posteriorly to occur most often because of the mechanical forces at work at the time of injury to the spine. Most injuries occur when the spine is in flexion. This

the posterior portion of the annulus fibrosus is subjected to undue stress at the same time that the vertebral interspace is being narrowed anteriorly. This results in a squeezing of the compressible nucleus pulposus backward against an overstretched and weakened ligament. Rupture may not occur the first time but, if subsequent injury occurs, extrusion of the nucleus, or most of the disc, may result.(30)

Simonds states that it seems reasonable to assume that the cause must be due to a jackknifing type of injury not sufficiently severe to crush a vertebral body, yet of great enough violence to injure the disc, with protrusion of a small portion into the spinal canal.(45)

Experimental evidence of the effects of trauma on the intervertebral disc is scanty. Ribbets was able to produce Virchow's tumor (ecchondrosis) in rabbits by puncturing the intervertebral disc.(7)

Schmorl states that Roux was able to rupture the intervertebral discs in excised spines by compressing them hydraulically. (7)

Barr put two vertebrae from the lumbar spine, between which was an intervertebral disc, in a vise and compressed them. He found that pressure beyond a certain point caused sudden rupture of the disc at its periphery

with escape of a portion of the nuclear tissue through the longitudinal ligament. When the annulus fibrosus was punctured with a needle, the rupture unvariably occurred at that point.(7)

Pease, in 1935, reported twelve instances of injury to the intervertebral disc following lumbar puncture due, presumably, to trauma which occurred when the spinal needle was introduced too far. In none of his cases was there evidence of root or spinal cord pressure.(7)

In hypertrophy of the ligamentum flavum, direct trauma to the ligament and lamina, either acute or chronic, appears to be the most likely cause. The microscopic pathological study of the specimens indicates trauma is responsible for the fibrosis of the ligaments. The supposition that trauma causes hypertrophy is strengthened further by the fact that the lesion has always occurred at the lumbar spinal joint of the greatest mobility when the ligaments are placed on increased tension with the body in flexion.(47)

VI PATHOLOGICAL CONSIDERATIONS

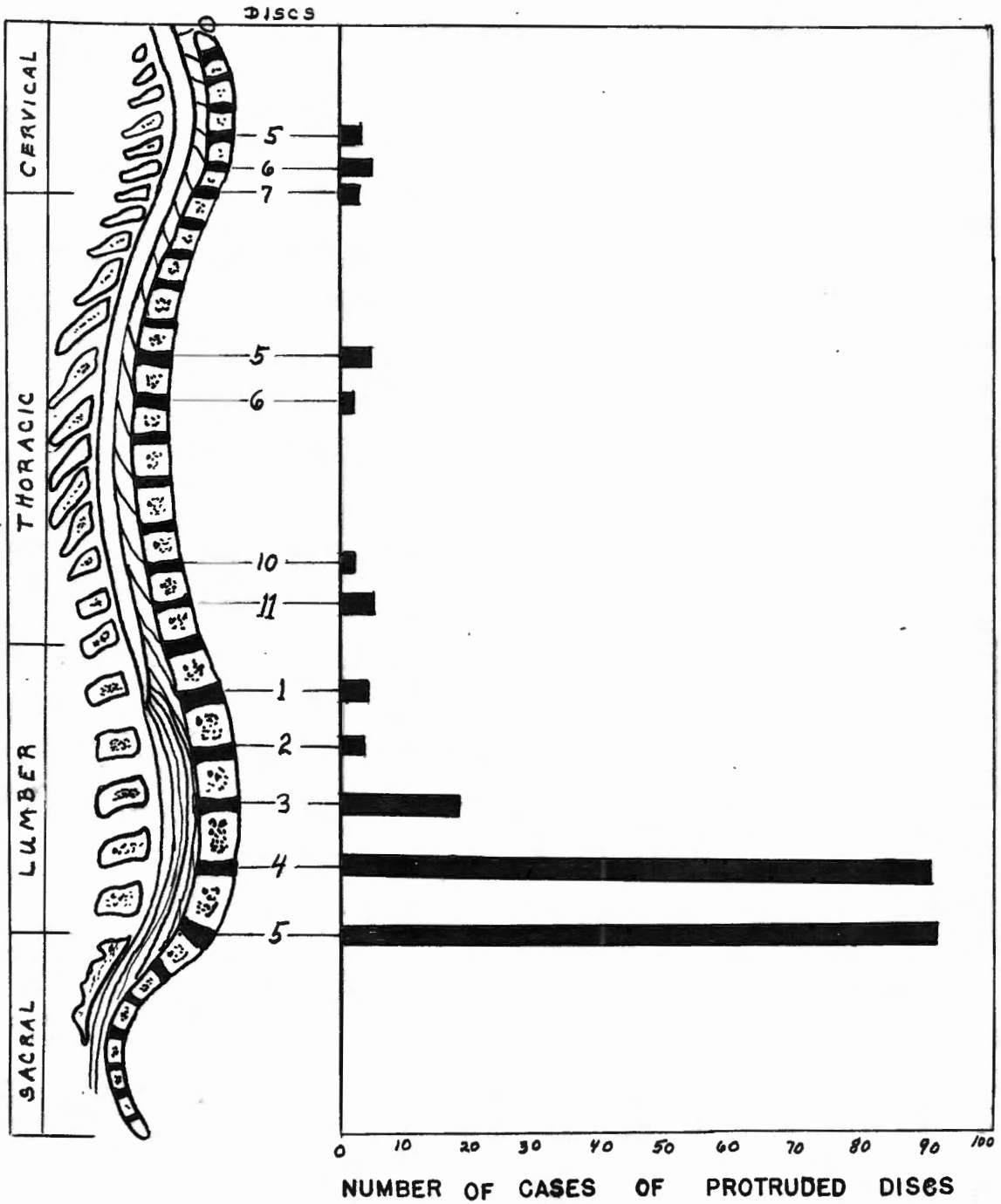
In a structure such as the intervertebral disc which is constantly under pressure, as has been shown, there are a great many pathological conditions which develop when these forces of pressure are for some reason unbalanced. When pressures are applied to the disc in excess of its ability to withstand such forces, the disc will burst with extrusion of its gelatinous nucleus. This extension may perforate the cartilaginous covering of the vertebral body and the fibro-gelatinous nucleus seeps into the spongy bone, or the annulus fibrosus bursts allowing extrusion, usually in the posterolateral position as will be shown. The commonest type of extrusion is prolapse of the nucleus pulposus into the spongiosa of the vertebral body. Schmorl, in examination of over two thousand spines at autopsy, has found this lesion in thirty-eight per cent of cases.(46) Although Schmorl believes that protrusion of the intervertebral disc into the vertebral body was of no clinical significance, Schanz suggested the possible relationship between these prolapses and back ache. This belief has been supported by several other authors.(28)

We are more interested in the less frequent but more significant clinical entity of the posterior protrusion of the disc into the spinal canal causing nerve root

compression. The posterior protrusions tend to group themselves in relation to the normal curves in the spinal column. Protrusions in the cervical and thoracic regions are found in greatest frequency at the site of the greatest curvature of that region. The majority of lumbar protrusions are of the third, fourth, and fifth discs, which are the site of the greatest lumbar convexity. This grouping of the protrusion of discs in relation to the normal curvatures of the spinal column is indirect evidence of the action of a mechanical factor in the causation of these protrusions for it is in these areas that the greatest mechanical stress occurs in lifting or in pushing.(55)

An explanation of the frequency of posterior protrusion is given by Naffziger. When the spine is flexed, the nucleus pulposus in the lumbar region migrates dorsally; tension is thrown upon the stretched annulus fibrosus. The magnitude of these forces, the dorsal migration of the nucleus, and the stresses thrown upon the posterior part of the annulus no doubt account for the greater frequency of dorsal herniations in the lower lumbar region. These are sufficient to account for herniation in a normal disc from a single trauma. In others, repeated trauma to the disc with attendant weakening of the annulus or in those with some degenerate changes in the annulus, these forces alone

LOCATION OF THE PROTRUSIONS OCCURRING IN 200 OPERATED CASES



— WALSH & LOVE 57 —

FIGURE 1

would serve as an adequate cause of herniation.(39)

The displacements of intervertebral discs may occur at any level of the spine. However, the majority will be found in the lower lumbar region, most often between the fourth and fifth lumbar vertebrae or the fifth lumbar and first sacral vertebrae. Figure 1 shows the location of posterior protrusion in 200 cases collected by Walsh and Love at the Mayo Clinic.(57)

There has been considerable disagreement among the early investigators as to exactly what the pathological process is. Schmorl and Junghaus, in 1932, described the protrusion as a "nodule", and Andre, in 1929, spoke of it as Knorpelknotenchen. He stated the belief that the pathological change was primarily prolapse of the disc secondary to a tear in the annulus fibrosus.

