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PATHOLOGIC CLASSIFICATION, WITH SURGICAL CONSIDERATION, OF INTRASPINAL TUMORS*

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A REVIEW of a large series of intraspinal lesions for which operations were performed at the Mayo Clinic reveals a preponderance of benign tumors which were operable. The earlier intraspinal tumors are recognized, the less will be the damaging effects on the spinal cord and the more complete will be the recovery of the patient when the pressure has been relieved by the removal of the tumor.

The factors responsible for the development of tumors of the meninges, nerve roots, blood vessels and the spinal cord are similar to those responsible for the development of tumors elsewhere. They occur most frequently in the third, fourth and fifth decades of life, but may occur among children or among elderly patients.[24] Trauma may be a predisposing factor to the development of osteomata, sarcomata, foreign body giant cell tumors and fibromata. Trauma is also responsible for the rupture of the intervertebral disks with protrusion of the nucleus pulposus into the spinal canal. Although the lesion under consideration may produce symptoms similar to those of caudal tumors, it is not a true neoplasm. Trauma and chronic infection may give rise to hypertrophic arthritis and osteitis, both of which are capable of producing radiculitis and slowly progressive myelitis simulating the symptoms of intraspinal tumor. Primary malignant tumors of the osseous system, as well as metastatic lesions, are rarely considered surgical lesions, although a number of patients having such tumors have been surgically explored when it was not possible to make a preoperative differential diagnosis. Hemangiomata of the vertebrae, Paget's disease of the spinal column and Potts' disease of the vertebrae frequently produce involvement of the nerve roots and spinal cord, but are rarely benefited by surgical intervention.

Symptoms.—Tumors which arise from the tissues surrounding the spinal cord have been designated as "extramedullary," in contrast to those which arise in the cord itself, which have been called "intramedullary." Oppenheim

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and Frazier have divided the symptoms of extramedullary tumors into three phases. The first phase is that of involvement of nerve roots;[31] the second, that of beginning compression of the spinal cord; and the third, that of extreme compression of the spinal cord, producing the clinical picture of transverse section of the cord.

The outstanding symptom of involvement of nerve roots is pain, which is usually characteristic and pathognomonic.[18] It may precede any other symptoms by months or years; it may be constant or intermittent, persist in a localized region, and radiate over the involved nerves. It is usually lancinating, and is aggravated by coughing, sneezing, lifting and straining at stool, and it invariably awakens the patient from four to six hours after he has retired. It often becomes so severe as to compel him to walk the floor or to sleep in a sitting position. The mechanism that produces this pain apparently is the ball-valve action of the tumor, which is forced downward by the increased pressure of cerebrospinal fluid above it, thus producing traction directly or indirectly on the nerve roots. Unfortunately, many of the patients are treated for neuritis, muscular rheumatism, or syphilis, and some have been thought to have had hysteria. The importance of recognizing or suspecting the first, or painful, phase in the development of tumors of the spinal cord was emphasized in a recent survey by Craig,[13] in which 10 per cent of the patients who had root pain had been operated upon for some thoracic or abdominal lesion other than an intraspinal tumor.

The symptoms which develop in the second symptomatologic phase, the phase of beginning compression of the spinal cord, differ from those of the first phase in that neurologic evidence of compression of the cord now becomes evident. The symptoms may develop simultaneously with the existence of pain,[13] or they may develop without pain in a small percentage of cases. If the tumor is situated anterolaterally, the symptoms will progress and produce the Brown-Séquard syndrome, a homolateral paralysis of the muscles below the level of the lesion, with impairment of tactile and deep sensibilities on the same side, together with loss or diminution of pain and temperature on the opposite side. If the posterior columns of the cord are the first to be compressed by the tumor, the deep sensibility is decreased and ataxia appears. Sensory disturbances resulting from compression of the cord are gradual in onset, and progress upward to a transverse level corresponding to the segment of the cord that is compressed. At the lower end of the spinal cord other difficulties may be encountered. The relative shortening of the cord incident to growth, and the emergence of the roots through the anterior foramina of the sacrum often make it extremely difficult to determine whether there is a tumor of the conus medullaris, of the cauda equina, or of the sacrum. The objective findings may be the same. In this group studies with radiopaque oil are valuable in localizing and differentiating the lesion. Paralysis below the level of the tumor comprises the third symptomatologic phase, and is caused by extreme compression of the cord.[12] The paralysis is usually complete, sensory functions are entirely lost, trophic disturbances are present, and there is definite loss of control of both vesical and rectal sphincters.

Intramedullary tumors rarely produce pain, but pass directly into the second symptomatologic phase. The sensory and motor disturbances are progressive until a definite transverse level becomes evident. The upper sensory level is less distinct than that produced by extramedullary tumors. Increased reflexes and loss of vesical and rectal control appear early in the symptom-complex.[1, 14]

Examination.—The symptoms which play important parts in the diagnosis of intraspinal lesions emphasize the necessity of a comprehensive history in all cases. Following the taking and recording of the history, a detailed general, as well as a neurologic, examination is necessary. These examinations should include such special features as spinal puncture, Queckenstedt studies, and roentgenograms of the spinal column, with or without the introduction of iodized oil.

Neurologic Examination.—In the case in which tumor of the spinal cord is suspected there is no investigation so important as complete neurologic examination. The information elicited by a detailed testing of reflexes, muscular strength, muscular tonus, sensory acuity, gait, coordination, and balance tends to distinguish between degenerative diseases and compression of the cord.

