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# DIAGNOSIS AND TREATMENT OF SURGICAL DISEASES OF THE SPINAL CORD AND ITS MEMBRANES

*BY*

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WITH 158 ILLUSTRATIONS
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# PREFACE

THE present volume is a record of personal experiences in the surgical treatment of diseases and injuries of the spinal cord and its adnexa. As all work must be in part based on the labors of the past, an account of the experiences of a single worker must include much that has been learned from others.

The attempt has been made to keep the book from extending beyond its proper limits—a consideration of the diagnosis and treatment of diseases of the spinal cord that may require surgical interference—and all matter which belongs more properly to text-books on neurology or general surgery has been given the briefest mention.

A certain amount of neurology has been included because the author is convinced that only those can do successful neurologic surgery who have gained a working knowledge of organic neurology. It has been the good fortune of the writer to be closely associated in his work with the neurologists of the New York Neurological Institute and of Mount Sinai Hospital, New York City, and it is with pleasure that the author expresses his indebtedness to Dr. Pearce Bailey, Dr. Joseph Collins, Dr. Frederick Peterson, Dr. Bernard Sachs, Dr. I. Abrahamson and their associates.

It may occasion some surprise that hematomyelia and spinal gliosis are included in a work on the Surgical Diseases of the Spinal Cord. In these diseases, much harm is done to the fiber tracts by compression, and the relief of this compression by surgical means, has already resulted in marked improvement in a number of patients. The time is at hand when selected cases will be regularly subjected to operative interference.

The chapter on the X-ray in spinal disease has been incorporated in the book in order to give illustrations of the abnormalities which are often found on the X-ray plate, many of which have nothing to do with the disease from which the patient suffers. The majority of the X-ray illustrations are from the collection of Mount Sinai Hospital, and the writer is indebted to Dr. L. Jaches, the Director of the Roentgen Laboratory, and to the physicians and surgeons of the Hospital for permission to use a number of X-ray plates. Dr. Ernest Fahnestock has kindly placed at the writer's disposal a most unusual X-ray of fracture dislocation of the cervical vertebræ, and Dr. Richard Derby, one of a bullet in the spine taken by Dr. Jangeas of the American Ambulance of Paris.

The illustrations for the volume are mostly original and were executed from specimens, dissections, and from sketches made at the operating table by Mr. Josef Lenhard. The artist has admirably succeeded in the reproduction of the actual appearance of spinal lesions found at operation. The attempt has been made to illustrate conditions as they appear to the surgeon, and Mr. Lenhard has accomplished this object most successfully.

Finally, the writer desires to express his thanks to Dr. Edward Rochfort and Dr. Ira Cohen for assistance in the preparation of the index and in the correction of proof, to Miss Edna Brucks for help in the preparation of the manuscript, and to his publishers, W. B. Saunders Company, for their coöperation and interest in the work.

Charles A. Elsberg.

701 Madison Avenue, New York City,
*June*, 1916.

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## PART I

## THE ANATOMY AND PHYSIOLOGY OF THE SPINAL CORD

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## CHAPTER I

### THE SURGICAL ANATOMY OF THE VERTEBRAL COLUMN AND SPINAL CORD

#### THE VERTEBRAL COLUMN

The treatment of diseases of the spinal cord will often require the exposure of the cord by removal of the spinous processes and laminæ of one or of a number of vertebræ. A thorough knowledge of the structure of the bones which make up the vertebral column and of the ligaments and muscles which bind them together is therefore necessary. For a detailed account of these structures the reader is referred to text-books of anatomy. In the following, reference will be made to a few facts of practical importance.

In the cervical and upper dorsal regions the vertebræ are smaller than in the other parts of the spinal column. The spinous processes of the cervical vertebræ are bifid at their tips, but the vertebræ do not fit closely upon one another and are rather freely movable the one upon the other. This makes the removal of spinous processes and laminæ the most easy in the cervical region (Fig. 1). In the dorsal vertebræ the laminæ and spines overlap and the vertebræ are more fixed upon each other. The spinous processes point markedly downward, so that the distance between the tips of the spinous processes and corresponding segments of the cord is greater than in the cervical region (Fig. 2). In the lower dorsal and lumbar vertebræ, the spinous processes and laminæ are thick and