Alpers, Grant and Yaskin, in 1933, pointed out that in their cases the herniated mass consisted of fibrocartilage which, histologically, was very different from the nucleus pulposus. There has been some discussion as to whether the protruded mass should not be considered a neoplasm. The data in one of the cases reported by Alpers, Grant and Yaskin(4) and in another by Bucy(10) furnish histologic evidence to this effect. Elsberg took an intermediate view, suggesting that the protruded mass is not a true neoplasm, but a form of local hyperplasia of cartilage which he described as

ecchondrosis.(5)

The protruded intervertebral disc material examined has been of two types. Either the protruded material may be removed easily at operation in one piece, in fact it frequently pops out by itself, or it may not be removed easily and it will be necessary to use a rongeur to remove it in several fragments.(22)

The gross appearance is characteristic. Most of the mass is made up of a dense fibrous tissue which makes it look like wet, rolled up blotting paper, the parts which were compressed before removal tend to broaden out. Besides these elements, there are usually one or several very soft, pointed processes with a smooth shiny surface. At operation these processes are seen to extend deep into the central part of the disc.(21)

The protruded portion consists of all the parts normally found in the unprotruded disc - annulus fibrosus and nucleus pulposus - with its occasional remnants of notochord. The tissue is almost unvariably altered in the protrusion. The most common and constant change in it consists of alteration of the normal architecture.(22) A predominant finding from pathological examination of the extruded nodule is degenerating fibrocartilage.(37) Advanced degeneration

is more frequent among patients of the older age groups. Marked degeneration of cartilage cells is much more common than degeneration of the fibrils. Fibrosis may occur in the form of proliferating fibrous tissue or it may be in close relationship to remnants of the notochord. In both instances the fibrous tissue tends to replace the normal fibrocartilaginous structures of the protruded portion of the disc.(22)

Edema of the protruded part of the disc is an important and frequent finding. It is more frequent in younger persons. The edema of the protrusion may be considered as a result of the capacity of the nucleus to swell if the normal forces keeping it in place and shape are decreased.(22)

Histologically, the material is peculiar and is neither hyalin nor fibrocartilage but on extrusion it becomes very similar to fibrocartilage, thus it has a tendency to regenerate.(46) Microscopic studies reveal annulus fibrosus and parts of the nucleus pulposus in all, and the presence of notochordal cells in many.(28) The nucleus pulposus microscopically has a network arrangement of the fibers and large round islands of cartilage and occasional areas of homogeneous mass. In many cases the presence of larger or smaller groups of notochordal cells, the remnants of the notochord, may be seen.

Near these cells and mixed up closely with them are connective tissue cells and fibers. Whether the fibrocytes came from the outside or are derived from the cells of the notochord can not be determined.(21)

The nucleus pulposus consists of a loose granular reticulum with spaces filled with mucoid material with occasional poorly differentiated cells which may be remnants of notochordal cells.(7)

From an analysis of pathological studied, it is evident that the term "posterior protrusion of the intervertebral disc" is more accurate than "posterior herniation of the nucleus pulposus" and that the older concept of these lesions as representing extradural neoplasms arising from the cartilaginous elements of the disc posteriorly should not be entirely discarded. (28)

In most cases operated upon, there is definite evidence of direct pressure by the protrusion on the nerve root where they ride over the protruded mass. There is erythemia of the nerve root proximal to the herniation. The portion lying over the protruded mass and distal to it are enlarged and present inflammatory congestion is evidence of irritation by the pressure of the mass. In one case the affected nerve root was four times the size of its fellow on the opposite side.(50)

It is important to understand the pathological anatomy when the protruded mass compresses nerve roots in order to interpret symptoms properly. At the fourth lumbar disc a posterolateral herniation compresses primarily the fifth lumbar nerve just above its exit through the dural sleeve. If it extends far laterally, it compresses the fourth lumbar nerve in its foramen. If it extends medially, compressing the thecal sac from the side, in addition to the fifth lumbar nerve, it will compress the first and perhaps the second sacral nerve. At either the fourth lumbar or lumbosacral disc an occasional herniation is sufficiently large to compress a number of roots against the lamina, thereby producing more diffuse signs. A common lesion is compression of the dural sac in addition to compression of the first sacral root, with resulting involvement of the second sacral roots. It is the compression of one or more of the components of the sciatic nerve which gives rise to the severe sciatica. From involvement of either the fifth lumbar or the first sacral root alone, pain can occur along the course of the entire nerve.

One of the most interesting features of prolapsed intervertebral discs which has not adequately been explained on a pathological basis is the intermittency of symptoms in these cases. In five hundred cases

diagnosed at the Mayo Clinic, eighty-four per cent gave a history of intermittent pain with periods of relief from pain.(36)

The first explanation was on a mechanical basis, that the actual disc protrusion itself must also be intermittent. With small protrusions which mildly compress the nerve roots against the pedicle, the protrusion may disappear when the spinal column is extended or when the direction of the axis of the spinal cord is changed. This phenomenon explains why temporary relief is obtained by rest in bed or traction and also explains why protruded discs sometimes are not found at operation. (3) Macey concurs with this explanation for he believes that in some manner a change in position of the dislodged nucleus beneath the annulus fibrosus results in reduction to approximately normal anatomic position.(37) Chamberlain and Fay have demonstrated in quite a series of cases that flexion of the spine tends to "withdraw" disc material from the spinal canal while extension tends to produce or emphasize protrusion. In one of their surgical cases, on the operating table, this "withdrawal" and recurrence of the disc protrusion with flexion and extension of the spine was demonstrated by Dr.Fay.(35)

Love and Walsh offer another explanation that the intermittency of symptoms may be due to degeneration

and interruption of pain fibers as a result of compression of the nerve root by the protruded mass.(36)

Walsh suggests that a slipping away of a nerve root from its point of compression between a protruded disc and the vertebral pedicle may explain some cases of this intermittency of symptoms.(55)

Deutcher and Love have recently offered the explanation that the occurrence of edema in the protruded mass may result in exacerbation of the clinical symptoms. In studying the disc material removed at operation they found marked edema was a frequent occurrence. The edema occurred more often in young patients. They found that in patients who had recurrence of pain just before operation, edema of the excised mass was usually found. These facts lead them to the supposition that edema may be the cause of recurrent exacerbations of pain. In other cases which had a history of recurrent painful attacks for years, a relatively small protrusion was found at operation. It seemed likely that repeated attacks were the result of recurring edema of the protruded portion of the disc. Edematous swelling and its subsidence under altered conditions, such as rest in bed, seem to explain the intermittency. The marked capacity of the nucleus of the disc to swell is well known. It has been demonstrated that the disc can swell twenty

times its normal size when placed in water. The nucleus is kept at its normal size by the various forces acting on it from all sides. If these forces are decreased, the nucleus swells by absorbing fluid. When protrusion occurs, the resistance to expansion is decreased and swelling occurs. Circulatory changes resulting from the displacement of the protruded portion are given as the cause of recurrent edema.(22)

A localized arachnoiditis has been found associated with protruded discs. Barr, Hampton and Mixer report three such cases.(8) Anderson suggests that the associated inflammatory process rather than the protrusion of the disc per se may be responsible for the symptoms. He quotes a case in which marked evidence of compression of the nerve roots was found clinically but at operation only a slight protrusion was found which was not large enough to account for the marked clinical symptoms. He found a spinal fluid cell count of two hundred cells per cubic millimeter and complete arrest of iodized oil just above the level of the lesion. He concludes that the pathological process is a local circumscribed arachnoiditis resulting from mechanical irritation from the protruded disc. Anderson cites other cases in which circumscribed meningitis produced all the symptoms of tumor of the spinal cord.(5) Thus we have a fifth

explanation for the intermittency of symptoms, for exacerbations and remissions of an arachnoiditis could cause intermittent symptoms of varying severity of compression of the nerve roots.