Spinal Puncture.—This examination is very important, because it reveals information concerning the physical properties and the hydrodynamic properties of the spinal fluid,[8] and allows its chemical reactions to be determined.[2] The puncture is usually performed at the fourth lumbar interspace, and before any fluid is removed the intraspinal pressure is estimated by means of Ayer's water manometer, which normally registers between 12 and 15 cm. As soon as the pressure has been estimated, Queckenstedt's test is made. This consists of reading and studying the rate of rise of the cerebrospinal fluid in the manometer following compression of both internal jugular veins. Sudden rise and rapid fall of the fluid on compression of both internal jugular veins indicate free flow of cerebrospinal fluid within the subarachnoid space. Slow rise and fall of fluid or its failure to rise on compression of the jugular veins suggests partial or complete intraspinal block.

Inability to obtain fluid at the fourth lumbar interspace may signify that the tip of the needle has failed to enter the subarachnoid space, that fluid is absent, or that there is a tumor at this level. Puncture should be made at another level, and it may be necessary to make multiple punctures. Occasionally, it is necessary to combine cisternal puncture with lumbar puncture.

Spinal block, if it results from tumor, frequently causes an increase in the concentration of globulin in the cerebrospinal fluid below the tumor. The fluid may also be xanthochromic[17] (Froin's syndrome[21]). The shade of yellow may vary, and occasionally the fluid above a block is decidedly yellow. The cell count is usually normal, but pleocytosis may occur if the tumor is situated in the spinal canal below the conus medullaris. This may help in distinguishing neoplasms from inflammatory lesions.

The presence of partial or total subarachnoid block is not pathognomonic of intraspinal tumor, since previous attacks of meningitis, acute myelitis, injuries to the vertebrae, or spinal deformities are all capable of interfering

with the free flow of cerebrospinal fluid. It is, however, apparent that the finding of partial or total block is extremely valuable in diagnosis when the block is accompanied by a history of root pain, and with a negative history of inflammation or trauma of the spinal cord.

Roentgenographic Examination.—Roentgenograms should be made of anteroposterior and lateral aspects of the vertebral column.[22] These should be supplemented by stereoscopic and oblique views, localized at the level where, on clinical grounds, a tumor has been suspected. According to Camp and Adson,[10] evidence of erosion of the vertebral pedicles, laminae, and lateral and spinous processes caused by pressure usually is discernible before such erosion is evident in the body of the vertebrae. In general, roentgenologic evidence of changes resulting from tumors of the spinal cord consists of shadows indicative of erosion secondary to direct pressure, invasion by the tumor,

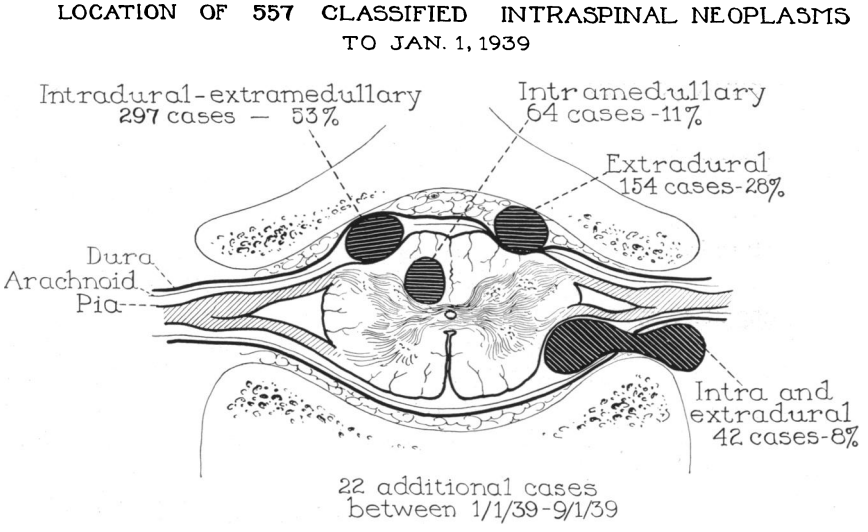

FIG. 1.—Location of 557 classified intraspinal neoplasms, to January 1, 1939.

destruction caused by benign or malignant tumor of the bone, metastatic diseases and hyperostosis.[9]

"Study with Radiopaque Oil.—In addition to the roentgenologic evidence of tumors which is apparent in routine examination of the spinal column, fluoroscopic and roentgenographic study by the use of radiopaque oil has furnished much additional information in diagnosis and localization of intraspinal tumors. Injection of 5 cc. of iodized oil into the subarachnoid space, either through cisternal puncture or lumbar puncture, allows visualization under the fluoroscope of the patency or lack of patency of the subarachnoid space. Fluoroscopic examination of the slowly moving oil is superior to examination of a roentgenogram, since the roentgenologist often sees the diversion of the current of oil around the tumor. However, roentgenograms should be made for confirmation of the levels where tumors are suspected to be. Intramedullary tumors are identified by division of the oil into two currents, one on each

side of the cord. Use of the heavier oils avoids their ascent into the cisterns and ventricles. Because introduction of these oils invariably produces irritation of the meninges, and occasionally radiculitis, they should be used only to localize tumors definitely. After the oil has been injected, the patient should