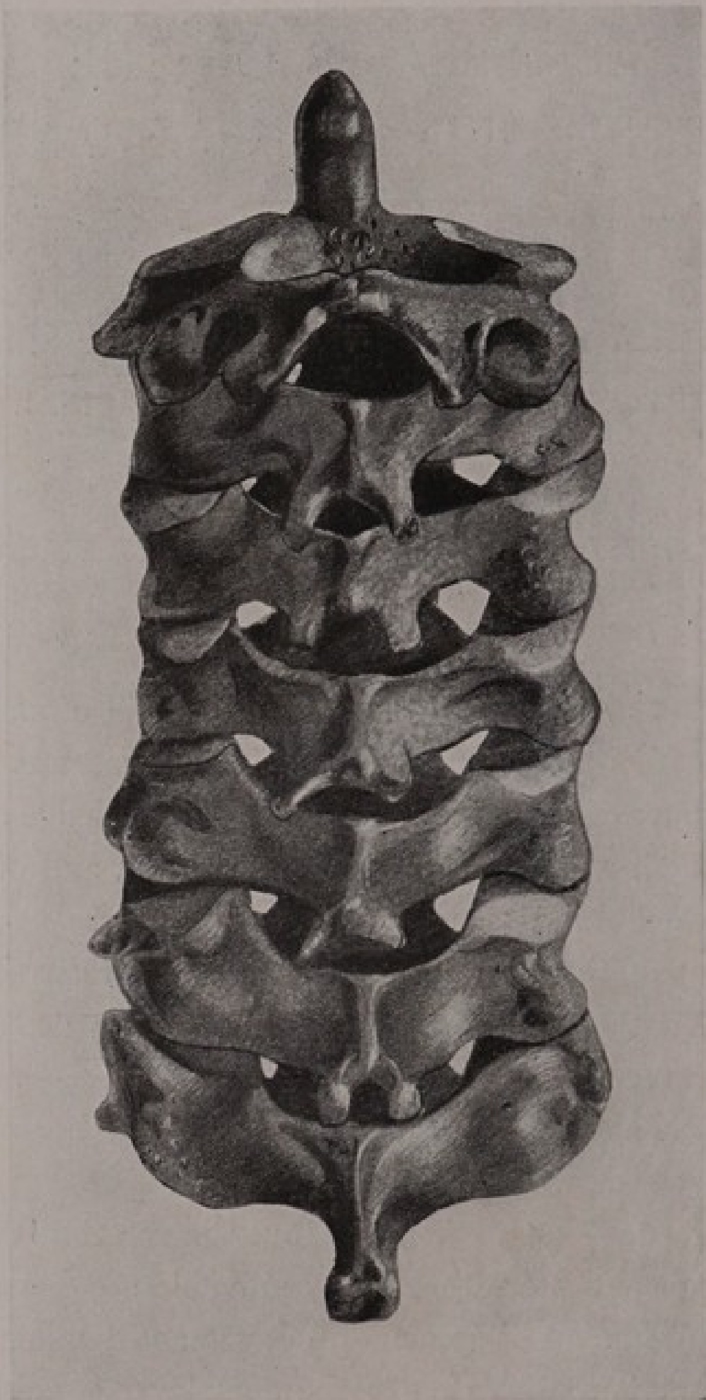


Fig. 1.—The cervical vertebræ from behind, showing the bifid spinous processes and the spaces between the laminæ (natural size).

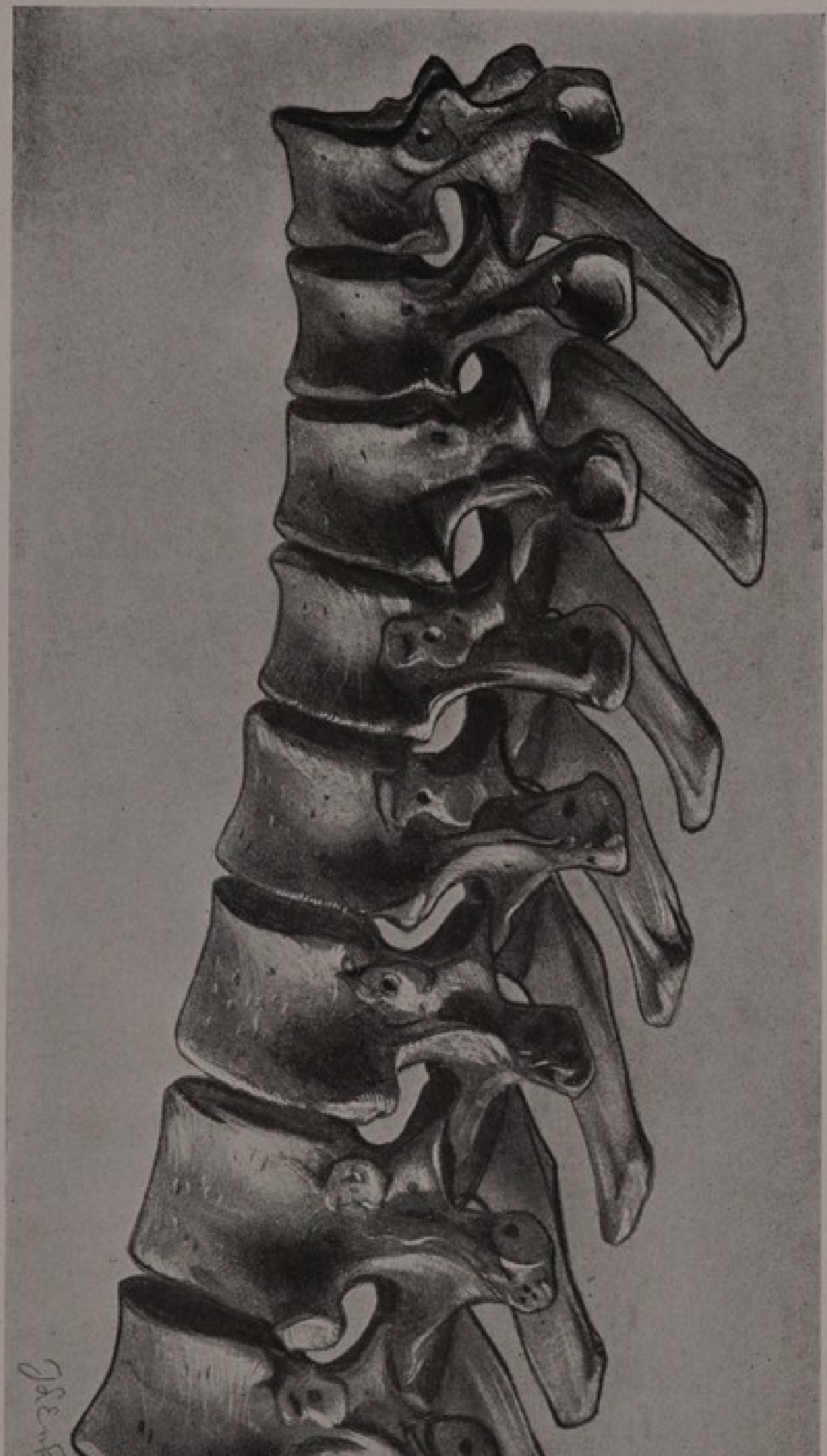


FIG. 2.—Lateral view of the middorsal vertebræ, showing the overlapping of the spinous processes (natural size).

