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Posterior protrusion of intervertebral discs in the lumbar region

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POSTERIOR PROTRUSION OF INTERVERTEBRAL DISCS IN THE LUMBAR REGION

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INTRODUCTION

The increasing interest of the past few years in the herniation of the intervertebral disc has been shown by the voluminous literature. As in the case of every newly discovered syndrome it is elevated to a place of great importance and then gradually recedes to its definite place.

This survey of the literature on this syndrome has been prepared with the idea of putting it in its rightful place.

At this time I believe this syndrome is assuming its rightful position, but I wish to add that this condition has caused increasing interest in the spinal column. Up until the present time it has been greatly neglected, due mainly to the inability to obtain material for close study, as it is not the common practice in this country to routinely examine the spine at autopsy. Yet almost every person over sixty years and many who are younger has some complaint in his back for which the cause is not known. Consequently, it is said to be due to old age. With the increase of industrial insurance the spinal column becomes of more importance, since there are many stresses and strains which seem to be an etiological factor in almost all pathology of the spinal

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column. The exact etiology of the symptoms must be known before treatment can be administered. To understand this syndrome one must understand the embryology, anatomy and physiology, not only of the intervertebral disc, but also that of the entire spinal column.

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Anatomists have known the presence of the intervertebral disc since its first known description by Vesalius in 1555. Although von Luschka in 1858 was the first to give an accurate description of its structure and embryology, Bardeen, in 1904 in his studies of the development of the spine, was the first to postulate as to its physiological importance,(49). The first report of an injury to an intervertebral disc was made by Kocker in 1896. In 1911 Goldthwaite first suggested that injuries to the intervertebral disc might be a frequent cause of lumbago and sciatica,(39).

Schmorl of the Friedrichstadten Krankenhaus at Dresden was the first to start the routine removal of the spinal column at autopsy in 1925. In 1927 he reported his observations and described the frequency of prolapses of the intervertebral disc into the adjacent vertebral bodies. In five years he had removed about seven thousand spines. Beadle and Mauric have written monographs on the anatomy of this structure from their observations of Schmorl's work, (80, 12).

After reviewing the literature, the importance of Schmorl's work can readily be observed. It depends not only on his own observations but the stimulus which

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it has given to the study of the embryology, anatomy and physiology of this structure and the whole spinal column.

The physiological and pathological significance of the intervertebral disc, as I have tried to stress, cannot well be appreciated without some knowledge of the developmental and structural anatomy of the entire spinal column, since the intervertebral disc composes about one-fourth of the spinal column and is responsible for the amount of motility with the marked degree of stability. It is like a link in a chain; the function and value of the spinal column is dependent on its weakest intervertebral disc.

Embryology

The embryology of the spine was first reported by von Luschka who traced the development of the notochord and the formation to the intervertebral disc. Kollicker in 1859 noted that the central portion of the intervertebral disc in a one year old child contained residual notochord cells. In 1879 Lowe found that the entire nucleus pulposus of the rat was formed from the notochord. Leboucq in 1880 believed, from his studies of human and other mammalian embryos, that the notochord

tissue was practically destroyed long before birth, although this is now known not to be true. Another false theory was that advanced by Virchow in 1857 and Dursy in 1869, suggesting that the nucleus pulposus was formed by degeneration of the annulus fibrosus fibers. Bardeen, 1905, and Williams, 1908, wrote extensive studies of the development of the spine and more recently Schmorl, Calve and Galland, and Beadle have made additions to this subject, (49).

The present concensus of opinion is with that of Keyes and Compere, who, after extensive studies, have combined the views of Bardeen and Williams. Each vertebral body arises from two centers of ossification; a cephalic and a caudal plate. They are formed by the migration of mesenchymal cells of the sclerotome to surround the notochord; the origin of which is not well established, but is generally accepted as being formed at a very early period from a thickening of the endoderm in the midsagittal plane which is known as the chordal plate. This plate is gradually pinched off and then is known as the notochord. These centers are each separated by the entrance of the intersegmental arteries. Each of these centers shows a massing of these cells laterally

into two groups--a light cephalic mass and a darker caudal mass. The cells nearer the intersegmental arteries receive more nutrition than those farther removed and hence are more rapid in their differentiation. Consequently the cephalic mass of the segment below and the caudal portion of the caudal mass of the segment above rapidly add cytoplasm, merge and become the anlage of the vertebral body. The cranial portion of the caudal mass being the furtherest removed from the source of nutrition remains undifferentiated as the anlage of the intervertebral disc, (49, 32).

The vertebral bodies gradually develop cartilage cells and ossification centers begin to develop. According to Saunders and Inman, with the ingrowth of vessels the ossification proceeds; first in the neural arches and later in the vertebral centers. From these vessels fine capillaries pierce the cartilage plates and supply the discs. These vessels later undergo progressive atrophy postnatally and in adolescence are represented as scars. Boehmig attached great importance to these vessels, since he believes that the faults commonly found in the cartilage plates are in the area of these scars. And he and Uebermuth believe that these defects

are predisposing factors leading eventually to fissuring of the plate and escape of nuclear material, (67).

The notochord is gradually extruded from the vertebral bodies and is finally confined to the central portion of the intervertebral disc, although the old site of the notochord remains in the vertebra as a streak of mucoid material. The annulus fibrosus fibers begin to form and bulge out from the sides of the vertebrae. It now is believed that the greater part of the nucleus pulposus in foetal life is formed from the notochord, but that the interspersed fibers and cartilage cells are formed from the fibrocartilage envelope. The growth of the nucleus after birth is mainly due to the increase of fibrous tissue. The content of fibrous tissue in the nucleus pulposus increases throughout life until it is composed almost entirely of a dense irregularly arranged fibrocartilage with an entire loss of its gelatinous character and resiliency. This can be illustrated by the determination of water content of the tissue; it has been agreed upon in general by many workers as about 88% in the full term foetus, 80% at eighteen, and 69% at seventy-two years, (12, 49).

Again in the description of the development of

the vertebral body there is some controversy. At six months the ossification center of the intervertebral disc divides the cartilaginous anlage of the vertebra into two separate plates covering the adjacent or intervertebral surfaces. It is from the central surfaces of these cartilaginous plates that osseous growth by enchondral bone formations is continued until full growth is obtained. This period varies from seventeen to twenty years; being earlier in the female. Keyes and Compere state, "This cartilage plate is entirely comparable to the epiphysis of long bones". Schmorl and Beadle believe that there are many ossification centers which are formed at different times. They first appear in grooves which have been formed by arresting development due to unknown causes. These centers gradually enlarge until they fuse and form a solid epiphyseal ring which is called the "Randleiste of Schmorl". During the period of epiphyseal bone formation the outermost fibers of the annulus lamellosus become firmly anchored in the epiphyseal ring as "Sharpey fibers", (12). The main point of controversy is that Schmorl and Beadle regard the epiphyseal ring of the vertebral body as being quite unlike other epiphyses because it does not contribute to the growth in

the height of the vertebra; yet, Donohue, Hass and many others agree with Keyes and Compere, (32, 12).

The perforated articulating surfaces of the body of an adult vertebra are bounded peripherally by a complete ring of compact bone, the fused epiphyseal ring. This ring is always above the general surface of the vertebra, although it varies in height in different regions, (49).

From the above general description of the embryological development of the spinal column it can be deduced that there is still a lot of controversy over the minor points of development which must be thoroughly studied before the exact explanation of the numerous anatomical and pathological abnormalities can be made. Some of these are congenital abnormalities of the spine, such as anterior spina bifida, hemivertebrae and the Klippel-Feil syndrome, (which is shortness of neck, limitation of head movements and hair low down on the neck). Mauric described complete absence of the disc in an otherwise normal spine, in which the subjoined vertebrae were fused together. Schmorl and Junghans have described what they called "Blockwirbel" in which the fused vertebrae is equal in height to two vertebrae and an

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intervertebral disc, (79).

In studying the anatomy of the intervertebral disc, one must also bring into consideration spinal ligaments which are a factor in preventing anterior herniation of the intervertebral disc, but their importance in posterior protrusions is only in their weakness.

Extending on the anterior surface of the spinal column is a strong dense ligamentous structure, the anterior longitudinal ligament, which is firmly attached to the bodies of the vertebrae and the intervertebral disc. Posteriorly in the spinal canal there is a similar structure, the posterior longitudinal ligament, which in comparison is relatively weak, and consists of a series of fan-like bands attached to the posterior aspects of the intervertebral disc, while over the vertebral bodies it is narrow, thin and only lightly attached. On the lateral sides there is also a suggestion of ligamentous tissue, but they are not thick enough or well enough developed to be of enough importance to have a name, (32, 49).

Beadle was the first to realize that the intervertebral disc was a highly specialized and very complex organ which was of essentially the same structure through-

out the spinal column, but adapted itself to its environment, not only at different levels in the spinal column, but during different stages in life, (12).

Histology

The intervertebral disc consists of three different parts: The cartilage plates, enclosing it above and below; the nucleus pulposus; and the annulus lamellosus.

The articular cartilages are two thin plates of ordinary hyaline cartilage placed between the bony surface and the fibrous disc. They are only present over the perforated areas of the vertebral bodies and disappear laterally into the fibers of the discs. They are separated from the actual bone by a very thin layer of calcified cartilage, which is lacking at points, corresponding to the perforations in the spongy bone, (12).

