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HERNIATION OF THE INTERVERTEBRAL DISK

by

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INTRODUCTION

The increasing frequency with which the diagnosis of herniation of the nucleus pulposus has been made during the past few years has made it a very much discussed current topic.

The ineffectiveness of treatment and futility of attempting to demonstrate the actual cause of many cases of sciatica and low back pain have been appreciated for ages. The recognition of this lesion as an important cause of many cases of intractable and recurrent sciatica, the development of scientific means of diagnosing the condition, and the remarkable effectiveness of the present method of treatment have been responsible for the more recent revival of interest in the topic.

It is the purpose of this paper to present as accurately as possible the facts of importance which can be found in the medical literature concerning this relatively common pathological condition.

DEFINITION

Herniation of the intervertebral disk into the spinal canal is a protrusion of the elements of the intervertebral disk, and more especially the nucleus pulposus, posteriorly into the spinal canal. It usually results from trauma and manifests itself clinically by signs of compression of the spinal cord or nerve roots, usually giving rise to recurrent attacks of intractable sciatic and low back pain. The symptoms are aggravated by anything which suddenly increases the cerebrospinal fluid pressure, and permanent relief is obtained only after operative removal of the protruded portion of the intervertebral disk.

The accompanying chart shows the terminology that has been used by the various authors in their description of what is apparently a single pathological entity. One is hence at a loss to know the proper and accepted term for the condition and must keep these more or less descriptive names in mind when reading the literature which deals with this subject.

Middleton and Teacher Barr Mixer and Barr Hampton and Robinson	Rupture of the Intervertebral Disk
Stookey	Ventral Extradural Chondroma
Bucy Alpers, Grant and Yaskin	Chondroma of the Intervertebral Disk
Dandy	Loose Cartilage from the Intervertebral Disk
Sashin	Intervertebral Disk Extensions
Hawk	Ecchondrosis of the Intervertebral Fibrocartilage
Peet and Echols	Herniation of the Nucleus Pulposus
Mixer and Ayer	Herniation of the Nucleus Pulposus
Love	Protrusion of the Intervertebral Disk
Simonds	Herniated Nucleus Pulposus

HISTORY

The earliest mention of extrusion of cartilage from an intervertebral disk due to trauma was made by Virchow (54) in 1857.

Kocher (28) in 1896 reported a case of rupture of the intervertebral disk. A man twenty-six years old fell a distance of 100 feet, landing on his feet. He died within a few hours from internal injuries and an autopsy was performed. He was found to have had a rupture of the disk between the first and second lumbar vertebrae without any fracture of the vertebral bodies and with no apparent cord damage.

About this same time the condition known as "railway spine" (29, 6, 47) was becoming a recognized entity but little was known about it. No pathological defect was demonstrable by the methods of examination available at that time and most of the writers felt that the damage was psychical rather than physical. At least in many cases the patient recovered soon after he had been granted damages by the railway company. It was not long, however, until the use of X-ray became more or less general in the study of the vertebral columns and sacroiliac joints of the patients whose complaints were backache and sciatica. Since no lesion was demonstrable by ordinary roentgenography, the condition known as "railway spine" practically disappeared from the literature and we have no way of knowing how many of the cases may have had protruded intervertebral

disks.

The first classic description of herniation of the intervertebral disk was given by Middleton and Teacher (38) in 1911. A man, thirty-eight years of age, felt something 'snap' in his back while he was lifting a heavy weight and was unable to straighten up. He had only local pain in his back until that night when suddenly he felt as if his legs had gone to sleep and he could no longer move them. On physical examination he showed a complete flaccid paralysis of the lower extremities with absence of knee and ankle jerks, anesthesia to the level of Poupart's ligament, and incontinence of urine and feces. The patient died from urinary infection and autopsy revealed a mass one and one-half by one-half centimeters in size anterior to the dura with its edges detached and free, at the level between the twelfth thoracic and first lumbar vertebrae. There was no injury to the vertebral bodies but the spinal cord showed definite damage grossly and microscopically. The mass itself was white and firm and particularly resembled the pulp of the intervertebral disk. This case was the first to direct attention to the importance of the lesion in producing compression of the nerve roots within the spinal canal.

The first report of a case of herniated disk in this country appeared the same year (1911) when Goldthwait (21) reported the case of a patient suffering from a "right sacroiliac strain", who developed a flaccid paralysis of the legs with genito-urinary and rectal disturbances following an ether manipulation to reduce

the subluxation. The paralysis partially disappeared after the patient had been placed in a good position but recurred when the patient attempted to move about freely. The only other finding was slight tenderness at the lumbosacral junction. A laminectomy was performed but no lesion of the cauda equina was found except for a "narrowing of the osseous canal at the lumbosacral junction". The patient made a slow partial recovery. Goldthwait concluded that the lesion was a posterior displacement of the lumbosacral intervertebral disk with pressure on the cauda equina and suggested that other cases of lumbago, sciatica, and paraplegia might be due to pressure on nerve roots from a displaced intervertebral disk.