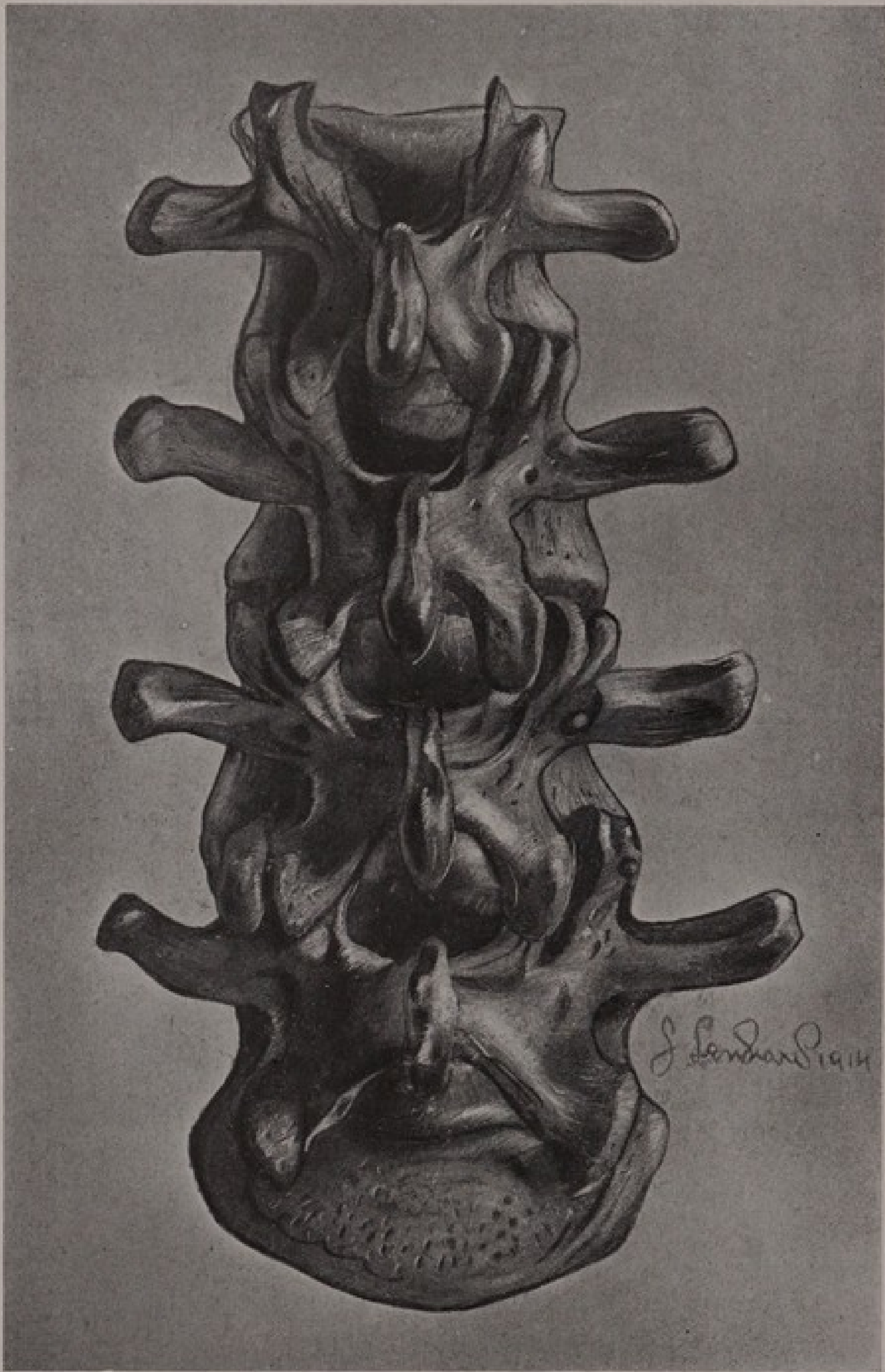


Fig. 3.—The lower four lumbar vertebræ from behind (natural size).