The division between the nucleus pulposus and the annulus lamellosus is not an artificial distinction, but it is often hard to see a definite line of demarcation. In the young, the nucleus stands out and is a definite organ. It is the part of the disc which plays the most outstanding part in the pathological condition

to be described. When the spine of a young adult is sawn through in a saggital section the nucleus stands out from the surrounding tissue. It behaves quite quite differently from the surrounding tissue, as it swells forward out of its bed and presents the appearance of a glistening, white, translucent cushion. On pressure it is of fluid consistency, but is also firm and elastic. It can easily be observed by scraping away the spongy bone and leaving the cartilage plates intact, that the nucleus is under considerable pressure through its own elastic turgor. This turgor depends on the fluid content of the tissue and diminishes gradually with advancing age, and is completely lost in various forms of tissue degeneration, (12).

Beadle and Schmorl in their description of the disc point out very definitely that there is no sudden change of structure in passing over to the annulus lamellosus, especially in elderly people. The annulus gives the permanent form and size of the disc as well as being the area with the most strength and tenacity. It serves for attachment and transmission of tension throughout the spine, (12).

Ubermuth carefully traced the development of

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the intervertebral disc and found that it was derived in part from the notochord. He found that the annulus appears in a cartilaginous matrix in the first few months after birth as a ring about the nucleus. The ring grows in extent at the expense of the cartilage plate from the periphery from which it originates. The outermost fibers become blended with the inner surfaces of the ligaments surrounding the spine and may be continued over the margin of the vertebrae to be firmly attached to the periosteum, becoming firmly imbedded in the epiphyseal ring of the vertebral body as "Sharpey" fibers.

The nucleus is surrounded in an area slightly posterior to the center, which is triangular in character, with the vertex directed anteriorly and corresponds roughly with the outline of the intervertebral disc itself. Passing to the periphery the annulus begins to show concentric folds, which form concentric lamellae, and these form a stout glistening crest which encircles the whole disc surface like rings. They are composed of fibers passing in various directions, but mostly obliquely. The number of these folds varies in different parts of the spine; in the lumbar region there ten to twelve which are exceedingly stout, gradually decreasing in num-

ber upward. If an attempt is made to scrape the annulus from the vertebral body, it is revealed that the annulus is much more loosely constructed posteriorly than anteriorly. Around the epiphyseal ring the fibers are strongly attached but more anteriorly than posteriorly. At this point of attachment to the vertebral bodies it is also attached to the longitudinal ligaments. The attachment with anterior ligament is much stronger in comparison to that of the posterior, (12, 32).

The microscopic picture of the nucleus is that of fine interlacing bands of connective tissue with a small admixture of elastic fibers. This tissue is very loose and contains in its meshes a highly fluid matrix, of which the water content is high. The strands are arranged in irregular bands which follow no set pattern except at the surfaces of attachment to the cartilage plates. In this meshwork there are also scattered various types of cells, such as fusiform and spindle shaped connective tissue cells, groups of cartilage cells, and in young individuals, clear vacuolated cells which are thought to be surviving cells of the notochord. Peripherally the fibrous network gradually becomes dense, finally arranging itself in the thick curving bundles

of the annulus fibrosus, (32).

The annulus gives permanent form and size to the disc and is the seat of its strength and durability. It is composed of dense interlacing bands of collagen with a small dispersion of elastic fibers and irregular, scattered cartilage cells, (32).

Due to the fact that the joints formed by the intervertebral disc allow a moderate degree of movement, flexion, extension and possibly rotation, yet possess no true joint cavities, they differ from the other articulations of the body. Although Schmorl, Junghanns and Luschka believe that these joints do contain potential cavities from microscopic studies, Donohue, Keyes and Compere, and Beadle believe that they are artefacts produced by injection with fluid, (32, 12, 49).

Donohue relates the investigations of Ubermuth and Bohmig in regard to the nutrition of the intervertebral disc; stating that there are blood vessels arising from the marrow spaces which perforate the cartilaginous plates in early life, and undergo progressive obliteration until at the end of the growth period they have completely disappeared. This obliteration may leave small scar-like defects in the cartilaginous plates and in

agreement with Schmorl have pointed out that these may be sites of potential weakness. This is a point of controversy, as Saunders, Inman and Beadle have not been able to observe these scars. It is agreed that the adult intervertebral disc contains no blood vessels. It is nourished entirely from the marrow by diffusion through the perforated bony end plate of the vertebral body, (32).

According to Donohue again, Jung and Brunschwig have investigated the innervation of the articulation of the vertebral bodies but could only demonstrate sensory nerves in the anterior longitudinal fibers with none in the intervertebral disc, (32). Yet Spurling and Bradford reveal that each of the spinal nerves gives rise to a recurrent branch just to the posterior root ganglion, which reenters the intervertebral foramen and supplies the ligamentous structure two vertebrae lower than the exit of the spinal nerve. Roofe in unpublished observations indicates that there is a profuse supply of sensory nerve endings in the annulus fibrosus and the posterior longitudinal ligament, (83).

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The physiology of the intervertebral disc can be likened to a system of hydraulic ball bearings. It is subject to the laws of fluids; that is, it is incompressible and confined to its normal shape and position by the strong bands of the annulus fibrosus. The amount of compression that it will stand depends on the elasticity and strength of the annulus fibrosus, (46).

The function of the nucleus pulposus depends upon its plasticity. While Sashin states that it is "highly expansile", almost all of the other authors state that it is not, (78).

Petter has shown that after removal of the lumbar spine from the body each disc increases in size about .7 mm. He also showed that the intervertebral disc increased about 1.2 mms. when the annulus was severed. Only by compressing the disc with thirty-two pounds, could it be returned to its normal shape, (72).

The increase in thickness of the intervertebral disc accompanying removal of the lumbar spine has been explained by Bradford as being due to the release of muscle spasm caused by "rigor mortis". He explains the increase in thickness when the annulus is cut as due to the relaxation of the compressing force upon the

nucleus pulposus and the escape of the nucleus between the cut edges of the annulus, (46).

According to Saunders and Inman, the change is about ten percent of the spinal column. They state that De Puky measured twelve hundred individuals between the ages of five and ninety years, and found daily oscillations in the total height that amounted on the average in females from one to two inches and in males from three to four inches. The youngest individual showed the greatest change and the value decreased steadily with the increasing age. The total height was greatest in the morning and decreased during the day. These oscillations were attributed to changes in the turgor of the intervertebral disc. They also related that these findings agree with the work of Ubermuth and Pueschel, both German writers, (67).

Bradford relates that the lumbar vertebrae of a fresh cadaver can hardly be bent manually using the knee as a fulcrum. He also states that the ratio of arms to the spinal muscles is fifteen to one. If a man lifts one hundred pounds, the movement of force is fifteen hundred pounds. Therefore, the muscles acting on the spine must exert an actual force of fifteen hundred

pounds, and with the lumbar spine as a fulcrum sixteen hundred pounds of pressure are exerted on the lumbar intervertebral disc, (46).

If sudden force is put upon the intervertebral disc, the nucleus pulposus is displaced laterally in all directions, distending the annulus firbrosus. This is the method of shock absorption. Along with this, and much more important, the pressure is equalized over the entire vertebral surface, due to the fact that pressure transmitted over a fluid surface is uniform. In regard to the intervertebral disc this is only true if the angulation of the vertebral bodies is not sufficient to displace the nucleus from one extremity so that the sides come together. If this should happen, the force would be borne disproportionately by the area from which the nucleus had been displaced, (46).

It can now easily be seen that the annulus fibrosus must not only resist pressures which tend to displace the nucleus pulposus, but also bind the margins of the vertebral bodies strongly together to prevent excessive angulation at any one articulation. If there is any injury to annulus fibrosus or the cartilage plates which allows the nucleus to escape, or any degeneration

of the nucleus pulposus which causes it to lose its plasticity, the annulosus is subject to alien forces and the weight is transmitted to a small area. Thus the annulosus becomes a simple washer and is ground between opposing vertebral bodies; thus, if the vertebral bodies have been weakened by disease, the bodies may be ground away. This may also occur if the intervertebral surfaces are not flat, so the nucleus is not able to exert its force, (46).

Before leaving the subjects of anatomy and physiology, I would like to stress again that the annulus fibrosus is supported anteriorly by a rather strong anterior longitudinal ligament, while there is no restraint from the bony rimledge and the posterior longitudinal ligament is much weaker.

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After an extensive search of the literature on the pathology of the intervertebral disc, I believe that the best classification is that of Joplin's, which classifies it in the following manner, (46):

1. Thick discs. At birth the discs are thick compared with the vertebrae, yet as they grow the discs become comparatively narrower. In diseases which decrease the strength of the spongy bone, the pressure of the nucleus causes a bulging of the intervertebral disc into the adjoing vertebral bodies. This is seen in osteoporosis, osteomalacia, cancer metastasis and myeloma, (46). McKay has also associated this condition with Paget's disease, (60). Donohue relates that this condition may proceed to such a marked degree that the intervertebral disc may almost touch or the vertebral body may resemble a fish vertebrae. The expansion of the disc is not due to the formation of new tissue, but to the increase of water content in the tissues. It should be remembered that if the degenerative processes have resulted in the loss of turgor of the nucleus, expansion will not occur no matter how great the weakening of the spongiosa of the vertebral bodies, (32).