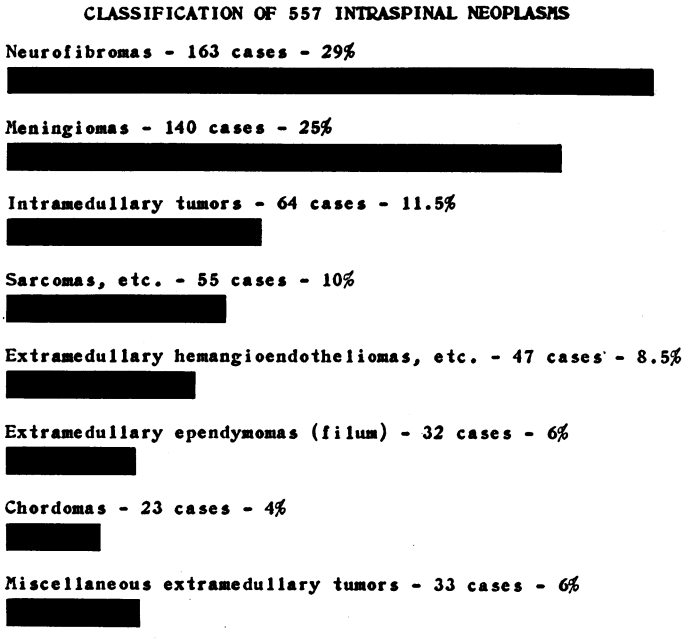

FIG. 2—Classification of 557 intraspinal neoplasms.

be placed prone on the fluoroscopic table, and the flow of oil should be observed when he is tilted in various positions, from horizontal to perpendicular. Experience with the use of radiopaque oil in the diagnosis of tumor of the spinal cord has indicated that oil should be used infrequently, only when tumors are suspected, and that the oil should be removed at operation whenever possible. The presence of extramedullary tumors usually is indicated by definite arrest of the flow of lipiodol. If there is no tumor or compression of the cord the oil descends and remains permanently in the sacral cul-de-sac."[32]

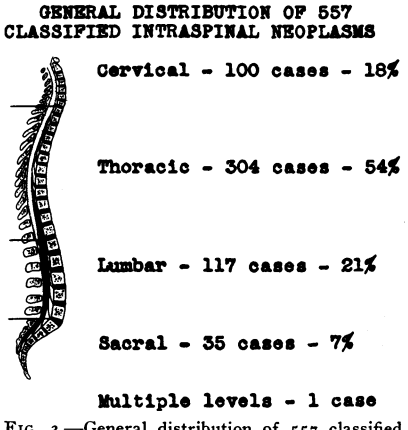

FIG. 3.—General distribution of 557 classified intraspinal neoplasms.

Pathologic Considerations.—Up to January 1, 1939, there had been performed at the Mayo Clinic operations for 557 verified intraspinal neoplasms (Fig. 1). These lesions have been classified pathologically and grouped according to situation (Figs. 2 and 3). It is apparent that the distribution of

these tumors with reference to the spinal axis has no predilection for any one region.

Neurofibromata constitute the largest single group (Fig. 4). *Meningiomata* compose the second largest group, and their primary distribution in the thoracic region is shown in Figure 5. *Intramedullary Tumors*: The various

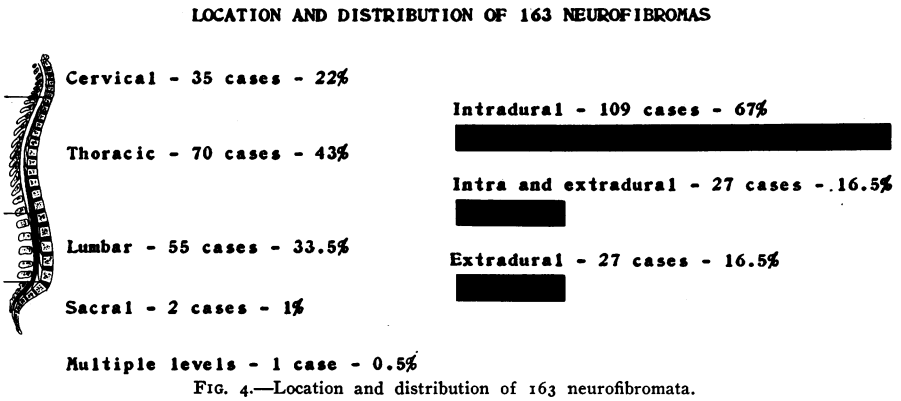

FIG. 4.—Location and distribution of 163 neurofibromata.

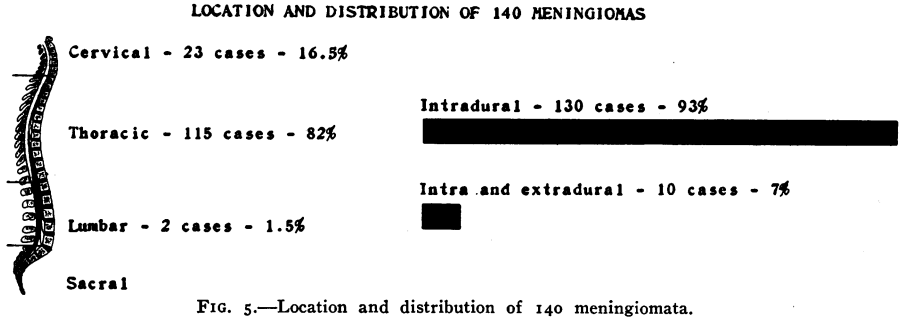

FIG. 5.—Location and distribution of 140 meningiomata.

types of tumors represented in the group of 64 classified intramedullary tumors[5] are best illustrated by referring to Table I, and their situation is illustrated in Figure 6. The *ependymomata* are fairly evenly distributed throughout the spinal cord (Fig. 7). Half of them arise from the spinal cord proper and the remaining half from the filum terminale.[6] *Vascular tumors* form a group including the hemangio-endotheliomata and hemangiomata, and their distribution and situation are illustrated in Figure 8.[4, 19] *Chordomata,* as previously stated, may be situated in any portion of the spinal column, but they have a predilection for the sacral region (Fig. 9). *Sarcomata,* under the heading "sarcomas," are included in a miscellaneous group of 55 sarcomatous