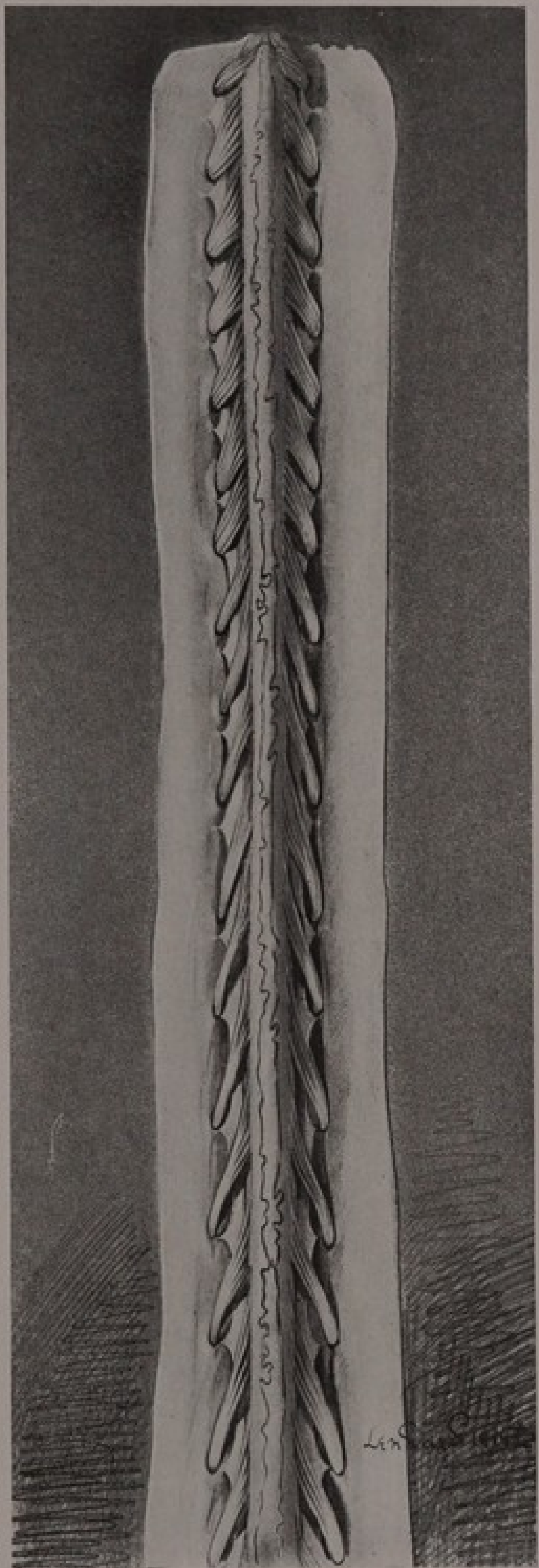


FIG. 4.—The cervical and dorsal cord from behind. × ½.

short; the spines point directly backward and are deeply placed between thick muscles. In this region the exposure of the dura in the operation of laminectomy is a more tedious procedure; the thick short laminæ have to be removed to the transverse and sometimes into the articular processes before a wide exposure of the field of operation is obtained (Fig. 3).

The dorsal and lumbar vertebræ are only slightly movable upon each other. When a fracture of the vertebræ occurs in this region, the injury to the spinal cord is not of necessity a great one. In the cervical region, however, the great mobility of the vertebræ upon each other will allow of much dislocation, so that severe crushing injuries with or without fracture are of more frequent occurrence (see Chapter XVI).

## THE SPINAL CORD AND NERVE ROOTS

The spinal cord is about 45 cm. long; it extends from the margin of the foramen magnum to the lower part of the body of the first lumbar vertebra. At its lower end it tapers conically (the conus medullaris) to end in a slender filament (the filum terminale). The lower end of the conus may extend only to the twelfth dorsal or as low as the middle of the body of the second lumbar vertebra (Fig. 5).

In the fetus the cord extends to the lower end of the spinal canal (Fig. 6). After the third month the canal grows in length more rapidly than the spinal cord, so that at birth the tip of the conus lies at the level of the third lumbar vertebra. The changes in the relationship between the spinal canal and the lower end of the cord and the nerves of the cauda equina in the fetus and in post-natal life have an important bearing upon the symptoms of some pathological conditions (spina bifida, *q.v.*).

On section the cord is almost circular, being, however, slightly flattened from before backward. The cervical and lumbar enlargements are almost entirely due to an expansion in a transverse direction. The cervical enlargement extends from the upper part of the cord to the level of the body of the second thoracic vertebra, while the lumbar enlargement begins at the tenth and is largest opposite the twelfth thoracic vertebra. The enlargements of the spinal cord are related to the large nerves which