Following this, Adson was the first to remove the protruded disk by operative procedure. In 1922 he performed a laminectomy and removed the disk which had been pressing on the cervical portion of the spinal cord with the consequent production of neurological symptoms in all four extremities. After fifteen years the patient was still alive and able to work as a barber (33, 34). The same year, Adson cured a dentist of intractable sciatica by removing a protrusion of a lumbar intervertebral disk (32).

Stoekey (52) reported seven cases in 1928 whose symptoms and findings were due to compression of the cervical portion of the spinal cord resulting from protrusion of cervical intervertebral disks.

In 1929, Dandy (14) reported two cases of "loose cartilage" which was detached from the intervertebral disk and caused pressure

on the spinal cord. He stressed the fact that the lesions were traumatic in origin.

Bucy (11) in 1930 reported a case of a patient who had a tumor of one of the lumbar disks which was removed at operation. The case was entirely similar to those already mentioned but he felt that the tumor mass represented a true neoplasm.

Until the last four or five years, these patients were operated on so infrequently and so late in the course of the process that at the time of operation the clinical picture was that of compression of the spinal cord such as it caused by a neoplasm. For this reason these cases were formerly classified as extradural tumors of the spinal cord. The reports of Mixter and Barr (41) in 1934 and of Mixter and Ayer (40) in 1935 served admirably in focusing attention on the condition and since that time the condition has been recognized earlier and operation performed before the classic symptoms and signs of neoplasm of the spinal cord develop.

ANATOMY

The intervertebral fibrocartilages or disks are interposed between the adjacent vertebral bodies and form the chief bond of union between the vertebrae. They consist of an annulus fibrosus, a nucleus pulposus, and two thin cartilaginous plates.

The annulus fibrosus is a circumferential lamellar layer surrounding the nucleus pulposus. It is firm, fibrous, and chemically water-poor. It is formed by numerous fibers, solidly and tightly interwoven, which are inserted deeply in continuity with Sharpey's fibers into the compact and bony zone forming the outside of the vertebral surfaces. It has a few cartilaginous and conjunctive cells.

The nucleus pulposus is situated slightly posterior to the center of the disk commonly at the junction of the middle and posterior thirds of the vertebral body. It is a very elastic and tightly compressed material, which bulges out freely when the confining pressure is removed. The nucleus is expansile, soft, water-rich, and has a constant tendency to spring out of its confinement in the direction of least resistance. The cartilage plates are thin layers of hyaline cartilage, which cover the proximal and distal surfaces of the bodies (43, 46, 50). The intervertebral disks comprise from one-fourth to one-third of the entire vertebral length. They vary in size and shape with the bodies they unite. They are widest and thickest in the lumbar region. In the cervical and

lumbar regions they are thicker in front than behind, giving rise to a forward convexity of the spine. In the thoracic region, the disks are flattened and have only a slight effect on the posterior convexity of the dorsal part of the spine (46).

Intervertebral disks occur throughout the spinal column from the space between the second and third cervical vertebrae to the coccyx, but those present in the fixed vertebral segments, i.e. the sacrum and coccyx, are rudimentary and rarely if ever are protruded (32).

According to Keyes and Compere, the adult intervertebral disk does not contain any blood vessels nor nerves (27).

The embryology of the nucleus pulposus is interesting in that it is formed by the proliferation and mucoid degeneration of the notochordal cells followed by a fibrocartilaginous invasion derived from the original mesenchymal intervertebral cells which form the fibrocartilaginous envelope (27). Pease has found that the nucleus pulposus occupies from one-half to one-sixth of the total volume of the intervertebral disk and that this varies inversely with the age of the patient (44).

The nucleus pulposus retains its semigelatinous consistency even beyond the fifth or sixth decade and on sectioning the fresh specimen it is partially extruded by the elasticity of the annulus fibrosus (27).

Histologically, the nucleus pulposus shows some loose fibrous tissue, a few cartilage cells, some remnants of the noto-

chord and a gelatinous matrix (45).