2. Thin discs. This condition is much more

common than the above. Although it should be remembered that normally the intervertebral discs in the sacrum decrease during life until they completely disappear, except for the first sacral and occasionally the second. With this exception any other thinning of the intervertebral disc in the spinal column is a pathological process--that is, any irregular change--because after the third or fourth decade there is a gradual degeneration of the discs normally, (46).

3. Displacement of intervertebral disc tissue is the third heading of Joplin's classification of the pathology. A prolapse into the bony portion of the vertebral body can readily be shown by roentgenogram and is usually called "Schmorl's nodule", although this condition was first described by Luschka, (46). Schmorl rediscovered this condition and believed that the importance of these nodules in the medicolegal cases was and is overemphasized. These nodules occur typically when there is a break in the cartilage plate which allows the nucleus pulposus to push its way out into the spongiosa of the vertebral body. This is accomplished by the normal turgor of the nucleus in the young and by the pressure of continual activity in the aged in whom the turgor

has been lost. This foreign tissue fills the marrow spaces of the spongiosa and causes atrophy of the bony trabeculae with gradual enlargement of the prolapse until a state of equilibrium is reached. In the course of time new bone is formed as part of the reaction to the foreign tissue and the prolapsed disc is surrounded by a layer of compact bone, thus preventing further prolapse. The above condition takes place more readily in the young individual and usually involves a group of vertebrae. In middle aged and elderly persons, the turgor of the intervertebral disc is diminished and the prolapse of the disc tissue does not extend as far, and in this age group there is usually only an isolated disc involved, (32).

The sequella which usually follows after these prolapses have developed after middle age is not the stimulation of new cartilage and bone formation, but vascularization and eventual cicatrization, both of the prolapsed tissue and the adjoining intervertebral disc. Blood vessels grow in from the spongiosa and gradually destroy the prolapsed tissue. The newly formed blood vessels penetrate the intervertebral disc and convert large parts of the disc into granulation. The final and

eventual outcome of this process is usually a solid fibrous union between the two adjacent vertebrae. Occasionally the spongiosa throws out bony trabeculae and the area becomes ossified. Schmorl found that prolapse of the disc in about thirty-eight percent of a group of all ages. The ratio between men and women was about two to one in a group below sixty, but in the group above sixty the ratio was reversed, (12). Donohue attributes this to the fact that women continue physical activity in the form of housework long after man have retired, (32).

Joplin explains this prolapse very well when he likens the condition to a partially deflated tire, since this condition decreases the height of the disc, lessens its elasticity, lowers its efficiency, and produces abnormal motion through release of the pressure in the annulus, (46).

Not only may the nucleus prolapse through a rupture of a cartilage plate, but it may also protrude through a break in continuity of the annulus fibrosus, the pathology of which must be considered under this heading.

Middleton and Teacher, 1911, in the Glasgow

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Medical Journal first called attention to the possibility of this condition causing nerve injury. They related the incident of a man who was lifting a heavy object and heard a "crack" in his back, suffered severe pain in the lumbar region and incidently developed a paraplegia. The patient died and at autopsy a herniated mass of tissue was found protruded between the twelfth thoracic and first lumbar. There was much hemorrhage and softening of the lumbar intervertebral disc, (64).

These posterior herniations have only been understood for the past twenty years. Previously they were considered to be tumors of the intervertebral disc. The histology was confused and there were many explanations of it. Adson in 1925 called this condition fibrochondromas of the intervertebral disc and advocated laminectomy, (2). Elsberg regarded this condition as extradural chondromas, and in an article described them at length, not being able to tell whether they were neoplastic or not, because in his opinion their growth was limited, (34). Stookey, in an extensive article in the Archives of Neurology and Psychiatry during 1928, described the same condition and also the treatment, which was considered to be hemilaminectomy, (88). Dandy, in

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1929, in an extensive article reported that loose cartilage from an intervertebral disc often simulated spinal cord tumor. He presents a very good article in which is discussed most of the phases of this syndrome, (45). In 1930 Bailey and Bucy described a case of sciatica developing after a patient strained himself lifting and upon operation found a fibrocartilaginous nodule, (8); Bucy comments on this case and had about the same idea as Stookey, (17). Alpers, Grant and Yaskin recognized that these tumors were predominately newly formed connective tissue which must have arisen from the intervertebral disc, and they were not sure that they were neoplastic, (5). Peet and Echols believed these fibrochondromas were not tumors, but intervertebral disc tissue which had undergone degeneration, (71). From the above it can be seen that there was a great deal of controversy over the pathology and the clinical syndrome was not clearly differentiated.

These extrusions are exposed by sawing through the pedicles of the vertebral arches and laying the spinal canal open. After removal of the cord, the nodules of displaced tissue may be seen on the posterior aspect of the intervertebral disc or vertebral bodies. They

appear as bluish-white, firm nodules, varying in size from that of a small wheat grain to that of a bean. They shine through the posterior longitudinal ligament. The tissue which extrudes usually originates from a disc with some degree of degeneration. The posterior part of the annulus always shows degeneration, and fissures or tears can be found in it where the tissue of the nucleus goes through. The break in the annulus may be very hard to find. While the extruded tissue usually appears under the posterior longitudinal ligament or among its fibers, it may burrow between the ligament and the posterior surface of the vertebral body for some distance before it forms a nodule, and this explains nodules which appear at some distance from the intervertebral disc. Microscopically the displaced tissue has an appearance characteristic of nucleus pulposus, but there is also an increase in the number of cartilage cells, (46). The posterior displacement of disc tissue rarely gives rise to lipping or to the formation of osteophytes, due to the fact that the posterior longitudinal ligament is but weakly attached to the vertebral bodies and, therefore, there is very little trauma to the periosteum, (32).

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4. Degeneration comes fourth under Joplin's classification of the pathology of the intervertebral disc. This heading is very hard to differentiate from thin discs. Under this heading the life history of the intervertebral disc must be discussed. While the pathology of the intervertebral disc is, in most cases, distinct and rather easily explained there are many cases, due to the fact that there is progressive continuous change in structure of the intervertebral disc throughout life, where it becomes difficult to distinguish between normal and pathological conditions.

Since degeneration is so common in supposedly healthy spines of middle age, changes which are present must be attributed to exposure of the structure to abnormal stresses and strains as a result of the individual's environment. Donohue relates that Norlem has investigated the relationship between arteriosclerosis and disc degeneration and found that there was no correlation, (32). According to Saunders and Inman, this degeneration is best described by Ubermuth and Pueschel, who divide the life history of the intervertebral disc into two stages. The first, extending from foetal life to approximately the third decade, is characterized by

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an increasing turgor and elasticity of the nucleus, together with the crystalization of the fibers of the annulus in response to functional stress and strain. The second, from middle age on, is distinguished by progressive dehydration of the disc. The degree of degeneration in any one spine varies from disc to disc; this is a matter of controversy.

Beadle points out that the earliest signs of degeneration are that of swelling of the nucleus and infiltration of the annulus, (12). While Pueschel states that the nucleus does this without changes in water balance, (67). The intervertebral disc becomes more fragile and loses its elasticity gradually. As this degeneration advances, a fibrillary degeneration develops with complete disappearance of the cells and fibers. The annulus becomes reduced to a peripheral ring and the fibers rupture. Associated with this condition there is a deposition of pigment of unknown origin and of varying amount which is called "Brown Degeneration". by Beadle, (12, 67). Schmorl relates that with less frequency necrosis may take place in the anterior part of the annulus with related calcification. The importance of these small areas of necrosis lies in the fact that they are often the start-

ing point of fissures and tears in the annulus. Donohue believes that these areas are also the beginning of senile kyphosis, (32). Also through these fissures tissues may prolapse posteriorly and undergo so called metaplasia. This condition will be discussed more full in the discussion of the clinical syndrome.

5. Calcification is the fifth grouping of Joplin. As in any other organ which undergoes degeneration, there is following calcification. Many authors have discussed this condition, among them Schmorl, Beadle, Lyon, and Barsony and Koppenstein. Calcification of areas in the nucleus pulposus are rarely seen, but because of their rarity they are frequently found in the literature, reported as individual cases. Calve and Galland were the first to describe them on section as soft, pale yellowish-white, chalky masses located in the nucleus, (18). Frequently seen with areas of necrosis in the annulus are small irregular areas of calcification. They are usually seen in the anterior part and vary from pinpoint to millimeters in diameter. Since these are readily seen in X-rays, they must not be mistaken for non-union of the epiphyseal ring. These areas have a cloudy appearance as if the calcium had

been precipitated on the preexisting fibers. In decalcified microscopic preparations the matrix is structureless and corresponds to similar areas of degeneration in any other organ. Also these primary areas of calcification should not be confused with conditions resulting from inflammatory conditions such as tuberculosis. Hemmorhages are occasionally found in the intervertebral disc, usually in the degenerated areas. They are probably of traumatic origin and arise from injuries to the cartilage plates, allowing blood to enter from the marrow spaces of the vertebral spongiosa, (32, 38).

6. Deposit of other types of tissue in the intervertebral disc is Joplin's sixth classification of the pathology of the intervertebral disc. Fibrous tissue has been reported in the nucleus pulposus, but is only found at autopsy. As has been described in degeneration of the vertebral disc there is often an ingrowth of blood vessels into the area with accompanying fibrosis and then calcification.