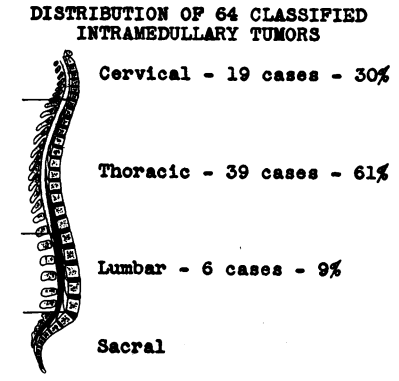

FIG. 6.—Distribution of 64 classified intramedullary tumors.

lesions consisting of lymphosarcomata, myelosarcomata, giant cell sarcomata, Hodgkin's disease, osteogenic sarcomata, *etc.* Eleven per cent are situated in the cervical region, 56 per cent in the thoracic region, 22 per cent in the lumbar region, and 11 per cent in the sacral region. Ninety-one per cent

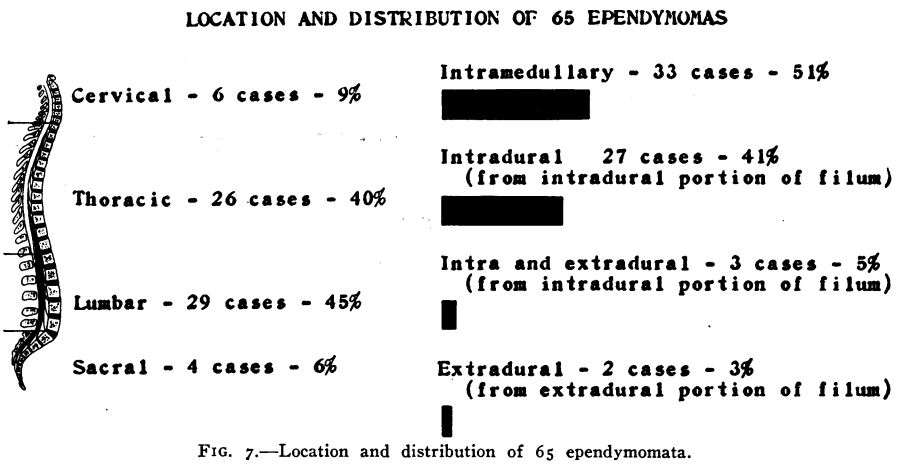

FIG. 7.—Location and distribution of 65 ependymomata.

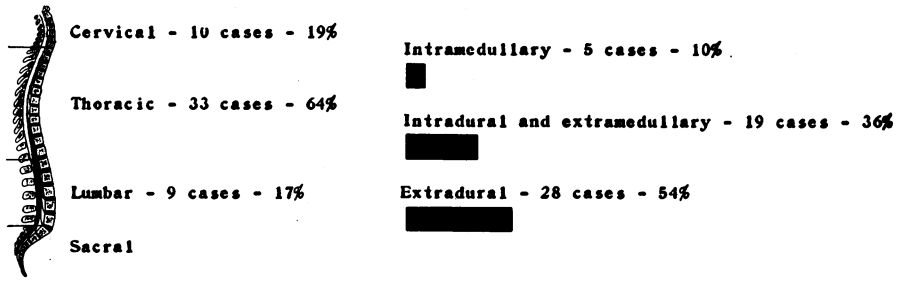

FIG. 8.—Location and distribution of 52 blood vessel tumors.

TABLE I

CLASSIFICATION OF 64 INTRAMEDULLARY NEOPLASMS

Tumor	Number	Per Cent
Ependymoma and ependymoblastoma	33	51.0
Astrocytoma and spongioblastoma polare	10	15.5
Oligodendroglioma and oligodendroblastoma	3	5.0
Spongioblastoma multiforme	3	5.0
Medulloblastoma	3	5.0
Ganglioneuroma and neuroblastoma	2	3.0
Hemangio-endotheliomata, etc.	5	7.5
Melano-epithelioma	3	5.0
Fibrolipoma	1	1.5
Neurofibroma	1	1.5
Total	64	100.0

were situated extradurally, 5 per cent were intradural and extradural, and 4 per cent were intradural and extramedullary.

Miscellaneous Extramedullary Tumors.—Included in this group were six astrocytomata, one spongioblastoma multiforme, two ganglioneuromata,[25] six chondromata, two osteomata, three lipomata, two fibromata, two dermoids and one teratoma.

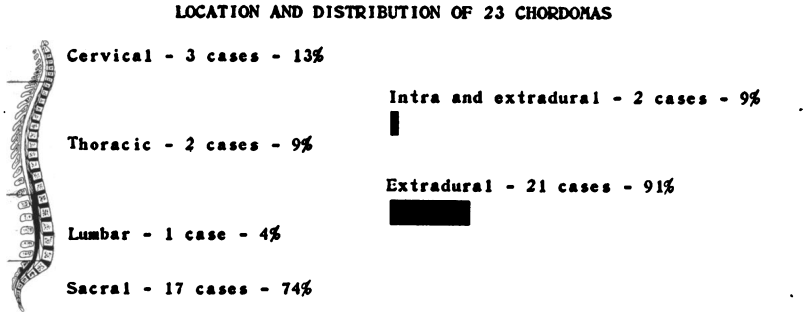

FIG. 9.—Location and distribution of 23 chordomata.