Another structure of anatomical importance in consideration of the intervertebral disk lesions is the posterior longitudinal ligament. It extends from the second cervical vertebra to the sacrum and forms part of the anterior wall of the spinal canal. It aids in maintaining the intervertebral disks in position. The spinal cord lies directly posterior to the posterior longitudinal ligament (32). When the intervertebral disk is protruded the mass comes to lie usually to one side of the midline, a position to which it is directed by this powerful longitudinal ligament which lies on the posterior surface of the vertebral bodies in the midline (38).

Walsh and Love attempt to explain the sites at which protrusion of the intervertebral disks occur by calling attention to the anatomical shape of the spinal column. They have classified one hundred cases and found them to occur only at the points of greatest convexity or concavity; namely, in the fifth, sixth, or seventh cervical, fifth, sixth, tenth, or eleventh thoracic, or the third, fourth, or fifth lumbar interspaces (55).

After grouping nearly three hundred cases reported by various authors (23, 32, 40), I found that at least 85 per cent of all the protruded disks occurred in the lumbar region. Barr has reported on forty cases located in the lumbar region. Of these, sixty-five per cent were located below the fourth lumbar vertebra and thirty per cent were located below the fifth lumbar vertebra (9). From this one would conclude that the majority of cases of

protruded disk are found either at the fourth or the fifth lumbar interspace.

PHYSIOLOGY AND PATHOLOGY

The nucleus pulposus acts primarily as a spring to keep the vertebral bodies apart. The shape and the position of the nucleus pulposus can be only slightly altered. If pressure is applied to the intervertebral disk, the following happens; either the vertebral surface is depressed, or the fibrous ring bursts. If at any point the cartilage covering is perforated, the fibro-gelatinous tissue of the disk or nucleus pulposus seeps into the spongy tissue forming a button, the size of which ranges from a pin's head to that of a small pea. Such are the characteristics of the nucleus; a structure under pressure transforming and modifying the force of strain.

The nucleus acts as a true bearing inserted between two adjacent bodies. It is on the nucleus pulposus that movements of flexion and extension as well as lateral movements can be resisted with elasticity. The nucleus pulposus is thus important as an axis for the movements. When under pressure, it provides for the elasticity of the intervertebral disk and transmits, absorbs, and equalizes pressure (12).

Descriptions of the protruded mass of intervertebral disk are somewhat variable. The first account of the gross appearance of the protruded mass was by Middleton and Teacher (38). They described it as an irregular, roughly circular, flat mass of firm, white tissue which looked like the pulp in the center of the inter-

vertebral disks. Elsberg described one which was a hard tumor one by three centimeters in size and which had a sharp edge. It was firmly fixed to the posterior surface of the bodies of the sixth and seventh cervical vertebrae. He considered it to be a true chondroma. (15) Those described by Stookey were one by one-half centimeter to one and one-half by one centimeters in diameter. The tissue separated readily into thin layers of frayed, curly, cartilaginous material and somewhat resembled oyster chips (52). One protruded mass was described by Bucy as being yellowish and rubbery (11).

The microscopic findings have been somewhat varied. The general picture is essentially one of degeneration of the fibrocartilaginous constituents of the normal disk. The degenerative processes may be either slight or quite marked (34, 45). Love points out that it contains both nuclear and annular material and prefers to call the entity protrusion of the intervertebral disk rather than the more accepted term of herniation of the nucleus pulposus (32). Middleton and Teacher found that microscopic examination showed the structure of the protruded mass to be characteristic of the pulp of the intervertebral disks. Its margins were ragged and there were a few red blood cells clinging to them and entangled in the shreds. There was no sign of an inflammatory reaction about it (38). It should also be mentioned that some calcium and even bone is often found in the protruded portion of the disk. Remnants of the notochordal tissue are found in many specimens.

ETIOLOGY

When considering the causative factors of herniation of the nucleus pulposus, the most constant factor by all odds appears to be trauma (23, 17, 14, 9, 46, 53, 40). In Kocher's case the herniation was incident to a fall of one hundred feet after which the patient landed on the stone pavement on his feet (28). The trauma, however, may be of various types and result from a multitude of causes. The lifting of a heavy weight is probably one of the more common causes of such injury (9). Middleton and Teacher (1911) felt that the injury in their case occurred when the man had his back more or less bent forward with the lumbar and abdominal muscles in full action. This would cause a powerful compression of the intervertebral disks with the anterior margins of the vertebrae approximated to one another and therefore in a favorable position for displacement of the pulp of the intervertebral disk backwards if that were possible. They tested this theory of injury by an experiment to see whether the pulp of the intervertebral disk could be squeezed out through the strong surrounding ligament and to see what direction it would take. They used the first three lumbar vertebrae from the body of a normal, well-developed man. These were placed in a carpenter's wooden vice and pressure made more to the front than to the back. The cord and nerves had been cut out leaving the dura in situ. Before pressure was applied, the position of the intervertebral disks was shown by a slight bulging anteriorly.