One point of importance is that occasionally the annulus may become filled with spongiosa while the nucleus retains its consistency. These are often misinterpreted as fractures of the rim in X-ray studies.

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These deposits occur mostly on the anterior border, parallel to the stratification of the fibrous ring and they may develop to a considerable size, (46).

Primary tumors of the intervertebral disc are unknown, either malignant or non-malignant. The discs are rarely effected by infections due to their lack of blood supply, (32).

Ghormley, after a study of a number of cases of destruction of the intervertebral disc with an infectious origin, classifies this condition along with a typhoid spine. The syndrome resembles osteomyelitis of the spine of a very mild type. This is the only reference of late on acute infections of the intervertebral disc, (38).

ETIOLOGY

The factors concerned in the etiology of posterior protrusion of the intervertebral disc are the sum total of the various stresses and strains placed on this, the main supporting member of the body architecture. The spinal column is so arranged and constructed as to meet these stresses and also the resultant of the forces predicated by any and all movements. One can see that the preponderance of injuries must, by the very nature of the supporting column, be at its weakest point, although this is the point at which we find the greatest stability with the most motility. Therefore, the following etiological factors will alter this relationship of stability to motility and produce herniation of the nucleus pulposus.

Before describing the etiology of this condition I would like to reprint a chart of the various names that have been given this condition by various authors in its ascent to its present level of importance, (9).

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CHART SHOWING AUTHORS AND VARIOUS NAMES GIVEN BY EACH TO POSTERIOR PROTRUSION OF THE INTER-VERTEBRAL DISC.

Author	Name
Baily and Bucy	Intervertebral-disc chondroma
Elsberg	Ventral extradural chondroma
Stookey Adson and Ott	Ecchondrosis
Veraguth	Myxochondroma
Alajouanine Petit-Dutaillis	Fibroma
Courzon Petit-Dutaillis Christophe	Fibrochondroma
Schmorl Klinge Kortzeborn von Pechy	Schmorl's nodule, (Knorpelknotchen)
Galland Calve and Galland Mixter and Ayer Mixter and Barr Peet and Echols	Rupture or herniation of the intervertebral disc. Herniation of the nucleus pulposus. Prolapse of the nucleus pulposus.
Dandy	Loose cartilage from the inter-vertebral disc.

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After surveying the literature and from the above chart, I believe thatthe logical name for this condition should be posterior hernation of the intervertebral disc and this will be the terminology used throughout the remainder of this article.

The most imoortant feature of posterior herniation of the intervertebral disc is not the fact that it interferes with the normal motion of the spine at that level, for this can be compensated for by the other vertebral joints, but the pressure which this protrusion may exert on the spinal nerves. A clear understanding of this can only be attained by studying the anatomy of the intervertebral canal and the ligamenta flava, which have definite significance in this syndrome.

The intervertebral formamen in the lumbar region, as visualized by X-ray, has the appearance of an inverted pear, although this does not hold true for the fifth lumbar foramen which is more oblique and irregular, and to a lesser extent to the fourth. It can be observed from X-ray examination that the shape changes with change in position, being larger and more elongated in flexion. Its upper boundary is formed by the pedicle and more anteriorly by the lower part of the vertebral body of the

upper of the two contiguous vertebrae and is deeply notched inferiorly. 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 onto the inferior aspect of the pedicle at the apex of the inferior vertebral notch. At the fifth lumbar foramen, and to a lesser extent at the fourth, the sulcus extends obliquely forward for some distance outside of the foramen, grooving the root of the pedicle, the base of the transverse process and adjacent body. In consequence 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. It is important to recognize that the spinal nerves of the lumbar region occupy only the uppermost portions of their respective intervertebral foramina, closely applied to the inferior aspect of the pedicle, and bear no direct relationship to the lower half of the foramen. The relationship of the nerve to the interarticular joint is very slight, occurring only at the most lateral part of the joint, (67).

The lower half of the foramen is bounded below

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by the shallower superior vertebral notch on the upper aspect of the pedicle. 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, due to partial offsetting of the inferior articular process. 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, (67).

On the medial side of the lower half of the intervertebral foramen, the apposition of the backward bulging intervertebral disc and the forward protrusion of the ligamentum flavum create a definite sulcus. This sulcus is related to the spinal nerve. Due to individual variation, the nerve may be lying at this point within the dural sac, as is more usual, or be about to emerge from the sac, or may have just emerged enclosed within its own sheath. It should be recognized that the nerve, no matter what relation it bears to the dural sac, is lying at this poing 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.

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The nerve is relatively fixed in this region because of its proximity to its point of emergence, although lying within the spinal dura. From the above description, the vulnerability of of the nerve to pressure by either the ligamentum flavum or the herniated intervertebral disc, or both, can readily be ascertained, (67).

The most important etiological factor in the posterior herniation of the intervertebral disc is the physiology of the spine itself. As has been shown by Bradford, Petter, Naffziger, and Inman and Saunders, the lumbar spine is under enormous stresses and strains, (13, 72, 66, 79). As in the case of any chain it always breaks first at its weakest link. In the case of the spine it is the intervertebral discs where stability has been replaced to some degree by motility. According to Bradford, when a person lifts one hundred pounds there is exerted on the lumbar spine a force of sixteen hundred pounds, (13). Since the spinal column is the main stay of the body in the erect position and since every movement which is made by the human has some effect on the spine, the amount of stress and strain which is put on the vertebral column in a single day is enormous. The above is even more true to a greater

extent in people of certain occupations--those who resort to manual labor. Add these strains up over a period of years, and not only this total, but also bring into consideration the change encountered in the tissues as age increases, degeneration and loss of turgor, one can readily explain the cause for such a high incidence of back pain.

Most authors--Barr, Williams, Love, Camp, Macey, Roundtree and many others--agree that in the majority of cases this condition is due to trauma, (9, 94, 51, 19, 59, 77). This trauma is usually of a twisting motion while lifting, although there are also many cases in which the trauma is due to falling or a direct blow. According to Saunders and Inman, Middleton and Teacher were the first to call attention to posterior herniation of the intervertebral disc and their case was a man, who, while lifting a heavy object, felt a crack in his back and suffered severe pain in his lumbar region and finally died of a paraplegia. They also state that Kocher described the finding of the disc between first and second lumbar completely smashed in a patient who had fallen on his feet from a height of one hundred feet, (64). Goldthwaite describes a case in

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which a paraplegia was formed after a manipulation for low back pain, (39). A method which has not been reported very often, and which should be of intense interest, is the protrusion of the intervertebral disc as a result of spinal puncture. Keys and Compere proved that if the cartilage plate of the intervertebral disc of a dog was punctured by a scalpel or a drill the nuclear material prolapsed into the spongiosa, (49).

Gellman reports a case of a spinal tap followed by pain in the lumbar region with a subsequent narrowing of the joint spaces. Milward and Grout have also reported five cases. This should be thought of in any case in which spinal puncture is to be attempted, (37, 70). There may be congenital inborn characteristics which tend to weaken the annulus fibrosus or strengthen the nucleus pulposus, which may result in the ultimate rupture of the annulus and posterior herniation of the intervertebral disc. Macey found in fifteen percent of one hundred cases of posterior protrusion of the intervertebral disc remnants of notochordal degeneration, (59).

Author	Ref No	Number of cases	#1 Location of Lesion	Incidence ♂	♀	Age (yrs) Average	Range	Intermittency	Trauma	Radiation Uni	Bil	Location of L 1	2	3
Barr	9	40	65% 4 30% 5	90%	10%			+	79%	34	6	100%	90%	70%
Williams	94	Observation				35+			+			+	+	+
Love + Camp	55	50				39	16-72		37	30	15	45	45	45
Hampton + Robinson #4	52	30	92% L 47% 4	77%	23%			+	60%	31%	8%	+	+	
Love + Walsh	57	500	76% L 20% 4 2% 5	35%	14%	42		84%	+	78%	16%			
Neffziger	67	Observation				40	18-63		+			+	+	
Keegen + Finlayson	48	40		65	35	40	20-50	+	70	+		++	++	+
Spurling + Grantham	84	125	39-4 51-5											
Love + Walsh	56	100	4 12.5 94% L 3 4% 4	7%	2%	40	20-80	86%	73%	69%	25%	+	+	+
Macey	59	100	41% 4 46% 5						52%		12%			
Barr + Mixter	11	155	90% L 81 - 4 57 - 5	78%	22%	40	16-65	40%	80%	80%	20%	95%	90%	75%
Craig + Walsh	26	499		+	+			+	75%	75	15	+	+	+
Love	52	Observation	+ L					86%	84%	+		+	+	+
Spurling + Bradford	83	Observation	90% L					+	+					
Walsh + Love	90	100	88% L 40% - 4 47% - 5	77%	23%	40%		90	63%		+	+	+	+
Johnson	45	40		66%	30%	41	17-65	+	73%	+		++	++	++
Love	51	300	96% L + - 4						+					
Skinner + Rountree	82	Observation	+ L + 4	+				+	+	+		+		
Brown	15	Observation	+ L + 4	+		40		+	+	+		+		
Craig + Walsh	27	300	96% L 47% - 4 46% - 5	75%	25%	40		81%	59%	95%	15%	+	+	+
Lyerly	58	Observation	+ L + 4	+		40		+	+	+		+		
Walsh + Love	52	200	92% L 88 - 4 91 - 5			40	16-74	90%	83%	70	16%			
Barr et al	10	50	80% - L C0% - 4 C92% - 5	74%	26%	37	20-56	60%	80%	+	±			+
Mixter Ayers	65	30	97% L	20%	13%	40	20-64	+	28	+		+	+	+
Dandy	28	37	96% L + - 4					+	+	+				
Henderson	43	Observation		2	1	40		+	+	+		+	+	+