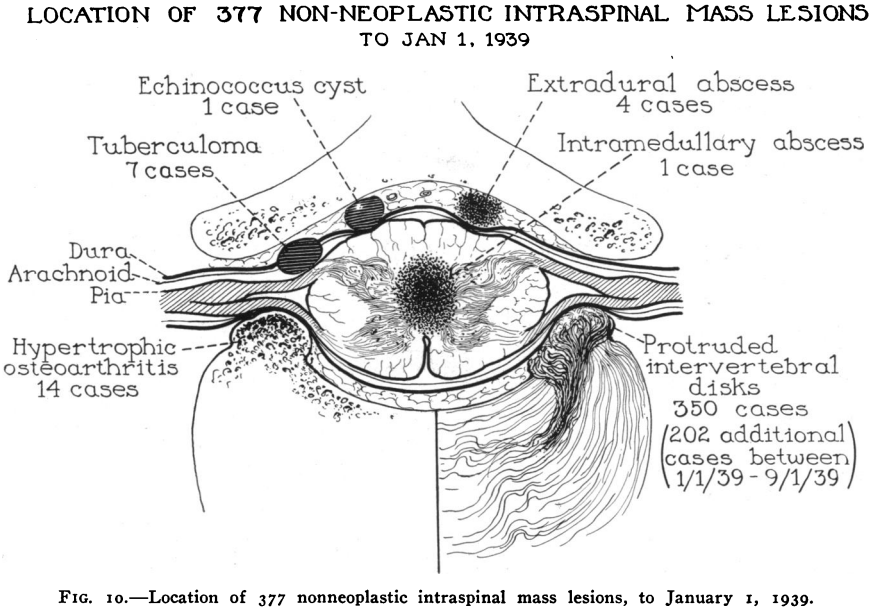

FIG. 10.—Location of 377 nonneoplastic intraspinal mass lesions, to January 1, 1939.

In addition to the described verified intraspinal tumors, there were 468 additional intraspinal lesions which produced irritation or compression on the nerve roots or the spinal cord, suggesting, clinically, the possible existence of an intraspinal tumor or compression of the nerve roots and spinal cord by a nonneoplastic lesion (Fig. 10). Of the 468 lesions there were 64 intramedullary lesions, presumably tumors or cysts of the spinal cord, which were not identified by biopsy. There were 29 additional, unclassified lesions situated within the spinal canal. The tissue removed to date has not been pathologi-

cally classified. In this same group of 468 cases, there were 377 nonneoplastic lesions, which includes protruded intervertebral disks, osseous compression of the roots and spinal cord and suppurative lesions (abscesses) within the spinal canal.[15, 34]

Surgical Consideration.—The technic of a laminectomy has become standardized and, therefore, a detailed description is unnecessary.[20] The anesthetic method we have found most suitable, after employing a variety of them, is that in which the ether is dropped onto an open mask which is held over a Magill intratracheal tube. The intratracheal tube is introduced as soon as the patient has been anesthetized with nitrous oxide and ether. In proceeding with a laminectomy one should make sure of the localization of the lesion, and bear in mind that unless the lesion has been localized by a roentgenogram the cord levels are situated above the corresponding osseous segments. A subperiosteal elevation of the periosteum and muscles will result in less bleeding than a lateral reflection of the erector spinae muscles by sharp dissection. Extreme care should be taken in removing the laminae from the tumor, in order to avoid additional trauma to the cord. The surgeon should also have in mind that dural pulsations will be detected above the tumor but will be absent below it, since this observation will direct him in extending the laminectomy in the proper direction in order to expose and remove the growth properly. Laminectomies performed in the thoracic and lumbar regions usually consist of removing both laminae and the spinous processes of from two to three vertebrae. However, it frequently becomes necessary to extend the laminectomy for longer distances when removing ependymomata of the filum terminale or neurofibromata of the caudal fibers. The tips of the spines, in immediate approximation above and below the site of laminectomy, are also removed in order to eliminate any bony prominences.

Hemilaminectomy is definitely indicated in removing lesions of the cervical portion of the cord, since bilateral laminectomy with removal of the spines may give rise to a slipping forward of the cervical vertebrae, one upon the other, and the entire cervical group upon the first thoracic vertebra. When it does become necessary to perform bilateral cervical laminectomy, extreme care should be exercised in closing the incision so that the cut edges of the ligamentum nuchae will be accurately approximated. When slipping occurs, the patient will exhibit progressive signs of a lesion of the transverse portion of the cord. Lateral roentgenograms will quickly confirm the suspicion. It then becomes necessary to place the patient in bed on his back with extension applied to the head. As soon as the symptoms subside, a cancellous bone graft taken from the crest of the ilium should be inserted along the freshened bone edges of a previous laminectomy.[3] The graft should be extended for a distance of one to two laminae above and below the site of the former laminectomy. Grafts should be placed well laterally to avoid pressure on the spinal cord. In a few instances in which the laminectomy has included the atlas and axis, the graft is brought in contact with the occipital bone. This same procedure has been employed to relieve the pressure on the upper

part of the cervical portion of the cord when an anterior slipping of the atlas on the axis has taken place following fracture or destruction of the odontoid process of the axis.

Neurofibromata.—Since neurofibromata may arise from the nerve roots within the dura, from the roots as they penetrate the dura, or from the peripheral nerve just lateral to the dura, it will be found that these lesions may be situated wholly within the spinal canal, intradurally or partly within the dura, and partly outside of the dura, or they may be situated extradurally with an enlargement and a protrusion into the intervertebral foramen, or they may present the typical dumb-bell appearance, with one portion within the spinal canal just described, with a similar projection beyond the intervertebral foramen. Neurofibromata situated in the spinal canal, even though they have eroded the bone around the intervertebral foramen, usually can be removed during a one-stage operation. Those which are dumb-bell tumors and are situated in the cervical region of the canal are more effectively removed through two separate incisions, and the extraspinal portion of such a tumor is removed first through a lateral cervical incision. This incision is closed and is then followed by laminectomy, frequently hemilaminectomy, through which the intraspinal portion is removed.