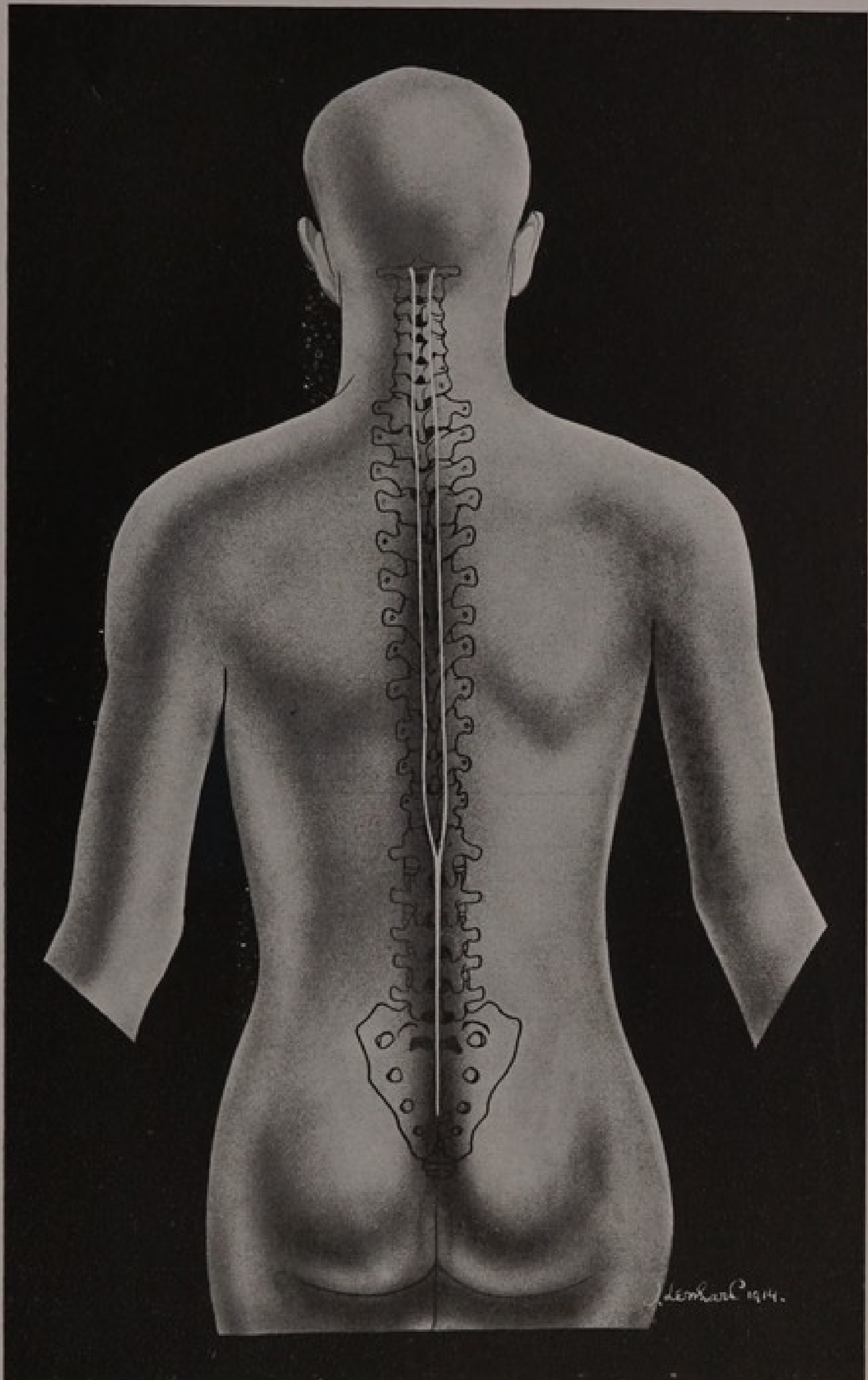



FIG. 5.—The extent of the spinal cord in the adult, ending at the first lumbar vertebra.

supply the upper and lower limbs. The relative size of the different parts of the spinal cord must be well understood for the proper recognition

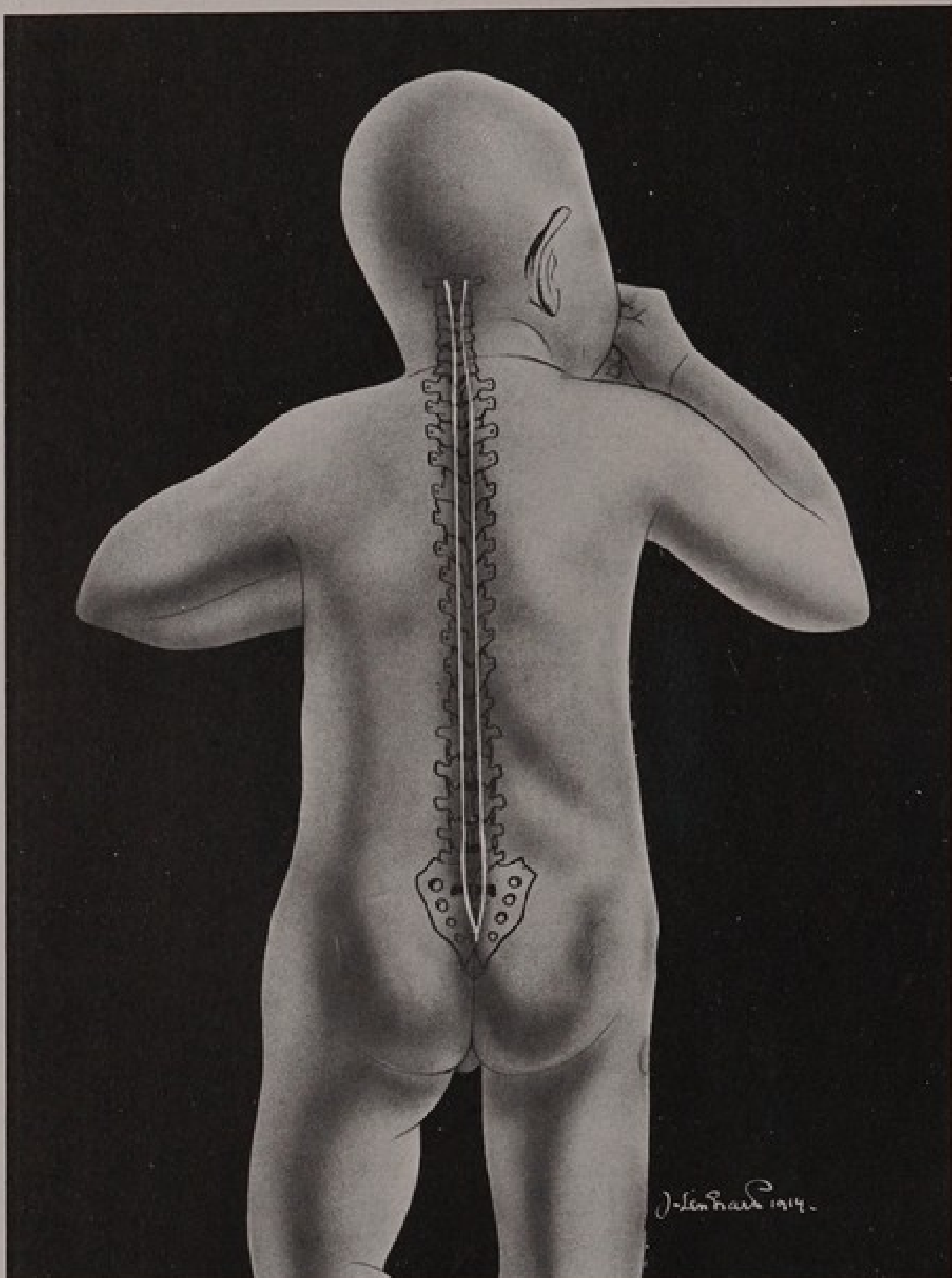


FIG. 6.—The extent of the spinal cord of the fetus at the fifth month (compare with Fig. 5).

of increase in size due to intramedullary fluid or tumors, or decrease in size due to sclerotic changes.