After pressure had been applied a definite rounded prominence could be seen opposite the disk between the first and second lumbar vertebrae close to the side of the posterior longitudinal ligament. The pressure had not been very powerful, certainly not enough to crush the bones at all. More pressure was used and the swelling increased slightly. The arches were then cut out and the dura raised. The rounded swelling was found with the outer layer of the intervertebral disk still intact. On cutting through the disk with a sharp knife, it was found that the swelling was actually due to a displacement of the soft pulp, which had forced its way through the inner fibrous layers of the disk as far as the outer sheath. The corresponding area on the other side was unchanged (38). Thus they had shown that the pulp had been displaced and that it had travelled in the direction which it must have taken in their patient.

Further proof of trauma as the chief etiological factor is cited by Barr, who reported forty cases seen at the Massachusetts General Hospital. Of these, thirty-five were men and only five women. There was a definite history of trauma in thirty-one of the cases and in twenty-one of these there was an immediate onset of symptoms following the injury. (9) It is also notable that most of the cases occur in adult life and among those doing manual labor (40).

Love holds that the actual etiological factor is undue stress or strain on the fibrocartilaginous annulus fibrosis, but he would not have us lose sight of the fact that in a large series of cases twenty-five per cent were not able to recall any trauma which

might account for the condition (32).

Mixter and Ayer believe that a degenerative process which weakens the annulus fibrosis may be important and that this may explain why many cases occur either without trauma or with only a minor insult (40).

Another very definite factor in some cases of herniated disk has been called to our attention by Pease (44). He sites the case of a two year old child suffering with miliary tuberculosis and tuberculous meningitis on which a diagnostic lumbar puncture was done. During the procedure, resistance was encountered which felt like bone and which was thought to be the posterior surface of the body of a vertebra. A roentgenograph taken without removing the needle showed that it had penetrated the intervertebral disk and impinged against the lower border of the fourth lumbar vertebra. When the needle was withdrawn, the lumen contained nucleus pulposus material. Roentgenography following removal of the needle showed diminution in the joint space between the fourth and fifth lumbar vertebrae. In order to determine more accurately the dangers which might result from misdirection of the lumbar puncture needle, Pease experimented on cadavers, passing the needle beyond the neural canal. By this means he found that it could terminate in the intervertebral disk, the vertebra, the interarticular facets, or the venous sinusoids in the vertebral body. A discussion of Pease's article by Compere (44) emphasizes the fact that the danger of herniation of the disk is much greater in the child than in the adult following lumbar puncture.

This is undoubtedly due to the proportionately greater amount of nuclear material in the child. This unusual type of trauma then is occasionally the cause of herniated disk in children, while almost never do the other types of trauma produce the condition before early adult life.

SYMPTOMATOLOGY

The outstanding subjective symptom which leads the patient to consult his doctor in most cases is pain (5, 9, 11, 13, 17, 34, 38, 40, 48, 53). Love states that the chief symptom is root pain (34). He defines root pain as pain which begins within or near the spinal cord and is projected peripherally to that part of the body or extremity innervated by the nerve fibers which leave the spinal cord through the spinal nerve root emerging at that level.

In order to emphasize the importance of pain, it may be noted that it was the chief complaint in forty-five out of fifty cases studied by Love (34) and in twenty-one out of twenty-three cases of herniation of the nucleus pulposus in the lumbar region reported by Mixter and Ayer (40).

Many of the authors point out that the pain is usually unilateral but is sometimes bilateral (48). Too, it is characteristically intermittent (9). In some cases, the pain alternates between the right and left sides.

There is usually a low backache (5, 11), becoming paroxysmal on turning, stooping, coughing, and sneezing, whereupon it radiates over the thigh and the posterior or lateral portion of of the calf (9, 17, 48).

The distribution of the pain along the course of the sciatic nerve in such a large percentage of cases explains why

this condition is so often confused with the many others that also produce or are associated with sciatica. A history of onset of pain immediately following some type of trauma is valuable, especially since herniation of the disk may occur in a patient, as reported by Bucy, who has suffered sciatic pain from other causes prior to the injury (11).

Barr emphasizes the fact that the symptoms may undergo relapses and remissions and often the patient may be entirely free from symptoms for weeks or months (9). A relapse is frequently brought on when the patient suddenly changes position (17) as in stepping down from the curb or by straining, especially when at stool (13).