Many of these so-called dumb-bell tumors involve the thoracic nerves, and the extraspinal projection may vary in size from a small nodule to a tremendous mass the size of a baby's head.[29] It is not infrequent for the thoracic portion not only to erode the bone around the intervertebral foramen, but also to erode the pedicles, transverse processes of the vertebrae, and portions of ribs. The erosion produced by a neurofibroma is similar to that produced by a meningioma, since it results in smooth erosion and not in the irregular, ragged type of destruction so characteristically produced by metastatic tumors.[11] When a malignant change takes place in a neurofibroma, the bony invasion and destruction resembles that of a primary malignant lesion, and recurrence is almost sure to take place even though a radical removal has been performed.

Since both laminectomy and thoracotomy are major operations, it has been our practice to perform laminectomy and remove the intraspinal portion of the tumor first and wait for the patient thoroughly to convalesce from the first operation before performing the second. This period of waiting usually extends over a month or two. There is one precaution that the thoracic surgeon has to consider and that is to effect complete hemostasis following the removal of the intrathoracic portion of the neurofibroma. Moreover, he must be especially cautious not to apply forceps or to introduce packs along the spinal column where the defect exists, a procedure which might cause trauma to the cord. We have found it advantageous at the Clinic for both the neurologic and thoracic surgeons to assume joint responsibility[16] in order that one may understand the objectives of the other and observe what has been done so that the strength of the patient may be evaluated before the second stage of the operation is begun.

Most neurofibromata within the spinal canal have a tendency to degenerate and become cystic, and in a number of instances, in the lumbar region, the neurofibromata have been known to grow to considerable size, eroding laminae, pedicles and bodies of the vertebrae without producing signs of complete paraplegia. On visualizing these cystic tumors, it is observed that the dura and extradural fat have become atrophic, that the lining of the cyst and the dura are almost inseparable, and that a puncture of the cyst has resulted in escape of the yellow fluid and collapse of the wall of the tumor, making it rather difficult for the surgeon to identify the lesion; but, on further observation, it is usually found that the root is involved and also the remaining nubbin of tumorous tissue. Neurofibromata involving the roots of the spinal cord are usually singular, but occasionally may be multiple and may be part of von Recklinghausen's disease.

Meningiomata.—Meningiomata, fibroblastomata originating from the arachnoid, may be situated in any portion of the spinal canal and be located in any part of the circumference of the canal about the cord, producing pressure at the point of origin. The most common site of origin of such a lesion is about a nerve root, but not originating from it. The meningeal attachment is usually rather limited, although the tumor may grow in all directions without becoming attached to the cord. Occasionally, the meningioma is sessile in type, instead of being rounded or oval in shape. When the tumor is sessile, it involves a large portion of the dura surrounding the cord. Usually it is possible to remove the tumor mass *in toto*, but in doing so it is necessary to remove a portion of the arachnoid and dura, since they are intimately attached at the site of origin. If the surgeon fails to do this, recurrence will develop. Hemostasis is most effectively accomplished during the removal of the tumor by applying electrocoagulation to the base of the tumor extradurally. Care must be taken not to overheat the tumor, since this could result in impairment of the circulation of the cord. In a few instances, in which the tumor is situated anterior to the cord, it may become necessary to remove the tumor by the piecemeal method in order to avoid undue traction or pressure on the spinal cord.

Following the removal of meningiomata and neurofibromata, the surgeon frequently observes marked indentations of the cord. These indentations may have compressed the cord to less than half its normal size, but we have also observed that even though the indentation has markedly flattened the cord, complete recovery of the patient will take place if the blood supply of the cord has not been destroyed.[7] The gradual growth of the tumor will have produced destruction and absorption of the myelin before destruction of the axis cylinder, results which explain why recovery takes place. As a rule, it is not necessary to attempt repair of dural defects resulting from the necessary removal of small portions of the dura with the attached tumor, if the surgeon is careful to maintain absolute hemostasis. We frequently cover the defect with a portion of animal membrane (prepared peritoneum of the ox) to prevent the entrance of blood into the arachnoid or subdural spaces.

This same rule applies to dural defects resulting from the removal of other tumors that are adherent to the dura.

Intramedullary Tumors.—The surgical consideration of intramedullary tumors is almost the same for the entire group of lesions, even though they may vary in their pathologic classification. Most of them are gliomatous in origin. The largest group is the ependymomata. These tumors originate from the ependymal cells lining the central canal. Several hemangio-endotheliomata have been found to be situated within the cord; one large intramedullary lipoma and one neurofibroma were found to have invaded the cord for an unusually long distance. Unless cystic degeneration has taken place in or about the tumor, the surgical approach is the same for all intramedullary tumors. Cysts are readily emptied, as is also the cystic cavity of a syringomyelia, and occasionally the surgeon is able to maintain constant drainage or prevention of filling by resection of the wall of the cyst, if it is possible to approach the cyst through the dorsal midline of the cord. The introduction of a small strip of folded gutta-percha held in place by a silk ligature has also been useful in the prevention of refilling of the cyst.

It is impossible completely to remove gliomatous lesions of the cord, since there is no line of demarcation permitting enucleation. A heroic attempt at removal is more likely to increase the symptoms of paraplegia than it is to reduce those already present. When such a condition does exist, it has been learned that a longitudinal section of the cord, extended into the mass of the tumor for its entire length, has proved to be of value in allowing the tumor slowly to extrude itself and thus relieve pressure on the noninvolved nerve tracts.[23] Hemangio-endotheliomata frequently can be removed by exposing them through a longitudinal incision of the cord, bearing in mind the fact that a dorsal midline incision without injury to the dorsal artery produces less motor disturbance than do lateral or anterior incisions. Although most intramedullary tumors are elongated masses which increase the size of the cord so that it has the appearance of a sausage, ependymomata of the spinal cord proper are found to be the longest of the group. Since they are fairly well circumscribed, although not definitely encapsulated, they do lend themselves to radical removal.