Protrusion of intervertebral discs need not be single and several authors have reported cases of multiple protrusions. Love reports a case of protrusions of all the intervertebral discs from the tenth thoracic vertebra to the lumbosacral juncture. This case was also complicated by a subdural extramedullary meningioma at the level of the tenth thoracic vertebra. (30) Camp reported two cases of multiple disc protrusions complicated by the presence of cord tumor. One was a meningioma and in the other case a neurofibroma was found. Multiple lesions are usually found by thorough roentgenological studies with iodized oil.(12)

Hypertrophy of the ligamentum flavum is often associated with protruded intervertebral discs. Recognition of this fact has become more general in the last few years. Craig and Walsh have found in one hundred seventy-five cases of disc protrusion varying degrees of ligamentum flavum hypertrophy.(18) Increasing numbers of cases are being reported in which the lesion is hypertrophy of the ligamentum flavum with no protrusion of the disc. Spurling, Mayfield and Rogers

reported seven such cases in 1937.(47)

The location of hypertrophied ligaments is invariably found to have occurred between the fourth and fifth lumbar vertebrae or at the lumbosacral junction.(9) (28)

Hypertrophy is explained by Naffziger in this manner: When the spine is forced into hyperflexion, its integrity is no longer fully guarded by the muscles. Strain is thrown upon the ligamentum flava, notably on the interlaminar portion. Such a mechanism sufficiently explains injury to the ligament. When torn, the elastic tissue fibers retract. Healing occurs by scar formation. That such scars undergo hypertrophy is understood when we consider that the injured ligament is not kept quiet. The persistent stimulation of the healing wound results in excessive fibrous connective tissue, and hypertrophy is greatest where movement is most. Once injury and scar formation have occurred, the factor of movement is continually operating, resulting in hypertrophy of the cicatrix. These conclusions are confirmed by the appearance of every specimen examined histologically.(39)

These observations are substantially the same as those of Brown who states that as the scar tissue causes further enlargement of the ligaments, compression of the nerve root results. If enlargement of the ligament

is generalized, the construction of the dura may often be striking. Normally the ligaments in the lumbar region are from two to three millimeters in thickness but, in the more marked enlargements, they have measured as much as one centimeter.(9)

Love and Walsh report that the hypertrophied ligamentum flava, instead of being homogeneously yellow, reveal white bands running throughout.(36) Instead of the usual soft pliable ligament, a mass of dense fibrous material is found totally different from the normal elastic ligament. In these masses numerous calcareous deposits are formed. Those which were excised intact measured from ten to sixteen millimeters in thickness. The thickened ligaments were always adherent to the dura. The predural fat was absent beneath the lesion.(47) Sometimes the nerve root may be imbedded in the mass of scar tissue.(1) Steele reports a case in which the hypertrophied, partially calcified ligament protruded seven and a half millimeters into the spinal canal and had almost worn through the dura.(50)

The microscopic pathological study of the specimens have shown replacement of the normal yellow elastic tissue with white fibrous tissue in which there were calcareous deposits. Fragmentation, usually longitudinal, of the elastic tissue fibrils is seen. The

ends of these frayed fibrils often appear shriveled. Blood vessels are few and those present are small in caliber as a result of hyaline substance deposited in their walls.(36)

The important point to remember about the ligamentum flavum is that although it may be of sufficient size to compress the nerve roots, causing intractable pain, this phenomenon is rare. In operating on three hundred patients who had proved protruded discs, we have encountered only twelve cases of hypertrophy of the ligamentum flavum without an associated disc protrusion. Whenever a hypertrophied ligament is found, a diligent search should be made for protrusion of the underlying disc.(35)

VII CLINICAL FINDINGS

History

Patients who are eventually diagnosed and treated for a protruded intervertebral disc usually give a history extending over several years during which time all the usual conservative methods of treatment for lumbago, sacro-iliac strain, lumbosacral strain, sciatica, arthritis and neuritis have been tried before the correct diagnosis was made.(31) Most patients have had prolonged orthopedic treatments of one type or another. Bed rest, heat, adhesive strapping, belts, corsets, back braces have all been used many times. Some patients have had manipulations to reduce a "sacro-iliac subluxation", sometimes with resulting complete paraplegia. None of these treatments have given the patient permanent relief.(7)

In a large percentage of patients, there is a history of some sort of trauma to the back. The commonest injury has occurred during flexion of the spine in lifting a heavy weight. There may be a sudden "snap" in the back followed by pain low in the back with gradually radiation of pain over the sciatic, distribution into the thigh, leg and the foot. Seventy-three of two hundred patients operated at the Mayo Clinic could recall that injury had preceded immediately the

onset of symptoms.(57) In the absence of a definite history of trauma, the onset of acute pain in the back usually is associated with lifting in a bent forward position or with sudden torsion of the trunk. Frequently the pain at the time of injury is slight, becoming severe after several hours or days.(48)

The duration of symptoms before removal of the disc averaged four and eight-tenths years at the Mayo Clinic.(31)

In a series collected by Bair, the duration of symptoms from onset to operation varied widely. The shortest period was six weeks and the longest twenty-two years. The average duration was thirty-four months. Sixty per cent were suffering from the original disabling attack. Forty per cent had had remissions with recurrences of symptoms. The symptoms usually became more disabling with each attack.(7)

Symptoms

The symptoms of protruded intervertebral disc vary with the location of the protrusion and the extent to which the mass encroaches on the nerve roots or spinal cauda equina.

The chief symptom is root pain, which is usually unilateral. The pain may be referred to the peripheral

distribution of one spinal nerve root or it may involve more than one peripheral segment, depending on the size and the location of the protrusion. The pain is often described as "sharp", "shooting" or "like an electric shock". It is usually brought on or made worse by coughing, jarring or sneezing. It is often precipitated by putting the particular nerve involved on tension, as bending the neck or back.(31)

The pain in the thigh and leg is commonly referred to as "sciatic". It is usually described as a deep-seated burning or shooting pain, often excruciating in intensity. The painful areas in order of frequency are:

- | | |
|-----------------------------------|------|
| 1. Posterior and lateral thigh | 100% |
| 2. Posterolateral calf | 90% |
| 3. Lumbosacral region | 70% |
| 4. Gluteal and sacro-iliac region | 65% |

The pain in the lumbosacral region is perhaps best explained by the local irritation of the injured disc.(7) An explanation for the back pain is given by Spurling and Bradford. They state that each spinal nerve gives rise to a recurrent branch just distal to the posterior root ganglion which reenters the intervertebral foramen and supplies the ligamentous structures two vertebrae lower than the exit of the spinal nerve. Roofe's

recent studies indicate that there is a profuse supply of sensory nerve endings in the annulus fibrosus and the posterior longitudinal ligament. The pain low in the back is variable or intermittent and is usually intensified by bending or lifting. Additional trauma may precede the extension of the pain along the course of the sciatic nerve. At this time the back pain may be an insignificant part of the clinical picture although usually present to a considerable degree.(48) The backache is in the lower part of the back and simulates all the conditions, neurological and orthopedic, which may occur in the region of the lumbosacral joint and the sacro-iliac synchondroses.(31)

Other symptoms are: numbness, muscle weakness, cramps in calves of legs, and urinary and fecal incontinence.(7) Sometimes, though rarely, there is little or no pain, and numbness and weakness is the complaint. Paralysis of one or more of the extremities or of the vesical or anal sphincters is usually a late development. (31) The clinical picture may vary considerably depending upon the amount of disc herniation and the location of the protruded material. Sometimes enough is protruded to compress the entire content of the dural canal, causing complete paralysis below the level of the lesion.(39)

The most characteristic feature of the syndrome is the remarkable intermittency of the symptoms. Love and Walsh found in 180 out of 200 cases this phenomenon. During the interval between attacks the patient may feel well, although frequently some residual aches in the back, paresthesia or muscular weakness may remain.(57) Periodic recurrences of symptoms may occur for many years. One patient of Walsh had had yearly attacks of sciatic pain for thirty-two years prior to operation.(54)

Physical Signs

Patients with herniated discs at the fourth or fifth lumbar disc exhibit much the same appearance of the lumbar spine as patients with other severe articular disease of this region. This part of the spine is usually straight, with spasm of the erector spinal muscles, especially on bending forward. The ilium is usually higher on the affected side. Limitation of flexion of the lumbar spine is marked in all patients in whom pain is conspicuous.(48) The position in which the lumbar spine is held varies. In some cases the list is away from the site of the lesion (contralateral), but in others the list is toward it (homolateral). In some cases there is a lumbar kyphos which can not be altered by active or passive attempts to hyper-extend the spine.

In most cases there is markedly restricted back motions. Tenderness to pressure is present in the midline at the level of the lesion in some cases over the posterior sacro-iliac ligaments and at the sacro-sciatic notch.