Love and Walsh explain the periodic disappearance of symptoms by the theory that the protruded nucleus pulposus in many cases returns into the intervertebral space only to be extruded again by additional trauma. In this connection they describe an experiment on a cadaver in their anatomical laboratory. A protruded fourth lumbar disk was found during dissection of the lumbar nerve roots. This person had a history of injury to the back with some subsequent back pain a year before death, but no other details were known. After exposure of the disk, it was decided to try the effect of kyphotic flexion and extension of the back. Kyphotic flexion caused the protruding disk to be drawn in so it was almost level with the posterior surfaces of the vertebral bodies. Hyperextension of the spinal column, on the

contrary, caused the disk to protrude markedly. The authors felt that some of the dramatic recoveries reported by irregular practitioners may have been the result of the return of the protrusion of the disk to the intervertebral space, thus freeing the nerve root of pressure (35).

Associated with the sciatic pain, one frequently finds the complaint of low back pain situated either in the lumbar region, over the sacro-iliac joint, or in the buttocks (32). Love and Walsh have conjectured that the low back pain is the result of pressure of the protruded cartilage on the posterior longitudinal ligament (35).

The wide variation, that is possible in the location and the extent to which the herniated disk compresses the cord or the nerve roots, makes it evident at once that there is necessarily a great variability in the location, radiation, degree, and constancy of the pain.

The lesion may be so extensive and so located as to cause a paraplegia in some cases; however, the sensory changes are usually quite variable or even vague. The vague sensory changes are most often found only in isolated and small areas. The sensation is usually reduced in these areas rather than lost. The cause for the vague sensory changes is apparent when one recollects that skin areas are usually supplied by more than one nerve root, but that the actual compression involves only a single nerve root. The patient often complains of motor weakness or paralysis but this

is undoubtedly due in part to the pain which is made worse when movement is attempted. The loss of sphincter control is present in those cases which suffer from severe damage to the cauda equina or medullary conus and is not an outstanding symptom (14, 38).

FINDINGS

When the patient is first seen, it is often noted that he moves cautiously to prevent jarring that would aggravate his symptoms (32).

On inspecting the back, there is frequently a postural alteration. This is often a loss of the normal lumbar curve, otherwise known as a 'poker spine', and/or a sciatic scoliosis (9, 32, 53). Fincher and Walker observe that the scoliosis may be either toward or away from the side of the pain (17). The reason for these alterations is generally agreed upon as a protective spasm of the lumbar muscles. Other changes in gait or posture may occur in any case and would be influenced by the location of the lesion and the extent of the damage to the spinal cord or nerve roots.

Simonds believes that percussion may be of value in some cases. He finds that there is tenderness on percussion over the low back region, the sacro-iliac joint, or the lumbosacral ligaments (48). Too, tenderness may sometimes be elicited by percussing directly over the herniated disk.

Neurological examination reveals a wide variety of findings and gives evidence of extradural compression of the spinal cord.

Motor weakness is frequently found and Stookey mentions the importance of muscle wasting (53). Not all of the writers would agree that muscle wasting is a significant finding. The muscles in

which atrophy is seen most commonly are the quadriceps, the small muscles of the foot, and gluteal muscles. Fibrillary twitchings may be present.

The sensory changes noted are exceedingly variable and often quite vague (53). Fincher and Walker feel that the only significant sensory finding is a slight sensory loss over the dorsum of the foot or calf (17). Sensory disturbances over the lateral malleolus are not uncommon, however.

The changes in the reflexes are more definite. Probably the most frequently altered reflex is the Achilles tendon reflex, which is either absent or diminished. Barr found the Achilles reflex absent in about half of the thirty-nine cases which he reported and in none of these patients did he find an absent knee jerk (9). A positive Lasegue's sign is also frequently found but is not especially significant (11, 55). Likewise, the Kernig sign may be positive.

It may be noted that Love and Walsh attempted to determine the exact location of the protruded disk in a series of one hundred cases by studying only the reflex changes, muscular weakness, and segmental sensory loss whenever present. They found it impossible to accurately do so but concluded that such findings do give excellent evidence as to the general region of the spinal column in which the protrusion may be found (35).

Lumbar puncture may yield valuable information but is a procedure which must be undertaken with caution in these patients.

Elsberg and Stookey site ten cases whose symptoms of spinal compression were aggravated after fluid had been withdrawn by lumbar puncture. Several became completely paralyzed after withdrawal of the fluid and one case developed a complete sensory loss below the affected cord level within forty-eight hours following puncture (16). Both Stookey and Dandy have confirmed the finding that lumbar puncture aggravates the symptoms (52, 14).