Ependymomata of the Filum.—Ependymomata originating within the filum, or even as high as the tip of the conus medullaris, represent a rather interesting group of tumors, since they may grow to considerable size, filling the lumbar and sacral canals before they produce paraplegia. These tumors are not encapsulated, but they are surrounded by pia mater. They produce marked erosion of the bone without invading it; grow in between the nerve roots of the cauda equina; increase the size of the lumbosacral canal; may enlarge the intervertebral foramen, and grow into the soft tissues of the back —but they apparently do not metastasize. The surgical problem that faces one, then, is to perform extensive laminectomy in order thoroughly to uncover the tumor, and then to proceed with careful dissection and removal of the tumor without impairing the blood supply or damaging the nerve roots.

Complete removal will result in a cure; failure to do so will result in recurrence.

Vascular Tumors.—Under the heading of "vascular tumors" we include hemangiomata and hemangio-endotheliomata. These may be situated extradurally, subdurally (but extramedullary), and intramedullary. They are usually benign and are fairly well encapsulated, but they are extremely vascular. The extradural lesions are flattened, elongated masses, whereas the intradural lesions are usually oval in appearance. The vascular tumors are usually operable, but extreme care is necessary in removing the tumor in order to avoid injury to the blood supply of the spinal cord. In addition to the typical vascular tumor, we have encountered several vascular lesions which would have to be classified as "varicosities of the cord" and "arteriovenous fistulae." In these instances, the task of the surgeon is to reduce the varicose mass in size by ligation and resection and by the employment of electrocoagulation; he should bear in mind, however, that the blood supply of the spinal cord itself or of the nerve roots must not be injured.

Chordomata.—Chordomata originate from the notochord, and although their site of predilection is the sacrum, and the clivus blumenbachii, they may originate in other portions of the spinal column. These tumors erode and invade the bony structure and fill the spinal canal, producing compression and destruction of the nerve root and the spinal cord. They are primary malignant tumors, but since their growth is slow and is accompanied by pain, the surgeon is frequently justified in attempting radical removal. Although situated in the sacrum, these tumors produce an explosive type of enlargement, that is, an erosion with an invasion of the bone and elevation of isolated fragments of bone on the periphery of the tumor. Following radical resection of these tumors, roentgenotherapy appears to offer additional relief in controlling the growth of the tumor and in retarding the process of recurrence.

Bony Lesions Which Produce Compression of the Cord.—Hemangiomata of the vertebrae result in osteoporosis and flattening of the body with compression of the cord. Occasionally, unilateral laminectomy, acting as decompression, offers some relief, but if such a procedure is employed, a cancellous bone graft should be inserted along the unoperated side.

Neurologic symptoms accompanying *tuberculous* involvement in the body of the vertebrae are usually relieved by placing the patient in hyperextension on a specially adapted frame. As the symptoms subside, the orthopedic surgeon usually inserts a bone graft as an additional support to prevent a collapse of the body of the vertebrae. However, if the neurologic symptoms fail to improve after hyperextension, the surgeon is justified in carrying out hemilaminectomy for decompressive purposes. Usually there is found an increased amount of granulation tissue within the extradural fat. Although removal of such tissue may be justifiable, extreme care should be taken to avoid an injury to the dura, since the dura acts as a barrier to the invading tubercle bacilli.

Foreign-Body Giant Cell Tumors may be recognized by roentgenographic observation. Since these lesions are benign, they lend themselves to surgical treatment which consists of laminectomy and removal by curet of the contents within the cystic cavity. This, in turn, relieves pressure on the meninges and spinal cord.

Myelomata.—At the onset, spinal myelomata may be single or multiple. When a single myeloma is encountered, the surgeon is tempted to try radical removal in order to decompress the spinal cord, but the procedure is rarely justifiable, since recurrence is sure to take place and other lesions soon follow. Roentgenotherapy has proved of very little value.

Osteogenic Sarcomata.—Although usually single at the onset, osteogenic sarcomata of the spinal column will recur and metastasize. The temporary relief obtained by radical removal, in order to decompress the spinal cord, is occasionally indicated, especially if osteogenic sarcomata involve the laminae and spinous processes.

Osteochondromata.—These may be benign at the onset but frequently become malignant; they originate in the intervertebral disk and the adjacent vertebrae. Growth of such a lesion into the spinal canal produces symptoms similar to those of any extradural tumor,[33] a point which emphasizes the fact that early recognition is essential and that a radical operation should be performed even though it becomes necessary to insert a bone graft to support the noninvolved portion of the spinal column.

Paget's Disease.—In a number of instances, the squashing process of this disease produces radiculitis and, occasionally, symptoms of compression of the cord. Again, it is doubtful whether decompression of the cord is indicated, since the relief obtained is of such temporary nature.

If either *hypertrophic arthritis* or *osteitis* extends into the spinal canal, the roots may become involved and the spinal cord compressed, with the resulting symptoms of transverse myelitis.[31] If it is possible to determine by neurologic and roentgenographic examination that the process is fairly well localized, and if it has been recognized in the early stages of the disease, it is possible to obtain satisfactory results by means of wide and extensive laminectomy over the involved portion of the cord. Occasionally, it becomes necessary to unroof the nerve roots as they pass through the intervertebral foramina.