(7) A limping gait is often noted due to muscle spasm and, in some cases, to actual muscle weakness.(57) The patient will walk with a limp favoring the extension of the affected thigh. There may be flattening of the buttock due to some relaxation of the gluteus muscles and a lowering of the gluteal fold of the affected side.
(46)

Neurological Signs

In diagnosing cases of intervertebral disc protrusion, neurologists are relying more and more on the neurological findings. A few years ago, when neurological examination was not done as thoroughly or as accurately as it is today, little faith was placed in the neurological findings in locating the lesion. Today, neurologists rely on neurologic signs to the extent that patients are operated without having had intraspinal injections of iodized oil to confirm the diagnosis. Spurling and Bradford state, "That the neurologic signs are accurate and reliable is attested by the fact that during the past three months, we have successfully removed nine consecutive herniations of

the nucleus pulposus without confirmation with iodized oil or other contrast media. The present high incidence of positive results of exploration, in contrast to our earlier results, we owe chiefly to the increased understanding of the neurologic picture".(48)

The three neurologic signs most helpful in diagnosis of protruded lumbar disc, according to Love and Walsh, after a study of five hundred cases, were: Lasegue sign, positive in 84%; Sciatic tenderness, found in 64%; and diminished or absent Achilles tendon reflex, in 60%. (36) Lasegue has pointed out that patients with severe sciatic pain keep the knee flexed to prevent direct tension on the sciatic nerve. Lasegue's sign consists of raising the leg with the knee flexed to right angles with the trunk. The leg is then extended until pain begins along the course of the sciatic nerve. Without further movement of the leg, the foot is passively dorsiflexed to determine whether this additional pull on the sciatic nerve exaggerates the pain. The results are positive in all cases of lateral herniation of the disc.(48)

In a moderate percentage of patients, sustained pressure over both internal jugular veins reproduced or exaggerated the sciatic pain. This, a positive Naffziger reaction, is pathognomonic of intraspinal

disease. Tests of motor power are usually not of much aid. Patients confuse pain on using the affected part with weakness, and testing is unsatisfactory because of the pain on exertion of motor power. Fibrillation of muscles of the leg is seen in some cases. More important is the diminution or absence of the ankle jerk which usually occurs with herniation at the lumbosacral disc. (48)

The sensory changes are most important in making the diagnosis. Whether the prolapse is at the fourth lumbar or lumbosacral disc, the lateral aspect of the leg will be hypesthetic in most cases. However, herniation at the fourth lumbar disc (involvement of the fifth lumbar and first sacral nerves) usually results in hypesthesia of the anterolateral aspect of the leg with inclusion of the great toe, while herniation at the lumbosacral disc (involvement of the first and second sacral nerves) gives hypesthesia of the posterolateral aspect of the leg with inclusion of the lateral aspect of the foot. Sensory changes may also extend to the posterior aspect of the thigh and the saddle region on one side, but, as a rule, no diminution is observed above the knee. Although the areas of hypesthesia can usually be determined with pin prick; testing with cotton wool or hot and cold test tubes frequently reveals a definite

area of hypesthesia where results of pin prick are equivocal. Stimulation of the hypesthetic zone may produce typical causalgic pain, limited to the area involved. The causalgia may overshadow the hypesthesia.
(48)

Patients with prolapse of the nucleus pulposus at the fourth lumbar and the lumbosacral disc have in common pain low in the back, severe sciatic pain, and hypesthesia or anesthesia below the knee. If the ankle jerk is unchanged and paresthesia or hypesthesia in the leg is more anterior, including the great toe, the fourth lumbar disc is more likely involved. If the ankle jerk is diminished or absent and the hypesthesia is more posterolateral, including the lateral aspect of the foot, the prolapse is probably at the lumbosacral disc. Although pain does occur in the dermatomes of the involved spinal nerves, it is more often lacking. Paresthesias are far more frequent and important in accurate clinical localization, especially when coupled with objective sensory signs. Only in exceptional instances is paresthesia or hypesthesia of the gluteal portions of the dermatomes of the fifth lumbar and first and second sacral nerves observed.(48)

Hampton and Robinson have demonstrated that, if rupture of the fourth lumbar disc occurs, the root

of the fifth lumbar is always involved, whereas if the rupture is at the lumbosacral disc, the root of the first sacral is the first nerve pressed upon. The effects of pressure on only one of the roots which go to make up the lumbosacral plexus is thus demonstrated. (26) In no instance of pressure on one root is there any objective sensory changes present. This serves to corroborate Foerster's observation that section of a single nerve root produces little or no sensory change because of the marked over lap in the sensory supply of the skin.(7)

There are no physical or neurological signs which are found alone in cases of protrusion of the intervertebral disc. All the known signs may also be found in other conditions.(31)

A summary of the clinical symptoms and signs has been prepared by Walsh and Love (34) at the Mayo Clinic in a study of 185 cases, as follows:

| | |
|--|-----|
| Unilateral sciatic pain | 70% |
| Bilateral sciatic pain | 16% |
| Accentuation of pain on coughing, sneezing, etc. | 48% |
| Night pain | 27% |
| Paresthesias | 50% |
| Sphincter incontinence | 5% |
| Positive Lasegue Sign | 78% |

| | |
|---------------------------------------|-----|
| Sciatic tenderness | 57% |
| Achilles reflex diminished or absent | 59% |
| Hamstring reflex diminished or absent | 21% |
| Muscular paresis | 21% |
| Sensory loss | 23% |

A later summary by these men of 500 cases showed substantially the same proportions.(36)

The history and symptoms of patients with enlarged ligamentum flavum are essentially the same as those of protruded intervertebral disc and clinical differentiation between these two conditions is extremely difficult or impossible. The most common objective findings are: Some degree of scoliosis with list to the unaffected side; restriction of movements of the back; limitation of straight leg raising on the involved side; local tenderness over the lumbar spine; some motor weakness; sensory disturbance of varying degree over the buttocks, posterior aspect of the thigh, calf and foot. The most common single finding is decrease in Achilles tendon reflex on the side of the lesion. A history of trauma, usually of relatively slight degree, is common. The most frequent history is of injury while lifting in association with flexion and torsion of the spine. The patient usually describes a snapping sensation in the spine followed by pain low in the back and, later, gradual radiation of the pain over the sciatic

distribution. In a small percentage, the sphincters may be affected. The symptoms are usually unilateral. Weight bearing usually aggravates the symptoms and rest in recumbency may afford some degree of relief.(9)

Since the treatment of both prolapsed disc and hypertrophy of the ligamentum flavum are the same, the difficulty in distinguishing them clinically is of no consequence.

VIII LABORATORY FINDINGS

In the course of the examination of cases suspected of being protruded intervertebral discs, an examination of the spinal fluid is routinely done. The routine tests are made of the fluid, but the only chemical determination of value in cases of protruded disc is estimation of the concentration of total protein in the spinal fluid. In the occasional cases where there is a localized arachnoiditis caused by the compressing lesion, there will be more or less increase in the leukocyte count of the spinal fluid.(5) (8) The cell count is also valuable in establishing the presence of a meningitis, in which case iodized oil injection is contra-indicated.(26)

Most writers have found that in the majority of cases of protruded discs, the total protein is in excess of forty milligrams per one hundred cubic centimeters of fluid. The usual proportion of increased total protein is shown in the series of two hundred cases reported by Walsh and Love,(57) In this series the total protein was forty milligrams or more in sixty-six per cent of cases, and less than forty milligrams in thirty-four per cent. Most neurologists feel that an increased protein content is of significance in diagnosis,

but that normal values of protein does not mean that no lesion is present.(18) The elevation of the spinal fluid protein is usually indicative of a course of irritation within the spinal canal, but it does not indicate the nature of the lesion or its level. However, since most lesions are at the level of the fourth and fifth lumbar vertebrae, and spinal puncture is usually done some distance above these lesions, normal values may be found because the total protein decreases rapidly with the distance above the lesion. Punctures should therefore be done as low as possible.(26) (23) When spinal puncture is done at the level of the lesion or below it, unusually high values are obtained. Love reports a case where the total protein was 1200 mgms.(35) Mixter and Ayers obtained fluid below the lesion in which the total protein was 1800 mgms.(38)

Since the lesions in the lumbar discs are below the level of the usual spinal puncture, the Queckenstedt test for block of spinal fluid is usually negative. At the Mayo Clinic they have developed a test for lumbar lesions which they have labelled the "Reverse Queckenstedt" test. It has proved valuable in their hands in diagnosing the presence of a mass encroaching on the domain of one or more caudal roots. The test is performed as is epidural injection which is used in the

treatment of sciatic pain. A caudal needle is placed in the sacral hiatus. A needle is placed in the lumbar sub-arachnoid space and a manometer is attached. Ten cubic centimeter fractions of a one per cent solution of procaine hydrochloride are injected into the caudal epidural space. Normally there should be a progressive rise in the manometric readings as the caudal sac is compressed by the extradural procaine. Four fractions of ten cubic centimeters each or a total of forty cubic centimeters of procaine are injected extradurally. If a tumor or a protruded disc of sufficient size to obstruct the caudal sac is present, no rise in the manometric reading will occur. A "block" on reversed Queckenstedt will have been established. In cases of compression of caudal roots by a tumor or a disc, the pain is unbearable and the epidural injection will have to be discontinued. The pain will follow the distribution of the compressed nerve root.(30) (31)