The spinal fluid pressure has not been emphasized except in so far as tests may be employed to determine whether a partial block exists. Barr found evidence of a block in only ten per cent of his series of cases while Mixter and Ayer found evidence of a block in only eight out of their thirty-four cases (9, 40). Certainly a negative result would not disprove the presence of a protruded intervertebral disk. Interference with the spinal fluid pressure elevation in performing the Queckenstedt test was also found in many cases by Fincher and Walker (17). Love states that the usual Queckenstedt test will reveal only a large lesion and that this lesion must be located above the fourth lumbar vertebra. Since a large per cent of the lesions occur at the fourth or fifth lumbar intervertebral disk, he believes that the "reversed" Queckenstedt test is much more valuable. The reason for the failure of the ordinary Queckenstedt test is apparent when one considers that the spinal puncture is usually done above the level of the lesion and thus no block is demonstrated. Since the technique for performing the "reversed" Queckenstedt test is not generally known,

it is included here. It is performed the same as is the epidural injection which is frequently used in the treatment of sciatic pain. A caudal needle is placed in the sacral hiatus and care is taken to be sure that the needle has not entered an abnormally low dura mater or a vein. A lumbar puncture needle is then inserted into the lumbar subarachnoid space, a manometer is attached and ten cubic centimeter fractions of a one per cent solution of procaine hydrochloride are injected into the caudal epidural space through the caudal needle. Normally there should be a progressive rise in the manometric readings as the caudal sac is compressed by the epidural procaine. Four fractions of ten cubic centimeters each or a total of forty cubic centimeters of a one per cent procaine solution are injected. If a tumor or a protruded disk of sufficient size to obstruct the caudal sac is present, no increase in the manometric reading will occur. A block on the "reversed" Queckenstedt test will have been established. Experience in performing this test is necessary lest one be misled into thinking a block is present when one does not exist. In cases of ordinary sciatic pain, not caused by pressure on the caudal roots, the sciatic pain usually is exaggerated and then relieved as the fluid diffuses and its anesthetic properties become manifest. In cases of compression of the caudal roots by a tumor or a herniated disk, the pain is unbearable and the epidural injection will have to be discontinued (30).

Regarding the spinal fluid itself, most of the authors

feel that the total protein content is the only valuable determination. Xanthochromia is found only rarely (40). The total spinal fluid protein is normally twenty to forty milligrams in one hundred cubic centimeters. Any elevation above forty milligrams per cent is considered as evidence of at least a partial block in the spinal canal. The level at which the block occurs does not seem to alter the finding of an increased total protein. Love and Walsh found it to be forty milligrams per cent or above in seven out of twelve cases in which the lesion was located in the cervical or thoracic region (35). Barr found the total protein to be forty-five milligrams per cent or above in thirty-six of his thirty-nine cases (9). Fincher and Walker found the total protein to be elevated in only one-half of their cases (17). One of the highest total protein findings was recorded by Love and Walsh whose patient had two hundred forty milligrams per cent (35).

Roentgenography by ordinary methods has not proved of value in intervertebral disk lesions (9). A narrowed intervertebral space is found in only a small per cent of cases and when found may mean only that there is degeneration and fibrosis with protrusion of the disk (30) or perhaps a protrusion either anteriorly or into the vertebral body. Hypertrophic changes about the margins of one or more joint spaces is seldom found and is not of value in localizing the lesion.

Compression fractures occur only rarely in connection with protrusion of the disk and do not aid in making a diagnosis (31).

The most convincing proof of the presence of a protruded intervertebral disk is obtained by fluoroscopy and roentgenography after instillation of a radiopaque oil into the spinal canal. This, however, should not be attempted until there is evidence that such a lesion exists. Love holds that if the spinal fluid protein is normal or low, that one should obtain a positive "reversed" Queckenstedt test before attempting to confirm diagnosis by the injection of iodized oil (35).

The choice of an iodized oil for intraspinal injection has been given much consideration by Frazer and Glaser. After experimenting on dogs and using a wide variety of iodized oils, they concluded that the most satisfactory, both physically and biologically, was iodized rape-seed oil diluted with ethyl olive oil. It is non-toxic and less irritating and has a lower viscosity so that it will not globulate as do oils of higher viscosity. Because of these qualities the authors claim that it can be used practically in spinal, cisternal, vascular, and ventricular injections (18). Regardless of these facts, the most widely used iodized oil is still the one called lipiodol. It is an iodized poppy-seed oil.