#(1) Lumbar (2) 4&5 Disk #(2) 1 Post +

#4 Simmonds 1937 reviewed these cases w

Pin #4	Pin #5	Tenderness 1	Tenderness 2	Tenderness 3 #3	Sciatic Con	Scoliosis Hump	Lumbar Kyphosis	Limit/Pain at Motion	Muscle Atrophy	Reflexes Ank	Reflexes KJ	Reflexes Bab	Lasegue sign	Sciatic Reflex	Sensory Loss	Sensory Sensation	Lumbar Pressure
65%	5%	15	14	10	13	11	27	+	+	50%	−	−	36	—	16	17	4
+	+	+	+	+	+		+			+			+	—	−	+	
45	45									+			+		+	+	−
		+			+		+	+	+	+			+		+	+	
		·		64%	+		+	+	25%	60%			84%		21%	50%	−
		+			+		+			+	−	−	+		+		−
+	+	+	+		+		+	+	25%	50%			+				
													+		+		
		+		63%	+		+	+	20%	57%			82%		31%	49%	−
			50%	37%	33%	5%	26%	80%	26%	60%			50%		64%		
65	20		50%		40%	2%	90%	90%	50%	70%			95%	+	35%		?
+	+				±			+	24%	57%	37%		81	19	22	50	−
+	+						+	+		+			+		+		
					+		+	+	+				+			+	
+	+												83%				−
+	+	+	+	—	+		+	+	+	+			+		74%		−
				+			+			+			+				
		+		+	+		+	+	+	+			+		+	+	−
		+	+		+		+	+	+	+			+		+	+	
		+	+				+	+	+	+			+		+	42%	
		+	+		+		+	+	+	+			+		+	+	
				31%					21%	57%			78%		23%	51%	−
+		+	+	+	+		+	+	+	+			+		+	+	
		+			+		+	+	+	+			+		+	+	
		+	+							+			+				
+	+	+	+	+	+		+	+	+	+			+	+	+	+	

Lateral thigh 2 Post Lat thigh 3 Lumbosacral 4 gluteal & sacroiliac 5 Lat C
4th confirmatory results

Rimture Protein	Naffziger	Queckenstedt-Reversed		Size of Disk Increased	Decreased	Lipiodal Value	Air value
35	—			12.5 sq.	63%	90%	
					+	+	
30			+		27	100%	
+	+		+		13	96%	
60%						90%	
±	+					+	
		+					
+						76%	
80%			+				
60%					28%	93%	
+	40%				+	90%	606
+			++			92%	
	+						
80%			++				
65%		+	+			94%	0
+					+		
+						+	
+	+		+			+	
66%			+			+	
+	+		+			+	
61%		50%					
+					33%	90%	
+			+				
±							
+							

Border of foot #(3) (1) Midline Level of Lesion
#(2) 2 Sacroiliac Lig (3) sacrosciatic notch

SIGNS AND SYMPTOMS

After surveying the literature, I believe that the most valuable way to interpret these conclusions as to the signs and symptoms is in the form of a chart, which I have produced from different articles by various authors.

Explanation of Chart of Authors Findings.

Laseque Sign--With the patient supine, the thigh is raised until it forms a right angle with the trunk and the leg, which has remained flexed, is extended until pain begins along the course of the sciatic nerve. Then, without further movement of the leg or thigh, the foot is passively dorsiflexed to determine whether additional pull on the sciatic nerve intensifies the pain, (84).

Reversed Queckenstedt--Performed as an epidural injection, which is frequently employed in the treatment of sciatic pain.

A caudal needle is placed in the sacral hiatus, care being taken to be sure that the needle is not in the dura or vein.

A lumbar puncture needle is inserted into the lumbar subarachnoid space and a manometer is attached.

Explanation of Chart of Authors Findings

Ten cc. fractions of a 1% Procaine Hydrochloride solution 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. Forty cc. should be injected. If a tumor or protruded intervertebral disc large enough to obstruct the caudal sac is present, no increase in manometric pressure readings occurs.

In cases of ordinary sciatic pain, not caused by pressure on the roots, the pain is exaggerated and then relieved on injection of each fraction. In compression of the roots, the pain is unbearable and the test will have to be discontinued, (52).

Naffziger Test--Occluding both jugular veins until a sense of fullness in the head is experienced and until the face is flushed. If pain in the back of the leg or paresthesia in leg are produced, it is indicative of intraspinal disease, (68).

Arid believes that this test is of diagnostic value in this condition, if prolonged jugular pressure is applied for about ten minutes with the use of a blood pressure cuff. In a series of cases he found that most of the positive findings were accentuated and in many

Explanation of Chart of Authors Findings

cases new findings were elicited, (7).

Brav found altered Achilles reflexes in most all cases of strain and cases of protruded intervertebral disc, (14).

Craig, of the Neurological Surgical Section of the Mayo Clinic, agrees in general with Love and Camp. He had deduced these ideas from his own observations, (24).

As can be seen the percentage or the number of cases in which the different findings are found is not given under each author. This is due to the fact that every author does not report his case findings, but his impressions. In the cases where a plus sign is observed it was the author's opinion that this condition was positive in the majority of cases.

In explanation of the above chart, I have tried not only to present the main symptoms and signs, but have added findings of interest that have proven to be of no value in the diagnosis of this condition.

To sum up the findings: These lesions occur mostly in the lumbar region and in most of the series observed it was above 90%. By far the most common place

Explanation of Chart of Authors Findings

was at the level of the fourth intervertebral disc. In regard to incidence it is most common in the male; being present about 78%. The age incidence varies from the teens to the seventies; the average age being around forty years. There are intermittent symptoms in by far the greater majority, as around 85% of them have this intermittency and there is a history of trauma in about 78% of the patients. The radiation of pain in the majority of cases is confined to one side, again about 78%. In locating the pain there is much overlapping, but most of the patients have pain in the posterior and lateral thigh regions, (95%). Next in order is the posterior lateral calf of the affected side, (70%). Descending in order of frequency comes the lumbosacral region, about 75% of patients have pain in this region; about 65% of the patients have pain in the gluteal and sacro-iliac region; the lateral border of the foot is involved in only about 20% of the cases. The location of the tenderness is a matter of controversy, although it appears that it is over the sacro-iliac ligament or in the midline at the level of the lesion, occasionally there is tenderness over the sacrosciatic notch.

There is usually sciatic scoliosis towards

Explanation of Chart of Authors Findings

the contralateral side about 35% of the time. Lumbar kyphosis, which is due to muscle spasm and disappears after the operation, is present about 60% of the time. Motion is limited in about 85% of the cases, while there is muscle atrophy of noticeable degree around 30% of the time. Of the reflexes the knee jerk is only affected about 5% to 10% of the time, while the Babinski is rarely involved, and the ankle jerk which is involved the most is diminished or absent 60% of the time. The Lasegue or leg raising test is of value in diagnosis, since it is positive about 85% of the time. The sciatic reflex is of doubtful value, being mentioned by only a few authors as present about 20% of the time. Sensory changes are important, since there is sensory loss in about 25% of the cases and paresthesia in about 50% of the cases. The Kernig is rarely affected.

The lumbar puncture is of some value when present with other symptoms, although the cell count and manometric readings are of no value. The protein is of value in some cases, since in about 60% of the cases the protein is above 40 mg. percent.

The Naffziger test is positive about 40% of the time, according to a few authors. While Queckenstedt

Explanation of Chart of Authors Findings.

is of no value, the reversed Queckenstedt is positive in about one-third of the cases. Although it is rarely performed, because there are enough other diagnostic findings.

In plain films of the lumbar spine there are changes in the lumbar vertebrae part of the time. There are hypertrophic changes with spur formation and increased density of the vertebral bodies in about 20% of the cases. There is narrowing of the intervertebral disc about 33% of the time. Concave vertebrae due to increase in the size of the intervertebral disc are present in around 13% of the cases. As will be discussed later, lipiodol examinations are about 90% accurate, while air myelograms are around 50% diagnostic.

M. S. Craig, M. N. Walsh and B. Stookey are in general agreement with the above findings, (87,27,24).

Paul C. Williams in four hundred cases of pathological lesions of the lumbosacral spine found that destruction of the intervertebral disc occurred in two hundred eighty-five cases, or 71.25%, (94).

M. S. Henderson of the Orthopedic Section of the Mayo Clinic in 1937 relates that the incidence of posterior herniation of the intervertebral disc among

Explanation of Chart of Authors Findings

all of the patients seen by the Orthopedic Section was 1.8%, (43).