IX ROENTGENOLOGICAL FINDINGS

The use of Roentgenographic studies after the intraspinal injection of a contrast medium has been a valuable means of confirming the presence and location of a protruded intervertebral disc or hypertrophy of the ligamentum flavum. Plain flat films taken of the lumbar spine, in the opinion of most writers, are of little value in the diagnosis of protruded discs. The findings in ordinary roentgenograms are only suggestive of a prolapsed nucleus. About all that is seen is narrowing of the intervertebral joint space at the site of the lesion and some proliferative changes of the bony margins. Since these changes are seen in so many lesions of the vertebral column, the finding of such pathology is of little significance. (13) (31)

For this reason, roentgenologists have used some contrast agent injected into the subarachnoid space for the indirect visualization of the protrusion. Several contrast agents have been employed. The most commonly used substances are iodized poppy-seed oil, air or oxygen, skiodan, and colloidal thorium dioxide. Each of these substances has certain advantages and disadvantages. (14)

To date iodized oil has been used more than

any other contrast agent for the roentgenologic visualization of the spinal subarachnoid space and, when employed under proper circumstances, it has resulted in an accuracy of diagnosis that is shared by few other roentgenologic procedures.

The chief objection to the use of iodized oil is that it is more or less of an irritant to the meninges and is contraindicated in the presence of inflammatory disease.(14) Lipiodal injected into the spinal fluid space often produces a definite reaction usually lasting several days, which is characterized by elevation of the spinal fluid cell count, change in color and chemical composition of the fluid, headache, increase in the pain of which the patient complains, and slight fever.(26)

Another reason for objection to the use of iodized oil is that it is very slowly eliminated and in the event that laminectomy is not done with the removal of the oil at that time, it will remain in the spinal subarachnoid space for years. Walsh and Love believe that it will take from seven to ten years for most of the iodized oil to be eliminated from the subarachnoid space.(56)

For these reasons most writers condemn the

indiscriminate use of iodized oil in cases of low back or sciatic pain. The use of lipiodal should be restricted to cases in which the characteristic symptoms and signs exist to allow a presumptive diagnosis to be made, but in which verification and accurate location of the lesion is desired.(56) Careful selection of cases from the clinical standpoint will permit a high percentage of positive findings on roentgenological examination after administration of the contrast medium.(57)

If radiopaque oil is used to localize the lesion, some men feel that roentgenologic examination should be carried out on the day of operation so that it may be immediately removed when the dura is opened in the course of the operation.(35)

The iodized oil must be introduced in adequate amounts, since the majority of protrusions produce no obstruction and occur in the region where the spinal canal is relatively large so that it is useless to attempt to visualize them with one or two cubic centimeters of lipiodal. The generally accepted amount of oil necessary is now five cubic centimeters.(31)

Following the injection of the radiopaque oil, the patient is placed on a tilting roentgenologic table in the prone position and, under the fluoroscope, the

movements of the lipiodal in the spinal canal is followed. By tilting the patient, the oil is made to flow up and down the canal. If there is an irregular protrusion into the canal, the column of fluid will bend around it or hesitate in passing it.(39) If a persistent defect is observed, films should be made as quickly as possible without disturbing the position of the patient. The modern "spot-film" device is ideal for this work. Fluoroscopic examination should include observations in the prone-oblique and lateral positions in order to accurately determine the anterolateral position of a mass that indents the column of oil. After excursions of the oil have been studied in these positions, the examination is repeated with the patient in the supine position so that the posterior wall of the canal may be explored.(31) (26) The upper thoracic and cervical area is not usually examined since there is danger of the iodized oil entering the skull.(8)

The deformity of the iodized oil shadow resulting from a protruded intervertebral disc is influenced by the following factors: (1) the position of the protrusion, (2) size of the protrusion, (3) associated hypertrophy of the ligamentum flavum, (4) changes in the nerve roots (displacement, edema, non-filling of affected nerve root sleeve) and (5) anatomic variations of the cul-de-sac.(14)

Since the majority of protruded discs present on one side of the median line, the classic defect is a sharply defined unilateral rounded indentation of the iodized oil shadow opposite an intervertebral disc. It occurs in about sixty-five per cent of cases. Midline protrusions, when of moderate size, may produce only a central defect. In the lateral position, the defect of a central protrusion will be quite obvious and the shadow of the iodized oil that passes over the peak of the protrusion will be clearly defined. Partial obstruction to the movement of oil is common in large central lesions.(14)

The extent of the iodized oil defect is influenced by the size of the protrusion. Any deformity to be of diagnostic significance must be persistent. The larger the protrusion, the greater the tendency to produce a bilateral deformity, which occurs in about thirty-five per cent of cases.(14)

Because of the anatomic location of the ligamentum flavum, this structure, when it hypertrophies, will compress the column of oil posteriorly and laterally, when it occurs without protrusion of a disc, the defect is characterized in the lateral view by a broad or rounded indentation on the posterior aspect of the column of iodized oil. Because of the size and extent

of the normal ligamentum flavum, the deformity in the lipiodal that results when it hypertrophies will extend over a larger area than that occupied by the contiguous intervertebral space and the area occupied by a protruded disc.

In addition to the outline of the defect produced by the mass of the protruded disc, significant changes in the shadows of the nerve roots may be present at the level of the lesion. These consist of edema of one or more nerve roots, which may be recognized by a broadening of the negative shadow of the nerve root if it is outlined and by displacement or deformity of the shadows of the nerve roots within the subarachnoid space. Nerve root sheaths fill so inconsistently that lack of filling on one side cannot be depended on as a reliable sign of protruded disc.(13) (31)

Anomalies of the terminal portion of the cul-de-sac which occur in about five per cent of cases, may complicate the roentgenologic diagnosis of a protruded disc.(14)

That the use of radiopaque oil is an accurate means of diagnosing the protruded disc lesions is shown by the figures of Camp who reports that in a series of 203 cases in which laminectomy was performed and in which roentgenologic diagnosis of a protrusion had been

made, the diagnosis was confirmed in 194 instances by the surgeon.(14)

The surgeon sometimes has difficulty at the operating table in associating the pathological picture found with the roentgenologic shadows. This is explained by the fact that the fifth lumbar root and most of the first sacral root are extradural at the lumbosacral juncture so that a lesion compressing either of these roots may produce a minimal defect in the contiguous subarachnoid space.(26)(31)

In recent years, the irritating effects of iodized oil to the meninges has led to the use of air or oxygen as a contrast medium in the spinal canal for the visualization of a protruded disc. The advantages of this method are that the procedure is harmless, since the air is quickly absorbed leaving no dangerous sequelae such as might develop if the contrast media were an unabsorbable substance; stereoscopic visualization of the dural sac is possible; and the air does not adhere to the caudal filaments as the oils often do, thus confusing the normal with the pathologic.(17) (58)

The technique of injection varies somewhat but in general the air is injected through a needle in the subarachnoid space at the second lumbar interspace.

The patient is placed in a lateral decubitus position with the head of the table lowered to an angle of about twenty-five degrees. Spinal fluid and air are exchanged in five cubic centimeter quantities until air escapes from the needle. Usually it takes about forty to fifty cubic centimeters to fill the lumbosacral sac. Following the injection of air stereoscopic anterior, posterior and lateral films are made. The evidence of narrowing of the lumbar canal or the protrusion of an intervertebral disc is not so convincing as in roentgenograms taken after injection of radiopaque oil.

(18) (52) (41)

There has been considerable discussion of the advantages and disadvantages of the use of air myelography as compared with iodized oil. The present day opinion in this regard was stated recently by Hampton. He says, "Air myelography is rapidly coming into use in the diagnosis of protrusion of the intervertebral disc. The accuracy of this type of examination varies considerably in the hands of different workers. Improvements will undoubtedly be made in the technique of this examination, and in the accuracy of the roentgenologic interpretation, but at present it is doubtful that a positive diagnosis of rupture of the intervertebral disc can be made in over fifty per cent of

cases. Even if this error in air myelography persists, the procedure should be used, as a preliminary, before injection of iodized oil, because in that way it will probably be possible to eliminate the use of iodized oil and its questionable ill effects in half of the patients. Air myelography is of distinct value when the findings are unequivocally positive, but of little value when the findings are equivocal or negative."(25)

X DIAGNOSIS AND DIFFERENTIAL DIAGNOSIS

At the present state of our knowledge of the clinical picture and laboratory findings in protruded intervertebral disc, a rather definite diagnosis of this condition can be made. In establishing a diagnosis, the following symptoms, signs and laboratory findings should be kept in mind:

1. There is usually a history of trauma to the back. The most frequent story is that of feeling a "snap" in the back while lifting a heavy weight with the spine flexed or falling on the buttocks followed by persistent low back pain.