The technique for examination of the spinal column by using lipiodol has been well described by Love (32). Lipiodol should never be injected in the presence of a suspected inflammatory lesion. The temperature of the oil must not be above that of the body. It should not be used if it has become cloudy. Five cubic centimeters of the oil is injected into the second or third lumbar interspace

through a spinal puncture needle into the lumbar subarachnoid space. Careful fluoroscopic observation of the movements of the oil is then carried out while the patient is being tilted on a regular tilting fluoroscopy table. The characteristic defect produced in the column of lipiodol is anterolateral and situated opposite the intervertebral space. The table should be tilted enough so that the oil may be followed to the cervical region in all cases so as to determine if there are multiple lesions present. Often the defect produced by an enlarged, edematous involved nerve root can be detected in the shadow. It is also possible to detect a defect due to hypertrophy of the ligamentum flavum, if such a condition is present.

Simonds (48) emphasizes that since the most characteristic defect is produced by a mass ventral to the dural sac to one side of the midline, the defect can be seen best in an anteroposterior or an oblique view.

The success of localizing the lesion by this method is attested by Barr (9) who found it satisfactory in thirty-six out of thirty-nine cases. Hampton and Robinson (23) found that of twenty-three cases they studied with lipiodol, only one failed to show the location of the herniated disk.

Many writers claim there are no ill effects following the use of iodized oil but Hampton and Robinson (23) maintain that the reaction is definite and lasts for several days. This reaction consists of an elevated spinal fluid cell count, changes in the color and chemical composition of the spinal fluid, headache, slight

fever, and an increase in the symptoms produced by the lesion. Globus (20) has studied 138 cases of intraspinal injection of iodized oil. In only one case were there subjective complaints or objective findings which could be regarded as the aftermath of the injection. Sixty-five of these cases were again studied after a lapse of time varying from a few months to ten years. They were placed in the Trendelenburg position and examined under the fluoroscope. The mass of oil moved toward the dorsal region. It had not diminished in size and was not encapsulated. Three of the cases came to autopsy and there was no evidence of any leptomeningitis.

The advantages of using iodized oil for visualization of the intervertebral disk lesions have been summarized by Globus (20). In the majority of cases it helps to establish the exact level of compression of the spinal cord with a certainty greater than is offered by other methods. It often helps to distinguish an extramedullary from an intramedullary tumor. It may disclose the presence of several blocks at different levels. The patient is not subjected to unjustified hazards and yet may share all of the diagnostic advantages of the method. By excluding the existence of neoplasm, it often saves the patient from the hazards of an unnecessary operation. By guiding the surgeon to the exact level of the lesion, it often spares the patient one or more laminae.

Many objections have been raised to injecting into the spinal canal a nonabsorbable substance such as lipiodol. This is especially true in compensation cases where the opposing attorney

can show X-ray pictures of the foreign material that has been left in the canal and can claim that it is responsible for the patient's symptoms. These objections have led to some experiments in the use of other materials for visualizing the space. Stookey (53) reports that he and his associates have used air injections into the lumbosacral subarachnoid space in order to avoid introduction of a foreign substance. His method is to tilt the patient buttocks upward and by using from twenty to thirty cubic centimeters of air he has been able to outline the whole of the lumbosacral sac and demonstrate an impingement on the dura such as a herniation of the nucleus pulposus. He is encouraged by the results of his experiments and in at least one case was able to demonstrate the obstructive lesion by injecting air. He then confirmed the results by iodized poppy seed oil injection and proved it by operation, at which time the oil was removed.

No further reports have been published, so far as I am able to ascertain, concerning the use of air or any other substance in visualizing the spinal canal.

Doctors Keegan and Finlayson have experimented here at the University Hospital with the use of "diodrast". Fifty to sixty cubic centimeters of ten to fifteen per cent diodrast were injected according to the technique already described for caudal injection in the "reversed" Queckenstedt test. However, this method has not proven satisfactory as yet for visualizing the defects produced by herniation of the intervertebral disk.

DIFFERENTIAL DIAGNOSIS

Many conditions must be considered in the differential diagnosis of herniation of the intervertebral disk.

The most important one is probably an intraspinal neoplasm. This however does not cause much concern since its treatment is the same; namely, laminectomy and operative removal.

Some of the other common conditions which most closely resemble protruded disk lesions are: low back pain from any cause, lumbosacral strain, sacro-iliac disease, spondylitis and hypertrophic conditions involving the spine.

Some cases may resemble the clinical picture of syringomyelia or of multiple sclerosis. Sciatic neuritis and fibrositis may also be troublesome in making a differential diagnosis.

It is suggested by Love and Camp (34) that whenever any patient considered to be suffering from any of the above conditions has had sufficient conservative treatment and is not responding favorably, the possibility of a protruded intervertebral disk should be seriously considered as the cause of his disability. Certainly it should be considered in any case of intractable and recurrent sciatica.