SIGNS AND SYMPTOMS

From the previously described signs and symptoms I will try to put together a composite picture of posterior herniation of the intervertebral disc. This lesion usually occurs in a middle aged male, who, at sometime during his life, has done a great deal of heavy manual labor, although this is not necessary. There is usually a history of some sort of an injury to the spine--a fall, twist or a contusion. There is a history of attacks of pain of varying degrees, with periods of varying degrees of freedom or complete freedom. Deucher and Love have shown in 37% of their cases on which laminectomy was done edema of the impinged nerves, and have advanced this as a theory for the cause of intermittent pain, (31). Walsh agrees with their explanation of this intermittency of symptoms, as do Brown and Lyerly, (59, 93, 43).

Low backache is usually present and may be accentuated by coughing, sneezing, etc., and is relieved usually by bed rest. There is pain which is referred down the back of the thigh and laterally on the leg. Spurling and Grantham have advanced the idea of localizing the lesion in three areas. Many others believe that more stress should be put on this than on radiographic

SIGNS AND SYMPTOMS

studies; among them is Dandy, (28).

They localize lesions to the third lumbar interspace, if the following signs and symptoms are elicited: Disability of the lower part of the back with local tenderness at the third lumbar vertebra and reduction in lumbar lordosis. A positive Laseque test, along with a positive Naffziger test, producing paresthesia in the fourth and fifth lumbar dermatomes. Reduction or absence of the knee jerk and the ankle jerk unchanged. Hyperesthesia and paresthesia in the fourth and fifth lumbar dermatomes, (84).

They confine the lesion to the fourth lumbar interspace, if there is disability of the lower part of the back with stiffness of the lumbar portion of the spine and localized tenderness at the level of the fourth lamina, with reduction of the lumbar lordosis. Again a positive Laseque test and Naffziger test, but with paresthesia involving the fith lumbar and the first sacral and perhaps the second sacral dermatomes. Ankle and knee jerks uninvolved. Hyperesthesia and paresthesia in the fifth lumbar and first sacral dermatomes, (84).

If in the fifth lumbar interspace, there is disability of the lower part of the back with absence

SIGNS AND SYMPTOMS

of lumbar lordosis and localized tenderness to pressure over the fifth lumbar interspace. Again a positive Laseque test and Naffziger test, producing paresthesia radiating into the first and second sacral dermatomes; diminution or absence of ankle jerks; along with this, hyperesthesia involving the first and second sacral dermatomes, (84, 69).

There is some controversy over the presence and importance of these symptoms. I believe that this is due to the frequency of the lesions in the fourth and fifth lumbar and the failure of some men to include this in their interpretations.

To continue with the general symptoms of this syndrome, there is usually paresthesia present, along with a feeling of weakness in the affected leg. There is a picture of sciatic scoliosis toward the affected side and usually lumbar kyphosis, which is due to muscle spasm and disappears with rest. The Laseque sign is positive and the Achilles tendon reflex is usually diminished or absent. There may or may not be any alteration in the spinal fluid protein. There is no value in manometric studies or other spinal fluid determinations. The Naffziger and reversed Queckenstedt are of doubtful value.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of this condition does not present any difficulty after symptoms of nerve involvement have developed. It consists mainly of ruling out degenerative changes in the spinal column. After nerve involvement, the patient is entitled to an operation, whether it is due to a cord tumor or metastasis. The conditions which most closely resemble posterior herniation of the intervertebral disc are low back pain, (whatever the cause), lumbosacral strain, sacro-iliac disease, spondylitis, and hypertrophic changes involving the spine. Meyerding found that 60% of the cases of spondylolisthesis with sciatica had an accompanying protrusion of the intervertebral disc, (62), Lumbosacral plexus neuritis may be confused with this condition, but with an increase in the total protein in the spinal fluid and fluoroscopic studies this can readily be differentiated. Usually there is a rather minor amount of neurological findings, but in some cases there may be a clinical picture simulating cord pathology such as syringomyelia or multiple sclerosis. At the Mayo Clinic, Love and Camp diagnosed a case as diabetic neuritis because of the severity of the diabetes mellitus. They also had trouble differentiating between sciatic neuritis and

fibrositis, but since the pictures were not altogether typical and were of such a long duration, they examined the spinal cord with lipiodol and elicited the lesion, (55, 69). Anderson reports a case and brings up the possibility that pressure on the cauda equina may be produced by a meningitic cyst which has been produced by the mechanical irritation of a protruded intervertebral disc, (6).

It is generally agreed that when a patient has received the routine conservative treatment for any of the above conditions, without any appreciable benefit, the possibility of a posterior protrusion of the intervertebraldisc should be considered as the cause. It should also be considered in all cases of intractable and recurrent sciatica. Adson emphasizes the importance of adequate physical therapy, but does not want the patient to go too long, (3).

One cannot discuss the diagnosis of posterior herniation of the intervertebral disc without describing the roentgenographic examination. When this is attempted a point of the greatest controversy is approached. This divergency of opinion is over the value of X-ray studies in the presence of the above described symptoms and also

in the media used to visualize these lesions.

The trend in the above controversy is to place the roentgenographic studies in a place of confirmation rather than diagnosis, due to the fact that Schmorl and many others found that this lesion was present in about 15% of cases in which it did not cause symptoms. It has also been established that air should be used first and then, if indicated, lipiodol should be used finally. This is due to the fact that many cases of intraspinal irritation have been reported with the use of lipiodol.

The value of lipiodol and air injections has been shown in the above charts. It has been found by most investigators that lipiodol injections are around 90% diagnostic, while the value of air myelography varies all the way for 50% to 90%. This will undoubtedly be stabilized somewhere between the two figures, as experience in the interpretation of air myelography increases.

Hampton has advanced, in my opinion, the best indications for the use of lipiodol. He states that while lipiodol may be safely injected into the spinal subarachnoid spaces, if the procedure is properly carried out, the patient who is to be the subjected to this

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examination should be carefully selected, and if the patient is suffering from a disease sufficiently disabling to warrant a major surgical procedure for relief, but the discovery of a narrowed joint space by plain roentgenogram is not an indication. It should be remembered that iodized oil in the spinal canal is a foreign substance and remains as such for many years. Most of the post-injection complaints of patients who have had this injection, result when the oil is allowed to enter into the cranial vault. They are usually in the form of intense headaches, and there is no known treatment for them other than symptomatic relief, due to the fact that there is no method for the removal of the lipiodol. Therefore, the patient should be instructed not to stand on his head after the injection, (41). Camp in an earlier article agrees with Hampton, although he emphasized the importance of multiple lesions. He found that 12% of patients had multiple lesions, (20).

In all cases fresh iodized poppy seed oil should be used. It is usually colorless, but when allowed to stand it becomes amber or yellow. If the patient has had previous injections of air, this procedure should not be carried out until all of the air has disappeared,

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as the collapse of the subarachnoid space or retention of air may prevent a free flow of the oil during the examination. A previous lumbar puncture may allow a leak and interfere with the interpretation. Five cc. of the oil are required, since lesser amounts do not fill the spaces adequately and more are not necessary, as there is a greater incidence of untoward symptoms. The examination may be made at any time after the injection, although it is preferable on the same day, due to the fact that the patient may be uncomfortable for a few days after the injection and his cooperation is valuable.

The patient should be placed upon a tilting fluoroscopic table and the table tilted until the desired level of the fluid is obtained; then, using a spot-film attachment, anteroposterior, oblique and lateral films should be taken. This is essentially the technique in general usage, (41). This is the same technique used by Barr, Hampton and Mixter in 1937, (10).

Walsh and Love have come to the conclusion, after a search of the literature, that there is some variability in the reaction of the meninges to iodized oil. They found that there is a transitory meningeal irritation similar to that of air injections, spinal or

cysternal punctures. They have observed oil present in the subarachnoid space after a period of ten years. They state that after seven to ten years, the oil is transmitted to the nerve sheaths of the spinal nerves, where it causes no symptoms, (90). They are in direct agreement with Craig, who earlier advanced the same ideas, (25).

While the exact interpretations of the defects produced by the shadow of iodized oil are too much involved to be discussed in this dissertation, the factors which influence this shadow, as related by Compere and Love, are of interest. They are: the position of the protrusion, the size of the protrusion, associated hypertrophy of the ligamentum flavum, changes in the nerve roots (displacement, edema, nonfilling of affected nerve root sleeve), and anatomic variations of the cul-de-sac, (20, 54).

Reichert first substituted air for iodized oil as a contrast media in 1937, (75). Stookey, in 1937, used air for demonstration of these lesions with good results, but still he wouldn't substitute this method entirely for lipiodol, (87). In 1939 Reichert reported thirty-five cases with excellent results, calling the

procedure "Pneumomyelography", (76).

Chamberlain and Young in 1939, after use of air and oxygen in over three hundred cases, found that they were excellent contrast media for the visualization in the spinal canal of posterior protrusion of the intervertebral disc or any other space filling lesion, (22).

The technique that the above authors followed varied somewhat in visualizing lesions at different levels, but for lesions below the third lumbar vertebrae the following procedure was followed: The patient is placed in a lateral decubitus position with the head of the table lowered to an angle of about twenty to twenty-five degrees. A spinal needle is inserted at the second lumbar interspace, and spinal fluid and air are exchanged in five cc. quantities until air escapes through the needle. This usually is about forty to fifty cc. Visualization of air with this technique depends on roentgenograms of good contrast and detail. They used "overexposed" films and therefore raised the kilovoltage. They found that the minimal film requirements were sterioscopic lateral and posterior studies, but also advised the use of oblique sterioscopic projections. Following

the above technique, the diagnosis depends in every case, except in complete block where the inferior margin of the shadow is demarcated as a definite bubble, upon the indentation or encroachment of the limiting membrane of the subarachnoid space, (22). Coggeshell and von Storch showed the same results previously, although their experience was limited to three patients, (23).