2. Persistent or recurrent pain low in the back unrelieved by the common conservative measures.

3. Persistent or recurrent pain radiating down the back of the leg, going as far as the knee or traveling into the foot over the distribution of the sciatic nerve. This pain has been given the name "Sciatica" or "Sciatic pain".

4. Varying degrees of hypesthesia or paresthesia in the dermatomes of the fifth lumbar and first and second sacral nerves.

5. Diminished or absent Achilles tendon reflex on the side of the sciatic pain.

6. Increased concentration of the total protein in the cerebrospinal fluid obtained by lumbar spinal puncture.

7. Positive findings in the Reversed Queckenstedt test.

8. Diagnosis is established by and protrusion of the intervertebral disc is identified by roentgenographic studies after injection of some contrast medium into the subarachnoid space. Air or oxygen will demonstrate about fifty per cent of lesions. Iodized oil gives more conclusive results, but is irritating to the meninges.

In the differential diagnosis of protruded intervertebral disc, there are many conditions to differentiate. Chief among these is intraspinal neoplasm. In this condition the symptoms are not intermittent, which is so characteristic of disc protrusions. The treatment for a neoplasm is the same as for protruded disc so differentiation is not so important.

The conditions which most closely resemble protruded disc are: low back pain, lumbosacral strain, sacro-iliac disease, spondylitis and hypertrophic changes in the spine. In some cases the clinical picture may be

that of syringo-myelia or multiple sclerosis. Sciatic neuritis and fibrositis may be confused. Carcinoma of the rectum or vertebrae and vertebral fractures must be ruled out by roentgenologic studies in the diagnosis of protruded intervertebral disc.(46) (57) (42) (31)

XI TREATMENT

When the presence of a protruded intervertebral disc has been diagnosed, the amount of discomfort and disability will determine the method of treatment. If the patient's symptoms are mild and do not interfere to any great extent with his usual activities, some one of the more common therapeutic measures may be employed. Rest in bed, traction, analgesics, and other conservative methods may be tried. However, in most cases in which there are enough symptoms and signs to make a diagnosis the pain and disability are usually sufficient to demand operative treatment. The surgical treatment consists of the removal of the protruded portion of the involved disc through a laminectomy wound. The laminectomy should be as short as possible, yet adequate to permit a satisfactory exposure of the protruded disc.(35)

The anesthetic used varies in the different clinics. At the Mayo Clinic, ether by the open drop method is used after the patient is under with nitrous oxide and oxygen mixture.(31) Spurling does the laminectomy under local infiltration with procaine Hydrochloride.(47)

The extent of the laminectomy depends upon the location of the protruded disc, the degree to which the

lesion has been localized by diagnostic procedures, and the skill of the surgeon.(19)(15) With proper localization of the lesion before operation, extensive laminectomy need not be done. In some instances unilateral laminectomy may be adequate.(39) At the Mayo Clinic the amount of bone removed has gradually decreased as skill in diagnosis and operative technique have improved with experience. When they began operating for this lesion a comparatively extensive operation was done. Two and often three pairs of laminae were resected. As experience increased, less bone was sacrificed. The technique was modified so that hemilaminectomy was done. Later, a partial laminectomy technique was used in which no neural arch was interrupted. Recently the neurosurgeons there have removed a protruded intervertebral disc protrusion without removal of any bone.(36)

In most instances removal of a portion or all of the fourth and fifth lumbar laminae is necessary to permit adequate exposure. After removal of the laminae, the ligamentum flavum will be seen as yellow bands crossing the dura. If there is a protruded disc, its presence will usually be signaled by a marked thickening of the ligamentum flavum at that particular interspace.(35) When the ligaments are pathological, they will not only be thickened, but will show evident

fibrosis with no clear line of cleavage between them and the dura, and will need to be dissected free. Under the thickened ligaments, the dura is frequently greatly thickened.(39)

Having resected the ligamentum flavum, both sides of the dural canal are carefully palpated. A small nodule may be felt, which feels like and has the consistency of a hard rubber cork.(46) If the lesion lies laterally and can be felt without opening the dura, it may be possible to remove it extradurally. Lateral traction is made on the ligamentum flavum, and the cord, with the dura intact, is gently displaced to the opposite side. Great care is necessary in this maneuver for there is a rich plexus of blood vessels around the dura which are easily torn and bleed freely. When the lesion is visualized, its relationship to the affected nerve may be seen. In some, the nerve may be pushed medially, in others, it is pushed laterally.(46) At times the fibrocartilage will be lying free and only need be lifted out with forceps. At other times it will have a fibrous covering which will need to be incised and the material removed.

It is usually necessary to open the dura to see the position and size of the lesion accurately. Before opening the dura, the head of the patient is

raised so that the lipiodal gravitates to the sacral cul-de-sac. After the dura is opened, the lipiodal is removed by suction.(7) When the dura is opened the filaments of the cauda equina are freed from their arachnoidal covering and the interior of the canal is inspected. From its inner surface each root is observed and only then may a small nodular protrusion be evident. It will be seen compressing a nerve root as it emerges from the dural canal, and ordinarily the root involved will be injected and edematous. In the instances in which the mass is recognized only after the dura is opened, it is removed by a transdural approach. A short incision over the mass will permit the material to be picked out readily.(39) It can usually be removed in toto without sharp dissection. Sometimes it is necessary to sever its attachments to the intervertebral disc. If a probe is stuck into the spot where it is removed, it can usually be pushed down a hole into the depths of the disc. After removal of all the prolapsed material, the defect in the anterior dura is closed. The posterior dural incision is sutured and the operative incision closed in the usual fashion.(7)

When thickening and alteration of the ligamentum flavum are found, the ligament is completely dissected

out and is cut close to its attachments to the intervertebral foramen.(39)

There has been some disagreement over the necessity of a bone graft to strengthen the spine following laminectomy. Barr believes that the exploration weakens the spine. Therefore, he follows the laminectomy by a bone graft if the patient does heavy work.(8) At the Mayo Clinic, fusion and bone graft is rarely done. In five hundred cases fusion was done only in fifteen cases. They believe cases should be individualized in this regard. When patients have a well developed spondylolisthesis or lumbosacral arthritis in addition to protruded discs, fusion should be done.(36) However, they point out that a bone graft operation requires six weeks in bed, while without it the patient is bedfast but two weeks.(33)

Following operation drainage is usually necessary for twenty-four to forty-eight hours. A Penrose cigaret drain, left in just above the level of the dura, is used. Patients are kept in bed twelve to fourteen days. They rest on soft pillows so arranged as to keep the spine straight. Skin sutures are removed on the tenth postoperative day. Catheterization is done every eight hours if the patient is unable to void. Patients sit up on the twelfth day and usually leave the hospital

on the fourteenth day. They are advised to refrain from heavy lifting for three months, after which time they may gradually return to former activities. No braces or special supports are advised.(31)

Results of operation for removal of protruded intervertebral disc are in most cases very good. By far the majority of patients are completely relieved of their pain and disability. Usually the relief from pain is noticed at once following operation. Since most cases have been treated in the last five years, the permanent results are still undetermined. However, the results obtained by Love and Camp in their first fifty patients operated up to 1937 is typical of those of most clinics. In this series of fifty, there were no post-operative deaths. Thirty-three patients have been completely relieved of their symptoms, fifteen were benefitted but not completely cured, and two received no benefit from the operation.(31) In most cases the longer the symptoms have been present, the less the relief obtained by operation because of more severe damage to the nervous system. (31) In a study of fifty cases made by Barr, Hampton and Mixter which were operated up to 1937, the figures are almost identical with those of Love and Walsh.(8) However, Keegan states that the results of most neurosurgeons are not as good as one would think by reading

the literature. Actually there are about fifteen per cent of cases in which no relief is obtained by operation.(29)

Recurrence of symptoms following operation are extremely rare. In more than five hundred cases operated at the Mayo Clinic, there have been but five recurrences. (36) If recurrence happens, it is usually due to further protrusion at the site of the original protrusion. The explanation for recurrence is offered by Love who says that in these cases the disc was probably broken into many fragments only one of which had been protruded at the time of the first operation. When the swelling of the enlarged nerve root and other soft tissues subsided following release of pressure, another fragment was allowed to escape from the disc, reproducing the symptoms.(33)

XII REPORT OF CASES

In a series of twenty cases operated by Dr. J. J. Keegan, the findings are in accord with those of other neurosurgeons in the country. As will be seen by the summary below, the average age of patients is forty years. The duration of symptoms averaged three years and two months, the longest being seventeen years and the shortest two weeks. Twelve gave a history of definite strain to the back and nine had remittency of symptoms with remissions. The ankle jerk was absent or diminished in one half of the cases and hypesthesia occurred in thirteen cases.