Protruded Intervertebral Disks.—The subject of protruded intervertebral disks has received unusual attention in the last few years,[26, 27, 28, 30] due to the fact that tumor-like masses can be recognized by roentgenologic examination of the spinal canal by employing radiopaque oils or air. The finding of these masses in patients suffering from chronic, recurring sciatica has led to exploratory laminectomies and removal of the masses which were producing pressure on the nerve roots. The relief obtained from the surgical treatment of this condition has more than justified these newer procedures in the treatment of chronic, recurring sciatica when physiotherapeutic measures have failed. The lesions occur as the result of a tear in the annulus fibrosus, and

a rupture of the intervertebral disk with an expulsion of a portion or all of the nucleus pulposus. Although the condition had been recognized, and occasionally treated, for a number of years, its importance was not emphasized until the introduction of roentgenographic studies made with the aid of radiopaque oil. These tumor-like masses, the nucleus pulposi, are not neoplastic, even though they produce symptoms similar to those caused by intraspinal tumors. After recognizing the lesion by the aid of the clinical history, neurologic observations and roentgenographic studies, they can be readily removed through hemilaminectomy, removing a portion of one and occasionally two laminae at the site of the lesion. The ligamentum flavum has frequently been ruptured and hypertrophy has taken place, so that it becomes necessary to remove the affected ligamentum flavum with the protruded disk. The involved spinal root is found to be compressed between the protruded portion of the nucleus pulposus and the pedicle of the vertebrae opposite the intervertebral foramen. Removal consists of dissecting free the edematous root and retracting the dura toward the midline, following which the completely prolapsed nucleus pulposus may be found to be lying free within the canal and can be removed without further dissection. If the protrusion is incomplete, it may be necessary to use a sharp knife or even a curet to remove the partially dislodged nucleus pulposus. The dura is not opened unless radiopaque oil has been used, in which event the oil should be thoroughly removed before closing the incision. The protruded masses are usually single, may be multiple, and are usually situated lateral to the posterior longitudinal ligament. They have occasionally been found to be situated in the midline when the protrusion is situated at the lumbosacral junction. When that does occur, transdural removal may be required. The largest number of protrusions occur in the lumbar and lumbosacral regions, but they may occur in any part of the spinal column. The second most common site of occurrence is the cervicothoracic region.

Hodgkin's Disease or Echinococcus Cysts may enter the spinal canal through the intervertebral foramen, and when they do so they are found to be situated extradurally, producing symptoms referable to the cord by extradural pressure. Usually, these masses can be removed by means of routine laminectomy without opening the dura, just as a surgeon would remove an extradural neoplasm. If the lesion is recognized as that of Hodgkin's disease, there being other manifestations, it is wise to employ a course of deep roentgenotherapy before resorting to laminectomy. On the other hand, if the symptoms of paraplegia are very pronounced, it may be unwise to defer laminectomy. In some instances, the operation has been performed first and then the roentgenotherapy has been employed.

Metastatic Lesions of the Spinal Column.—Metastatic lesions of the spinal column produce symptoms similar to those of intraspinal tumors except that they develop much more rapidly than do benign lesions. They occur at a later age than the average intraspinal tumor does, which should make the surgeon extremely careful during examination of the patient to determine, if

possible, the presence of a primary lesion. Exploratory laminectomy is rarely indicated, since removal of one metastatic nodule accomplishes so little that it is scarcely justifiable. Occasionally, an operation must be performed when no primary lesion has been located, and there is some doubt as to whether the lesion is malignant.

Inflammatory Lesions; Chronic Radiculitis and Meningomyelitis.—These are capable of producing symptoms simulating intraspinal tumors, but fortunately, studies of the spinal fluid, of jugular pressure (Queckenstedt test), which are employed to determine the presence or absence of an intraspinal block, and roentgenographic examinations made with the aid of radiopaque oil have made it possible to differentiate these lesions from true neoplasms. It is obvious that surgical treatment is not indicated in this group of lesions.

Suppurative Lesions.—Suppurative lesions, such as extradural and intramedullary abscesses, rarely occur and can be differentiated and localized by the usual diagnostic methods, taking into consideration, of course, the fact of the accompanying suppurative infection and the rapidity with which symptoms of compression or destruction of the cord result. Surgical drainage has proved to be most effective in the treatment of this condition, but if it is employed, it should be instituted before the symptoms of transverse myelitis are complete.

Postoperative Care.—Following the operation, the patient is placed in bed in the lateral position on pillows, to avoid undue pressure on the tips of the shoulders and on the hips. It is preferable to turn the patient from side to side and on the abdomen, rather than to allow him to lie on his back, because sweating may result in maceration of the skin and contamination of the incision, and may interfere with primary union. The patient, otherwise, is treated as is the average surgical patient. If urinary incontinence is present, it is safer to insert an indwelling catheter rather than to repeat catheterization daily. As an additional prophylactic measure, the patient should receive 15 Gm. of sulfanilamide daily. The catheter should be changed every four or five days, and the bladder irrigated twice daily with an antiseptic solution. Usually, daily doses of mineral oil combined with milk of magnesia are administered to prevent distention and fecal impaction. In addition, a daily enema is necessary. The patient is kept in bed for two weeks, at the end of which period he is permitted to sit in the upright position in bed; he is subsequently allowed to be taken about in a wheel chair and to walk, if possible. The usual postoperative course continues for three weeks. Physiotherapy is advised if muscular cramps and motor weakness exist. Indwelling catheters should be removed permanently when the patient has recovered sufficient control of the bladder to empty it thoroughly.

Contractures and defensive reflex spasms are corrected and relieved during the period of convalescence by the application of Buck's extension to the feet and legs while the patient is in the reclining position. The recovery of motor, sensory, vesical, rectal and sexual functions takes place in the reverse order of their previous disappearance.

CONCLUSIONS

The frequent occurrence of primary intraspinal tumors, which are usually benign and operable, justifies thorough examination of all patients who complain of root pain or of progressive motor or sensory disturbance of the extremities. The diagnostic methods at our disposal will invariably affect the differential diagnosis. Surgical treatment, if it is to be instituted, should be employed before the patient becomes paralyzed.

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