Both Chamberlain and Young, Scott and Young, Coggeshell and von Storch found that air studies are not misleading, as in no instance in which air myelograms indicated a lesion was it not verified at operation, (22,23,95). They found that the advantage of air over oil myelography was that in air myelography there was no unabsorbable, irritating substance left in the spinal canal, and therefore, there should be less hesitancy about subjecting the patient to myelography, (22, 23, 89).

Young and Scott reported good results when three to six cms. of air were injected into the spinal canal and trapped by the lesion. Roentgenograms were taken in the sitting position and the air was shown trapped by the protrusion. They found positive findings in the thirteen cases that they examined. The disadvan-

tages of this method are the same when less than five cc. of lipiodol are used, the bubble cannot be controlled and doesn't completely fill the desired level of the subarachnoid space, (95, 89).

One cannot discuss this syndrome without mentioning the hypertrophy of the ligamentum flavum. As has already been described, the upper boundary of the intervertebral foramen through which the spinal nerves pass is formed by the ligamentum flavum. Elsberg in 1913 was the first to describe this condition, and since then many authors have related its presence, usually in conjunction with a posterior protrusion of the intervertebral disc, (33). Flothow, in 1938, brought out the similarity of posterior protrusion of the intervertebral disc and hypertrophy of the ligamentum flavum; relating that this condition should be looked for if the protruded disc cannot be found, (36).

The ligamentum flavum inserts between continuous lamina and is connected in the midline with the interspinous ligament, laterally it joins the anterior capsule of the apophyseal joint. In the lumbar region the upper portion of the intervertebral foramen is transversed by the spinal nerve and the lower portion is a

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slit bounded in front by the intervertebral disc and behind by the ligamentum flavum. Therefore, the nerve may be compressed, either as it descends into the slit or as it leaves the foramen. Horwitz suggests that the ligamenta flava hypertrophies due to injury are usually a rather minor injury, and the patient may not even think of this as a cause. This lesion occurs almost always in the lumbar spine. Microscopic studies made by Horwitz showed thickening of the vessel walls, fibrosis, areas of blood pigment and calcification. Abbott agrees with the theory that the hypertrophy of the ligamentum flavum is due to antecedent trauma and the formation of scar tissue, (1). Abbott also stresses the importance of hypertrophy of the ligamentum flavum in cases where objective findings of posterior herniation of the intervertebral disc are lacking. He believes that many of these conditions are overlooked, since so much emphasis is placed on lipiodol injections, (1).

Meredith and Lehman, in a review of the twenty-three cases of hypertrophy of the ligamentum flavum that had been reported in the literature up to October 1938, pointed out that in all cases the symptoms caused by the hypertrophy resembled very well the same syndrome caused

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by posterior herniation of the intervertebral disc, and therefore, its only significance was its pathology, (61).

Spurling, Mayfield and Rogers, in 1937, called attention to hypertrophy of the ligamentum flavum in low back pain, and also to the fact that the syndrome closely resembles that of the posterior herniation of the intervertebral disc. They also called attention to the fact that not only a hypertrophy of the ligamentum flavum entered into this picture, but also the thickness of the vertebral laminae. In a series of cases they found that the ligamentum flavum in the lumbar region was on the average about 7 mms. thick and that the laminae were on the average about 7.2 mms. thick; thus proving that there is no significant difference in the size of the laminae and ligamentum flavum in the lumbar region, (85).

Love noted in one hundred seventy-five consecutive cases of posterior herniation of the intervertebral disc that, in one hundred fifty-five of these cases, there was hypertrophy of the ligamentum flavum. He then calls attention to the fact that hypertrophy of the ligamentum flavum rarely, if ever, occurs without the accompanying posterior protrusion of the intervertebral disc, and therefore, in every case at operation

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when a hypertrophy of the ligamentum flavum is found there should be a very diligent search for the protruded disc, (51).

TREATMENT

The treatment is different from that usually advocated for the treatment of a newly formulated syndrome in that there is general agreement as to the treatment after the condition has been diagnosed; that is, laminectomy; the only controversy being over the type of laminectomy which should be performed. Capener, as late as 1937, hesitated to remove the lamina for treatment of this condition because of interference with motion of the spinal column, (21).

It is again in general agreement that every case of low back pain should have the usual conservative treatment for an adequate period of time; if no relief is obtained, then the more radical treatment of laminectomy or spinal fusion should be thought of.

Conservative

P. C. Williams has brought out the fact that in the treatment of posterior herniation of the intervertebral disc or any other lesion of the lumbosacral spine--either conservative or surgical--two mechanical principles must be accomplished; First--a widening of the posterior half of the lumbosacral intervertebral joint space; thus, increasing the size of the intervertebral

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foramen. Second--an elimination of motion at the lumbosacral articulation. He believes that during the acute attack following the original trauma or during a recurrent attack, the primary treatment is the same--conservative, (94).

There are many different methods used for conservative treatment, such as plaster jackets, braces, belts, bed rest with traction or with flexion. In general their main use is to accomplish the above mentioned principles--widening of the intervertebral foramen and elimination of motion at the lumbosacral region.

Probably the most efficacious method is the ambulatory treatment with a plaster cast. Williams has the best description of its application and use. His method is with the patient in such a position as to eradicate the lumbosacral lordosis as the plaster of Paris jacket is applied. The above position is best obtained by having the patient rest his weight on his elbows which are supported on a table the height of which is above that of the lower rib margin. Posteriorly, the cast is applied from the scapula to about the third sacral segment. Anteriorly it extends down to the pubis. if the patient tries to stand in an erect position he

he experiences pressure on the buttocks which forces the sacrum and the pelvis forward; this reduces the lumbo-sacral lordosis. The cast should be worn from two to four weeks after the symptoms have subsided, (94). Barr and Mixter agree that the above mentioned method is in all probability the best method of conservative treatment, and state that patients who do not experience relief within a few weeks by the above method or bed rest usually require surgery, (11). Steele treats this condition with minor surgery, such as hospitalization, heat, massage and epineural injections with novacaine, but in my opinion if any surgery is indicated, it is a laminectomy,(86).

Kuhns has advanced another method of conservative treatment for these conditions. He believes that the best method of securing immobilization and ligamentous relaxation in the low back is to keep the patient in a firm bed with the entire body horizontal except for a slight flexion of the hip joint to relieve any strain on the ham string muscles. This is best accomplished when the patient is on his back by placing a pillow under his knees, and when the patient is on his abdomen the pillow should be under the abdomen. Along with this he

advocates physiotherapy, which appears to be of definite value. He lists the following criteria for good spinal support by means of the conservative treatment: It should be long enough to extend several vertebrae beyond those attached to the sprained ligaments. It should be firmly attached to the pelvis. It should be fitted to hold the joints of the lumbar spine in a position midway between flexion and extension--the optimum position for function, (49).

Radical

When surgery for the above condition has been decided upon as the method of choice, there is much controversy over the procedure to follow; not only in the type of laminectomy, but also who is to do it. Some people believe that the neurosurgeon should perform the operation, since he is familiar with the surgery of the nerves and their sheaths; while others believe that, since the condition is one in which there is involvement of the skeletal structures, the orthopod should be the one of choice, (16). Barr and Mixter believe that the orthopod should treat the chronic case until it is decided that the conservative treatment is of no avail.

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Then the neurosurgeon should be called in on consultation and a myelogram done. Both of the specialists should perform the operation, and the neurosurgeon should take care of the postoperative orders, but the orthopod should prescribe the postoperative exercises, (11).

I shall attempt, in the following paragraphs, to give the description of the operative procedures of choice. It is the one, which after a survey of the literature and reading the various authors ideas, is the method advocated. It should be remembered that according to Johnson's statistics and those of other authors, these patients have suffered about five years from the initial onset and, therefore, anything that can be done for their increased comfort is indicated, (45). All authors bring out the chronicity of this condition.

Love and Walsh have described the procedure of laminectomy very concisely and thoroughly, and many of the authors refer to it in their treatment of the posterior herniation of the intervertebral disc. They advocate that the patient enter the hospital the afternoon before the operation. If the patient should be in acute pain, enough sedation--morphine or barbiturates--should be given so the patient obtains a good night's

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rest. The routine preoperative orders are given, (57).

There is increasing use of sodium pentothal in the more recent literature, but the usual anesthetic is nitrous oxide and oxygen induction, then the use of ether. It is also agreed by Love and Camp, that ether is the anesthetic of choice, especially with the use of an intratracheal tube, (52).

The patient is placed on two longitudinal pillows which extend above the shoulders and rest on the clavicles, and a large pillow is placed directly under the crests of the ileum at right angles to the long pillows. This is not only an aid to breathing, but also flexes the patient's back which separates the spinous processes and facilitates the laminectomy. The skin is given the routine preparation, although it is better to have it done the night before.

The muscles, (erectores spinae), are reflected from the bone, (spinous processes and laminae), subperiosteally; this minimizes bleeding and trauma to the muscles and is of advantage in closing. The muscles need to be reflected on only one side in a hemilaminectomy, although it facilitates working and it is often advantageous to expose the other ligamentum flavum, since

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it may be hypertrophied and require resection also. It is not necessary to strip the muscles widely, undercut or crosscut them, as packing gauze sponges between the bone and reflected muscle not only controls bleeders but also irons out the muscles, giving a suprising and adequate amount of exposure, (57).