In all but one case the diagnosis was confirmed by roentgenographic studies using intraspinal injection of lipiodal. In one case air was used as a contrast agent.

Laminectomy was performed in all cases with a high per cent of recovery and relief of symptoms. There was one recurrence of symptoms. When the patient was subjected to another operation, another fragment of the same disc was found to have protruded following the initial laminectomy.

In two cases the symptoms were found to be due to hypertrophy of the ligamentum flavum alone, and in two cases hypertrophy of the ligament complicated disc protrusion. The other fifteen cases were true prolapsed intervertebral discs.

Summary of Twenty Cases Operated by Dr. J. J. Keegan
for Posterior Protruded Intervertebral Disc and
Hypertrophy of the Ligamentum Flavum

| | <u>No.</u> <u>Cases</u> | <u>Per</u> <u>Cent</u> |
|--|----------------------------|---------------------------|
| Total Cases Operated | 20 | |
| Males | 9 | 45% |
| Females | 11 | 55% |
| Average Age | 40 Years | |
| Youngest Patient | 25 Years | |
| Oldest Patient | 51 Years | |
| Patients employed at heavy labor | 6 | 30% |
| Duration of Symptoms - Av. 3 yrs. 2 mos. | | |
| History of Back Strain | 12 | 60% |
| History of Remittency of Symptoms | 9 | 45% |
| Absent or diminished Ankle Jerk | 10 | 50% |
| Areas of hypesthesia | 13 | 65% |
| Motor paresis | 6 | 30% |
| Sphincter loss | 2 | 10% |
| Fluid block | 4 | 20% |
| Total Protein below 40 mgm. per 100 cc. | 19 | 95% |
| Lipiodal used to confirm diagnosis | 19 | 95% |
| Air myelography used in diagnosis | 1 | 5% |
| Hemilaminectomy at Operation | 11 | 55% |
| Complete laminectomy at Operation | 9 | 45% |
| Postoperative Diagnosis | | |
| Hypertrophy Ligamentum Flavum | 2 | 10% |
| Combined H.L.F. and pro-I.V.D. | 2 | 10% |
| Protruded Intervertebral Disc | 15 | 75% |
| Spinal Fusion at Operation | 1 | 5% |
| Cures | | |
| 100% Cured of Symptoms | 12 | 60% |
| 90-100% " " " | 5 | 25% |
| 80-90% " " " | 3 | 15% |
| Recurrence of Symptoms following Operation | 1 | 5% |

XIII SUMMARY AND CONCLUSIONS

Summary

1. Posterior protrusion of the lumbar intervertebral disc causing compression of the component nerve roots of the sciatic nerve provides us with a real anatomic and pathologic explanation for the disability experienced by many patients.

2. By far the most common location for protrusion of the intervertebral disc is in the lumbar region due to the peculiar anatomy and physiology of this region of the vertebral column.

3. Hypertrophy of the ligamentum flavum frequently accompanies protrusion of the disc or it may occur without disc herniation producing the same symptoms of nerve root compression.

4. Intermittency of symptoms is characteristic of this condition. This phenomenon has not been definitely explained but is thought to be due to recurrent edema of the protruded portion of the intervertebral disc, to periodic "withdrawal" of the fragment back into the intervertebral disc, to release of pressure on the compressed nerve, or to a recurrent arachnoiditis.

5. The etiology of disc herniation is trauma to the intervertebral discs which may be accompanied by degenerative changes in the supporting structures.

6. The lesion occurs most commonly in men during the period of life when physical activities are the greatest.

7. The chief symptom of protruded discs impinging on the sciatic nerve roots is recurrent low back pain or unilateral sciatic pain radiating along the distribution of the sciatic nerve.

8. The most common sign is diminution or absence of the ankle jerk on the affected side, with varying degrees of paresthesia or hypesthesia in the dermatomes of the lower lumbar and upper sacral nerve roots.

9. The most useful laboratory finding is elevation of the total protein in the cerebrospinal fluid obtained by lumbar puncture.

10. Diagnosis can accurately be confirmed by use of roentgenographic studies after the injection of iodized oil. The chief objection to the use of oil is its irritation to the meninges and its slow elimination from the dural sac. Recently, air and oxygen have been used as contrast agents

but the accuracy of this method does not approach that of methods using iodized oil. However, air or oxygen is not irritating and is quickly eliminated from the dural sac.

11. The treatment of protruded discs and hypertrophy of the ligamentum flavum consists of laminectomy with the removal of enlarged ligaments and the protruded portion of the intervertebral disc.

12. The results from operative removal of the disc protrusion have, in the large proportion of cases, been excellent with complete recovery and relief of symptoms. However, about fifteen per cent of patients are not relieved by surgical procedures.

Conclusions

Protrusion of the intervertebral disc has been correctly diagnosed and successfully treated by laminectomy for a comparatively short time. It has been enthusiastically hailed as a great advance in the understanding of and alleviation of sciatica and low back pain. We are now in the period of ascendancy of its popularity. Where its proper place as a cause and treatment of nerve root pain is remains to be

seen. We do know that less than two per cent of sciatic pain is now thought to be due to protruded discs, thus there are a great many cases of sciatic pain which are not due to this lesion.

There has been a shift in the approach to diagnosis of this condition recently. Formerly, most cases were diagnosed by the use of roentgenographic studies following the injection of radiopaque oil into the subarachnoid space. The tendency lately has been to avoid this procedure when ever possible because of the irritating effect of the iodized oil on the meninges and its slow elimination. Air and oxygen are being used more and more as the improvement in technique and accuracy in roentgenologic interpretation by this method increases. Skill in locating the lesions by neurological examination is improving so that a growing number of cases are being operated without the use of iodized oil in diagnosis.

The importance of hypertrophy of the ligamentum flavum in the syndrome of nerve root compression is not definitely evaluated. With increased awareness of the possibility of enlargement of this ligament, more cases are being found.

In spite of the glowing reports of the surgeons on the results of operative removal of the

protruded fragment, in about fifteen per cent of patients symptoms persist after apparently successful operative procedures. Whether this is due to poor operative technique or to psychological factors in the patient has not as yet been adequately explained.

However, in properly selected cases in which accurate diagnosis has been made, laminectomy with removal of the protruded fragment will restore many patients to useful activity within a relatively short time.

BIBLIOGRAPHY

1. Abbott, W.D.
Compression of the Cauda Equina by the Ligamentum Flavum
J.A.M.A. 106:2129-2130, 1936
2. Adson, A.W.
Diagnosis and Treatment of Tumors of the Spinal Cord
Northwest Med. 24:309-317, 1925
3. Adson, A.W.
Chronic Recurring Sciatica, Diagnosis and Treatment of Ruptured Intervertebral Disc.
Arch.Phys.Therapy 20:325-330, 1939
4. Alpers, B.J.; Grant, F.C.; and Yaskin, J.C.
Chondroma of the Intervertebral Disc.
Ann.Surg. 97:10-19, 1933
5. Anderson, G.C.
Protruded Intervertebral Disc, Report of a Case, Note on Inflammatory Etiologic Factor
Arch. of Surg. 39:952-958, 1939
6. Bailey, P. and Bucy, P.C.
Chondroma of the Intervertebral Disc
Surg.Clinic N.Amer. 10:254-257, 1930
7. Barr, J.S.
Sciatica caused by Intervertebral Disc Lesions
J.Bone and Joint Surg.19:323-342, 1937
8. Barr, J.S.; Hampton, A.O.; and Mixter, J.J.
Pain Low in the Back and Sciatica due to Lesions of the Intervertebral Disc.
J.A.M.A. 109:1265-1270, 1937
9. Brown, H.A.
Enlargement of the Ligamentum Flavum, A cause of Low Back Pain with Sciatic Radiation
J.Bone and Joint Surg.20:325-338, 1938
10. Bucy, P.C.
Chondroma of the Intervertebral Disc
J.A.M.A. 94:1552-1554, 1930