Somewhat arbitrarily, the cord is divided into segments, each portion which corresponds to the attachments of a pair of spinal nerve roots being termed a segment. The nerve roots are, therefore, the guides to the segments of the cord, the boundaries of each segment corresponding to a horizontal plane through the cord midway between two adjacent nerve roots. There are thirty-one pairs of spinal nerves—eight cervical, twelve dorsal or thoracic, five lumbar, five sacral, one coccygeal. The first pair of cervical nerves emerge from the vertebral canal between the occipital bone and the atlas; the first to eighth cervical roots are named after the lower of the two vertebræ which form the intervertebral foramen of exit of the nerve. The eighth cervical nerve roots emerge from the

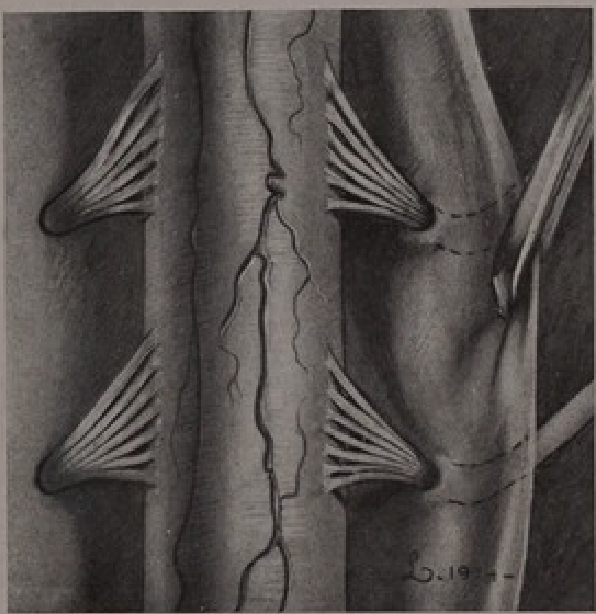


FIG. 7.—The structure of posterior spinal roots in the cervical region. Note the separate root bundles which unite near the dural opening (diagrammatic).

foramen between the seventh cervical and first thoracic vertebræ. In the thoracic, lumbar and sacral areas the spinal nerves are named after the upper of the two vertebræ which form the corresponding intervertebral foramen (Fig. 15).

Each spinal nerve is formed by the coalescence of two roots which spring from the lateral aspects of the cord, the anterior or motor root which originates from the anterolateral groove and the posterior or sensory root from the posterolateral groove. The anterior and posterior roots perforate the dural sheath separately with a thin septum of dura mater between them. In the cervical region the nerve bundles remain distinct until they have passed through the dura. The bundles are spread out like a fan, the broadest part being at the cord. At their origin the bundles are spread out so as to occupy 1 to 2 cm. of the cord; between their origin and the dura they lie closer together, forming a layer 1 to 1½ cm. in breadth; at the dural opening the nerve bundles are still distinct (Fig. 7). In the dorsal and lumbar regions the arrangement is different from that just described; the separate bundles soon unite to form one bundle which passes outward to the dural opening (Fig. 8).

From this arrangement it is clear that in the cervical region a tumor may, for a long time, make pressure upon only a few of the bundles which go to make up a posterior or anterior root. In the dorsal and lumbar regions the nerve bundles are

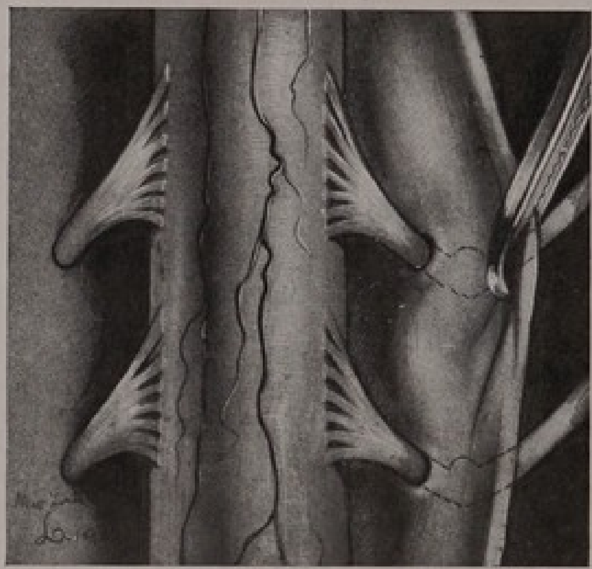


FIG. 8.—The structure of posterior spinal roots in the dorsal region (compare with Fig. 7).

united into one nerve near the cord; a tumor in these regions may press upon the whole nerve root from the very beginning of its growth. Clinical experience agrees with these anatomical facts; the earliest symptoms of pressure upon a cervical nerve root are usually confined to a small area of distribution, one or two fingers, for example, while in the dorsal or lumbar region the classical root symptoms extend over an entire root area. It is more exact, therefore, to distinguish between "root bundle" and "root" symptoms, and this distinction should be of clinical value.

There are marked differences between the course of the spinal roots at different levels. In the cervical and upper dorsal regions the nerve bundles unite to form the posterior root which passes out of the dural sac at almost a right angle to the cord. The root then perforates the dura and enters the posterior ganglion. From the ganglion each root passes outward with a slight inclination upward (Fig. 9).