TREATMENT

Prior to 1922, no effective method was known for treatment of cases of herniated intervertebral disk. One of the earliest methods recorded for giving relief in cases of spinal injury is that of Sayre (47) in 1893. He described four cases of spinal injury of long standing which were relieved when traction was made on the spinal column. It is not known whether the symptoms following these injuries were due to herniation of the disk but it is possible that one or more of them may have been. Relief in these cases lasted as long as the traction was maintained by a properly fitting plaster jacket.

The aggravation of symptoms and the danger of further injury to the patient which may result from manipulations of the vertebral column have been described by Goldthwait (21). He placed his patient in hyperextension. This greatly exaggerated the symptoms and resulted in sphincter loss as well as motor and sensory loss. Relief was obtained within two hours after the patient was removed from the hyperextension frame. Barr (9) also points out the fact that manipulations which place strain on the lumbar spine are hazardous and should be abandoned in treating herniated disk lesions.

The essential factor in treatment of herniated disk lesions is the removal of the protruded mass which is pressing on the spinal cord or nerve roots and producing symptoms of extradural compression.

Since Adson first successfully removed two herniated disks in 1922, there have been only minor changes in the operative technique. Laminectomy was performed in all of the early cases treated by operative removal. However, since the use of iodized oil, in localizing the lesion, has become an accepted method of diagnosis, the number of laminae removed has been decreased. Love, Adson, and Craig state that if there is only a single disk herniated, the removal of the spines and laminae of two vertebrae is sufficient (33).

At the University of California Medical School a hemilaminectomy is always done if the signs are unilateral in order to limit the removal of bone as much as possible. Stookey and others likewise advise hemilaminectomy as the operation of choice.

In order to lessen the amount of bleeding, Stookey (53) has advocated that the spines and laminae should be exposed by subperiosteal resection.

After opening into the spinal canal, the usual method is to incise the dura posteriorly in a longitudinal direction. This will allow one to examine the anterior dura for a bulging mass which would compress the cord or nerve roots. When this mass is located, the anterior dura is incised and the protruded portion of the disk removed. In many cases it is so sclerotic and firmly attached that it must be curetted out.

In contrast to the above described transdural approach for removal of the protruded portion of the disk, Adson (33) makes

an extradural approach in all cases in which the protrusion is lateral. This is facilitated by the resection of the ligamenta flava which are usually thickened in cases of protrusion of the disks. This affords adequate exposure for removal of the lateral protrusions.

An important consideration in connection with the laminectomy usually performed in these cases is whether the patient will ultimately have a strong back. Many surgeons have advised spinal fusion at the time of removal of the herniated disk in order to insure the patient of as strong a back as is possible. Love, Adson, and Craig (33), however, feel that the spinal fusion is not necessary. When not done, they maintain that no complications arise.

Love (33) keeps his patients in bed twelve days following the operation. He allows them to leave the hospital on the fourteenth day if there are no postoperative complications. They are not allowed to do heavy work for three months.

PROGNOSIS

Mixter and Barr (41) point out that with proper surgical treatment good results can be expected only if the compression of the cord or nerve roots has not been of too great duration.

Prompt relief from their sciatic pain following operation was experienced by all twenty-four of the patients reported by Fincher and Walker (17). However, Love and Camp are somewhat less enthusiastic in their reports, but have had excellent results. They cite fifty cases, thirty-three of which had complete symptomatic recovery, fifteen of which were benefitted and only two were not improved. One of these had had a paralysis below the sixth thoracic segment for two years and the cord was damaged beyond repair. The other patient had complained of backaches for twenty years, sciatica for twelve years, and also had a muscular dystrophy. The operative removal of his herniated disk was difficult and convalescence was prolonged.

It is noteworthy that these lesions seldom if ever recur once they have been properly treated.

The fate of the involved intervertebral disk is an important consideration. Barr (9) studied thirteen cases postoperatively and found in four of them that a definite narrowing of the intervertebral space had occurred.

Nearly all of the cases treated by operative removal of the herniated intervertebral disk have enjoyed freedom from the

symptoms of which they complained, some of them for as long as fifteen years without a return of the original symptoms.

SUMMARY

Herniation of the intervertebral disk is a definite anatomical and pathological condition which is rapidly gaining in importance.

The condition usually results from trauma which may be either slight or severe.

The most common symptom is root pain, usually of the sciatic type, which characteristically undergoes remissions and recurrences.

Diagnosis has been most successful after instillation of lipiodol into the subarachnoid space followed by roentgenographic examination of the spinal canal.

The treatment by laminectomy with removal of the protruded portion of the disk has been highly satisfactory.

This treatment is followed by complete or partial recovery in nearly all cases and the risk to the patient is minimal.

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