11. Calve, J. and G.
The Intervertebral Disc, Its Anatomy, Physiology,
and Pathology
J.Bone and Joint Surg. 12:555-578 1930
12. Camp, J.D.
Multiple Tumors Within the Spinal Canal, Diagnosed
with Lipiodal
Am.J.Roentgenol. 36:775-781, 1936
13. Camp, J.D.
Roentgenologic Findings in Cases of Intervertebral
Disc
Proc.Staff Meet.Mayo Clinic 12:373-377, 1937
14. Camp, J.D.
The Roentgenologic Diagnosis of Intra-Spinal
Protrusion of the Intervertebral Disc
J.A.M.A. 113:2024-2028, 1939
15. Capener, N.
Intractible Sciatica due to Protruded Interverte-
bral Disc, Treated by Laminectomy
Proc.Roy.Soc.Med. 30:1262-1263, 1937
16. Chamberlain, W.E. and Young, R.B.
The Diagnosis of Intervertebral Disc Protrusion by
Intra-Spinal Injection of Air
J.A.M.A. 113:2022-2024, 1939.
17. Coggeshall, H.C. and von Storch, T.J.C.
Diagnostic value of Myelographic Studies of the
Caudal Dural Sac
Arch.Neurol. and Psychiat. 31:611-613, 1934
18. Craig, W.M. and Walsh, M.N.
Diagnosis and Treatment of Low Back and Sciatic
Pain caused by Protruded Intervertebral Disc and
Hypertrophy of Ligamentum Flavum
Minn.Med. 22:511-517, 1939
19. Craig, W.M.
Treatment of Intractible Sciatic Pain due to Pro-
truded Intervertebral Disc
Am.J.Surg. 45:499-506, 1939

20. Dandy, W.E.
Loose Cartilage From an Intervertebral Disc
Simulating Tumor of Spinal Cord
Arch.Surg. 19:660-672, 1929
21. Deucher, W.G. and Love, J.G.
Posterior Protrusion of the Intervertebral Disc,
Pathologico-anatomic Aspects
Proc.Staff.Meet.Mayo Clinic 13:697-699, 1938
22. Deucher, W.G. and Love, J.G.
Pathological Aspects of Posterior Protrusion of
Intervertebral Disc
Arch.of Path. 27:201-211, 1939
23. Flothow, P.A.
Nucleus Pulposus and Hypertrophy of the Ligamentum
Flavum, Case Reports
Northwest Med. 37:14-18, 1938
24. Goldthwait, J.E.
The Lumbo-sacral Articulation, An Explanation of
Many Cases of "Lumbago", "Sciatica", and "Paraplegia"
Boston Med. and Surg.J. 164:365-372, 1911
25. Hampton, A.O.
Iodized Oil Myelography, Use in the Diagnosis of
Rupture of the Intervertebral Disc into the Spinal
Canal
Arch. of Surg. 40:444-453, 1940
26. Hampton, A.O. and Robinson, J.M.
The Roentgenological Demonstration of Rupture of
the Intervertebral Disc after Injection with
Lipiodal
Am.J.of Roentgen. 36:782-803, 1936
27. Henderson, M.S.
Discussion on Paper of Walsh and Love, The Syndrome
of Protruded Intervertebral Disc.
Proc.Staff.Meet.Mayo Clinic 14:233-234, 1939
28. Horwitz, T.
Lesions of the Intervertebral Disc and Ligamentum
Flavum of the Lumbar Vertebrae, An Anatomic Study
of Seventy-five Human Cadavers
Surgery 6:410-425, 1939

29. Keegan, J.J.
Personal Communication
30. Love, J.G.
Protrusion of Intervertebral Disc into the
Spinal Canal
Proc.Staff Meet.Mayo Clinic 11:529-535, 1936
31. Love, J.G. and Camp, J.D.
Root Pain Resulting from Intraspinous Protrusion
of the Intervertebral Disc, Diagnosis and Treatment
J.Bone and Joint Surg. 19:776-804 1937
32. Love, J.G.
The Role of the Intervertebral Disc in the Produc-
tion of Chronic Low Back and Sciatic Pain
Proc.Staff Meet.Mayo Clinic 12:369-372, 1937
33. Love, J.G.
Recurrent Protrusion of an Intervertebral Disc,
Proc.Staff Meet.Mayo Clinic 13:404-408, 1938
34. Love, J.G. and Walsh, M.N.
Protrusion of the Intervertebral Disc
J.A.M.A. 111:396-400, 1938
35. Love, J.G.
Protruded Intervertebral Disc
J.A.M.A. 113:2029-2035, 1939
36. Love, J.G. and Walsh, M.N.
Intra-spinal Protrusion of Intervertebral Discs
Arch.of Surg. 40:454-484, 1940
37. Macey, H.B.
Clinical Aspects of Protrusion of Intervertebral
Discs
Arch. of Surg. 40:433-443, 1940
38. Mixter, W.J. and Ayers, J.B.
Herniation or Rupture of the Intervertebral Disc
into the Spinal Canal, Report of thirty-four Cases
N.Eng.J.Med. 213:385-393, 1935
39. Naffziger, H.C. Inman, V. and Saunders J.B.deC.M.
Lesions of the Intervertebral Disc and Ligamentum
Flavum: Clinical and Anatomical Studies
Surg.Gynec.and Obst. 66:288-299, 1938

40. Peet, M.M. and Echols, D.H.
Herniation of the Nucleus Pulposus, A cause of
Compression of the Spinal Cord
Arch.Neurol.and Psychiat. 32:924-932, 1934
41. Reichert, F.L.
Discussion of Paper by Barr, J.S., Hampton, A.O.
and Mixter, W.J., Pain Low in the Back and Sciatica
due to Lesions of the Intervertebral Disc
J.A.M.A. 109:1270, 1937
42. Rountree, J.T.
Herniation of the Intervertebral Disc, A Report
of two Cases
Virginia M.Monthly 66:103-105, 1939
43. Saunders, J.B.de C.M. and Inman, V.T.
The Intervertebral Disc, A Critical and Collective
Review, Internat.Abstr.Surg. 14-29, 1939 in
Surg.Gynec.and Obst. 67: July, 1939
44. Saunders, J.B.deC.M. and Inman, V.T.
Pathology of Intervertebral Disc
Arch.of Surg.40:389-416 1940
45. Simonds, F.L.
Low Back Pain due to Herniation or Rupture of the
Intervertebral Disc Into the Spinal Canal
Nebr.St.Med.J. 22:456-459, 1937
46. Skinner, H.L. and Rountree, J.T.
Herniation of Intervertebral Disc and Associated
Lesions
Virginia Med.Monthly 66:575-591, 1939
47. Spurling, R.G.; Mayfield, F.H.; and Rogers, J.B.
Ligamentum Flavum Hypertrophy
J.A.M.A. 109:928-933, 1937
48. Spurling, R.G. and Bradford, F.K.
Neurologic Aspects of Herniated Nucleus Pulposus
J.A.M.A. 113:2019-2022, 1939
49. Spurling, R.G. and Grantham, E.G.
Neurologic Picture of Herniations of the Nucleus
Pulposus in the Lower Part of the Lumbar Region
Arch.of Surg. 40:375-388, 1940

50. Steele, W.A.
The Relief of Chronic Backache and Sciatica by
Minor Surgical Measures
N.Eng.J.Med. 219:474-483, 1938
51. Stookey, B.
Compression of the Spinal Cord due to Ventral
Extradural Cervical Chondromas
Arch.Neurol.and Psychiat.20:275-291, 1928
52. Stookey, B.
A Clinical Study of Herniation of the Nucleus
Pulposus
Arch.Neurol.and Psychiat. 38:899-903, 1937
53. Towne, E.B. and Reichert, F.L.
Compression of the Lumbosacral Roots by the
Thickened Ligamentum Flavum
Ann.Surg. 94:327-336, 1931
54. Walsh, M.N. and Love, J.G.
Protruded Intervertebral Disc as a Cause of
Intractible Pain,
Proc.Staff Meet.Mayo Clinic 13:203-205, 1938
55. Walsh, M.N.
Discussion of paper by Deucher, W.G. and Love, J.G.,
Posterior Protrusion of the Intervertebral Disc,
Pathologico-anatomic Aspects
Proc.Staff Meet.Mayo Clinic 13:699, 1938
56. Walsh, M.N. and Love, J.G.
Meningeal Response following Subarachnoid Injection
of Iodized Oil
Proc.Staff Meet.Mayo Clinic 13:792-796, 1938
57. Walsh, M.N. and Love, J.G.
Syndrome of Protruded Intervertebral Disc
Proc.Staff Meet.Mayo Clinic 14:230-234, 1939
58. Young, B.R. and Scott, M.
Air Myelography, The Substitution of Air for
Lipoidal in Roentgenological Visualization of Tumors
and other Structures in the Spinal Canal
Am.J.Roentgenol. 39:187-192, 1938