These authors recommend, in doing a hemilaminectomy, that none of the spinous processes be removed. They place a maximum of two spinous processes to be sacrificed, with the precaution that one may, through injudicious use of rongeurs, remove abnormal ligamentum flavum without realizing the fact.

This should reveal the affected nerve root, which is often enlarged and reddish purple; careful retraction of this root should show the protrusion. If the dura is to be incised for the removal of the radiopaque oil, this should be done only after the protruded portion of the disc has been removed. There are three advantages in this: One, better hemastasis. Two, less likelihood to cause trauma of the affected nerve root, as the cerebralspinal fluid absorbs some of the shock. Third, if one should incise and drain an inflammatory mass meningitis is less likely to occur.

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They make the exception in regard to the transdural removal of protruded disc in the case of midline protrusion; these are relatively infrequent in occurrence especially those which have produced a block and paraplegia. Because of the size and the edema of these protrusions in the midline, they are best removed transdurally.

The authors recommend that all incisions be dry before closure; the veins are more apt to cause hemorrhage with a resultant hematoma in the wound site. One may oftentimes secure hemastasis by: (one), placing a cottonoid strip along the extradural vessels and applying suction; (two), placing a small pledget of muscle in the same manner. In extreme cases when hemastasis cannot be secured, silver clips may become the method of choice. Electrocautery is not recommended because of the likelihood of injury to surround nerve tissue. In some cases a gauze strip one inch wide is packed along the extradural vessesls with the use of method one above, and the gauze strip is removed forty-eight to seventy-two hours afterward through the wound, (57).

Although many authors, notably Barr and Mixter,

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Dandy, use practically the same operative technique with little or no variation, the article from which I have taken the above incomplete procedure seems to be the rosetta stone of operative technique in posterior protrusion of the intervertebral disc, (9, 28).

The evolution of the above technique has been long and tedious. At first it was thought necessary to remove a number of laminae on both sides, with resultant vertebral weakness, thereby, producing more instability with a corresponding increase in the factors which produced the original condition. This was advanced by Love and Walsh, Mixter and Barr, Naffziger, Camp, (56, 11, 66, 19). For awhile fusion was done routinely; however, due to the work of Meyerding in 1938, it is now done only in cases in which spondylolisthesis is an accompanying factor, or according to Keegan, whenever after a lapse of time there is definite instability in the vertebral column, (63, 47). The main factor in the evolution of operative technique is how much bone should be removed. This has progressed through the stages of multiple laminectomies around 1930 to single laminectomy, to hemilaminectomy in 1938 by Keegan and Finlayson, Love, and many others, Hamby in 1940 advocating removal of

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posterior protrusion of the intervertebral disc at the fourth and fifth lumbar interspaces without removal of any bone, (40), to the present time when partial hemi-laminectomy in selected cases as advocated by Keegan and Love, where no bone is removed, (47, 57).

The postoperative treatment of a patient who has had a laminectomy should be routine. He should be turned every four hours for the first forty-eight hours, never being allowed to lie on his back and it should be done by the nurses. After forty-eight hours, the patient may turn himself. If no bone has been removed, the patient is allowed up on the day following the operation, but usually the patient is not allowed up till around the sixth to eighth day, and is allowed to go home on the twelfth day. It is advised that the patient should not do any lifting or straining for at least a period of three months. Love and Walsh bring out the fact that, due to the chronicity of the injury, the patient has a tendency towards psychosis--may have vague aches and pains, developing self-pity, and becoming just as bad as before the operation. Therefore, they recommend that the patient take a vacation, the longer the better, but two months is advantageous, (57).

Prognosis after Laminectomy	Barr	Love & Greig	Neffsinger	Mixter Ayers	Love Walsh	Barr Mixter	Farrell	Barnard	Keegan	Johnson
Reference Number	9	55	67	65	57	11	35	10	48	45
Number of cases	40	50	Obser.	30	500	155	Believes results of fusion alone just as valuable	50	40	40
Return To Unrestricted Labor	80	15%	75%	8		18%		64C	17.5%	83%
Restricted Labor	9C	15%	35%	12		18%		24	10%	12.5%
Died of Complications	1C			1%		2%		2%	0	0
Recurrence	1C?					5%		4%	0	0
Disabling muscle weakness Paralysis	2C			0					0	0
Post op Narrowing - Disk	13								?	0
Spinal fusion Complete relief Fused						91%				
Spinal fusion Complete relief Not fused				1		69%				
Spinal Fusion Partial Relief Fused						67%				
Spinal Fusion Partial Relief Not fused						25%				
Complete Relief	2	33	33			70		57.5%		
Relief of Pain	29	15	15			95%		88C		

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I shall attempt to show the prognosis of this condition after laminectomy. It is very difficult to evaluate the final result. I believe that the best way to show the findings of the various authors is to arrange them in the form of a chart, which will not only show the number or percentage of complete cures, but also the types of cures:

To explain the above chart: Complete recovery means that the patient, after laminectomy, had no residual symptoms of any sort and was able to return to his old occupation without any disability.

Relief of pain pertains to the sciatic pain. Patients still had some restriction of motion and were unable to return to manual labor.

Restricted and unrestricted labor is only a division of those with recovery. It shows how the patient may be rehabilitated.

The complications of which the patients died were limited to paraplegia of long standing, which was not relieved by the laminectomy and there were a few patients who died of postoperative pneumonia and one death due to anesthesia has been reported.

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Those patients who did not experience recovery complained of pain down the distribution of the sciatic nerve while in cases where there had been paralysis there seems to be a tendency for it to persist. There are others reported to have trouble sitting, but able to get around all right withoug any pain, (55, 9).

As can be seen in the above chart, the prognosis of recovery after laminectomy has gradually increased until at the present time the percentage of recovery varies from about 60% to 80%. The only way that this can be explained is that with the increasing experience of the operators, the surgery performed is more careful, and more important, with the increasing skill in diagnosis of this condition, the diagnosis is made much earlier before irrepairable damage is done, (16).

The advantage of this treatment can be ascertained by the above chart. It can be shown that and individual who is supposedly an invalid for life can be rehabilitated. He can be put back at his old job or at least can be helped to the extent that he is able to make a living.

The economic importance of this condition is

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just coming into the picture, since Adson brings up the fact that a patient receiving compensation in any form is the slowest to recover, along with those who have an inferiority complex, (4). There is going to be much controversy over this phase, due to the fact that so many people suffer some sort of back ailment. If this condition becomes compensatable everybody with a pain in his back is going to have a posterior protrusion of the intervertebral disc. Low back pain has always been a subject of much controversy with the insurance companies, and now that a definite pathological condition may be present, the strife has become of greater magnitude. Johnson in his article has shown the interval between diagnosis and operation was held up because of the difference of opinion between the insurance company and the patient, (45). Another reason for this feeling of uncooperation between insurance company and doctor is due to the fact that not all cases are cured, and if the operation is not a success the patient is entitled to draw compensation regardless. This also may cause the patient to malinger, even though the operation was a success and relief has been attained. The reason that I bring in the insurance side of this condition is be-

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cause most of the cases occur in industry, due to the fact that trauma plays such an important part in the etiology of this condition.

One factor which I wish to bring up in closing is the possibility of recurrence of this condition. This is becoming of importance and is explained by the fact that the affected disc may have been broken into many fragments, only one of which protruded and produced the symptoms at the time of the first operation; subsequently, a larger piece of the intervertebral disc has protruded since the first operation and may have deranged the supports of the intervertebral disc--namely, the posterior longitudinal ligament. Both Love and Walsh state that when there is a recurrence at the primary site it is usually larger and in the midline. This has been used as an argument for the routine spinal fusion after removal of the protruded disc, although again Love, Walsh, Keegan and Barr state that fusion is no assurance that the condition will not recur anyway. They also bring into consideration the economic factor of fusion, along with the fact that recurrence occurs in only about 1% of the cases. Therefore, from the literature I am inclined to believe that the treatment of

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choice in this condition is partial hemilaminectomy without spinal fusion until at least instability of the spine occurs, (56, 47, 9).

SUMMARY

In summarizing I should like to point out the following facts:

1. The importance of the entire spinal column in all forms of back pain cannot be stressed too highly. The mechanism of the production of posterior herniation of the intervertebral disc cannot be understood unless a thorough knowledge of the anatomy, physiology and pathology of the spinal column is at hand.

2. The importance of the spinal column in our response to our environment is one of natures most outstanding facts.

3. Due to the inaccessability of material for the study of the spinal column, this field had been neglected a great deal, not only in research, but also in the education of all young doctors.

4. Trauma is one of the most important factors in the production of posterior herniation of the intervertebral disc.

5. This condition can be diagnosed from the history and physical findings alone if they are given a very careful evaluation. One does not need laboratory tests, although they are of value.

6. After diagnosis, the treatment of choice is partial

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hemilaminectomy without fusion, since this gives the greatest benefit in the shortest time. The operation should be performed by a neurosurgeon with the aid of an orthopedic surgeon, who should prescribe the post-operative treatment.

7. There is a wide breach at the present time between compensation and amount of disability which can only be changed by time.

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