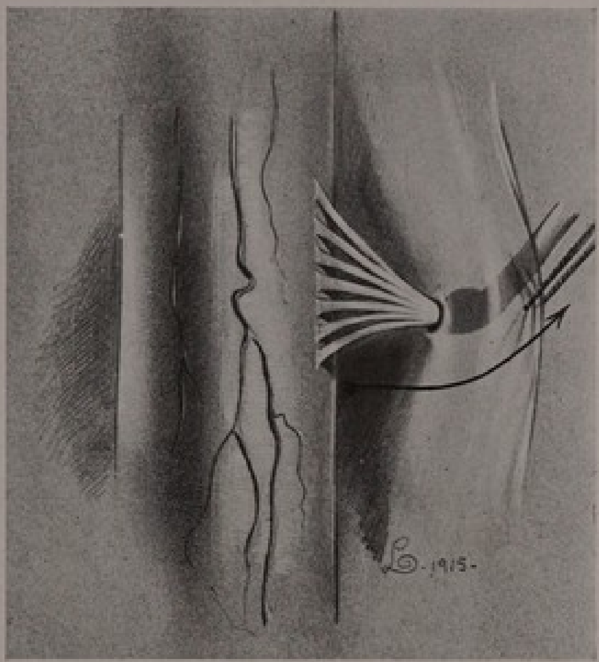


FIG. 9.—The course of a cervical spinal root (diagrammatic). (Compare with Figs. 10 and 11.)

FIG. 10.—The course of a dorsal spinal root (diagrammatic).

From the eighth cervical to the middorsal regions the course of the posterior roots is different. Each root has an inclination downward until it nears the dura; it bends upward at an angle just as it perforates the dura. In the middorsal region this angle is often very acute—40° to 45°. Beyond the ganglion each posterior root passes markedly upward before it divides into its anterior and posterior branches (Fig. 10).

In the lower dorsal and lumbar regions the posterior nerve roots pass downward and outward and perforate the dura; beyond the ganglia the direction remains unchanged until the nerve roots divide into their anterior and posterior branches. The course of the anterior roots corresponds to those of the posterior roots (Fig. 11).

Fig. 11.—The course of a lumbar spinal root (diagrammatic).

Taking into account the peculiar course of the nerve roots just mentioned, and the sensitive dura, it is easy to understand why a small metastatic focus of malignant disease in the posterior and lateral part of the body of a vertebra may cause those agonizing root pains from which the patients suffer. It is clear that only a slight inflammatory process near the dural opening may be responsible for the occurrence of marked root symptoms.

It is probable that the movements of the vertebral column (bending backward and forward) will increase an existing pressure upon any of the lower dorsal and lumbar posterior roots, because these can not yield as easily as the upper dorsal roots. Root symptoms in the lower dorsal and upper lumbar regions should become much intensified with forward and backward movements of the vertebral column. To a less degree this must also be the case in the cervical region, although here the bundles of the posterior roots are spread over such a large area that all are seldom pressed upon at the same time. Lateral movements of the spine are apt to increase a root

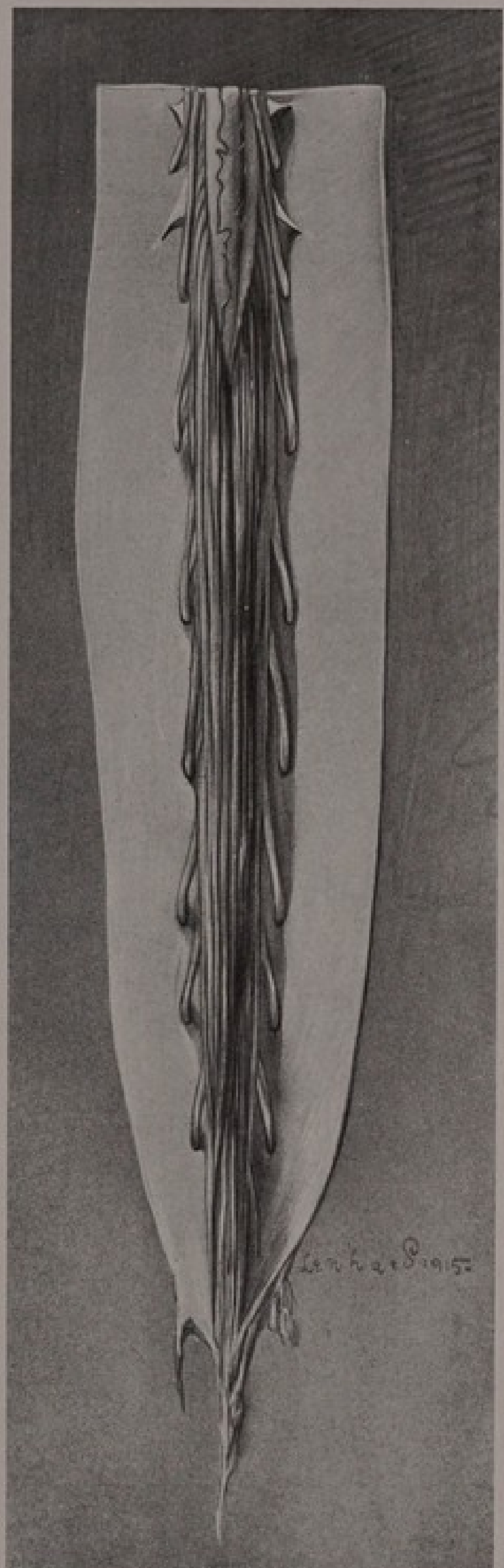


FIG. 12.—The lumbosacral cord and cauda equina. × ¾. (From dissection by the author.)

pain on the opposite side and to lessen a root pain on the same side to which the spine is bent. These facts probably have an important bearing upon the occurrence of rigidity of the spine, which is found in patients who have a tumor in the lower dorsal and upper lumbar regions and also in the cervical cord.

In general, the cervical nerves pass outward through the intervertebral foramina at almost a right angle to the long axis of the cord; the lower the level, however, the more is the downward slope, so that the fifth lumbar pair emerge six vertebræ lower than the level of their origin. The lumbar and sacral nerves descend in almost parallel bundles to form the cauda equina, and conceal the delicate filum terminale. The arrangement of the nerves of the cauda equina is such that the outermost bundles correspond to the uppermost nerves (Fig. 12).

The relation between the spines of the vertebræ and the sites of origin of the nerve roots from the cord is subject to considerable variation. This is especially the case in the thoracic region where some of the nerve roots show variations in their site of origin extending over a distance covered by as many as three spinous processes (Schaefer, Reid, Muskens).

### THE SPINAL MEMBRANES

The spinal dura mater forms a loose sheath around the cord and the cauda equina and is loosely connected by areolar tissue to the periosteum of the vertebræ. On each side are the double openings for the roots of each spinal nerve, a tubular prolongation of the dura passing over the nerves for a short distance. In contact with the smooth inner surface of the dura, but not adherent to it, is the arachnoid. This is a delicate membrane which invests the cord, being separated from it by considerable fluid in the subarachnoid space.

In addition to other functions the fluid acts as a buffer to support the spinal cord and to protect it from injury.

The subarachnoid space is incompletely divided into anterior and posterior compartments by the dentate ligaments.

The pia mater is intimately adherent to the cord and forms its sheath or neurilemma. Pia mater, arachnoid and dura mater are continuous over the spinal roots so as to form a sheath for them as they pass outward to the intervertebral foramina.

From each lateral surface of the cord a narrow fibrous band, the ligamentum denticulatum or dentate ligament, extends from the pia to the

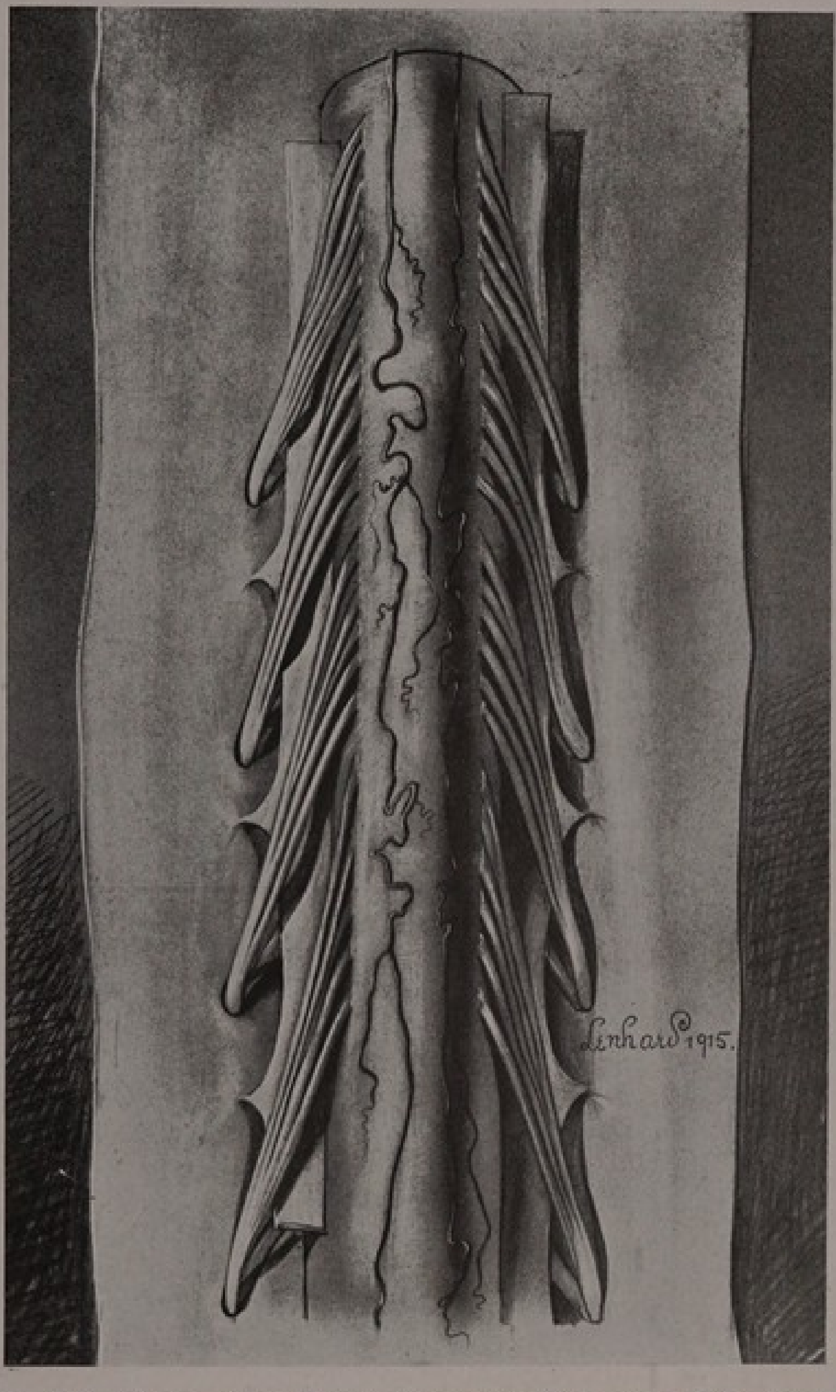



FIG. 13.—The relation of the dentate ligament to the cord and the dorsal roots. × 2. (From dissection by the author.)

dura throughout the entire length of the spinal cord (Fig. 13). It separates the anterior from the posterior roots and contributes to the support of the cord. On each side of the cord the ligament extends from the

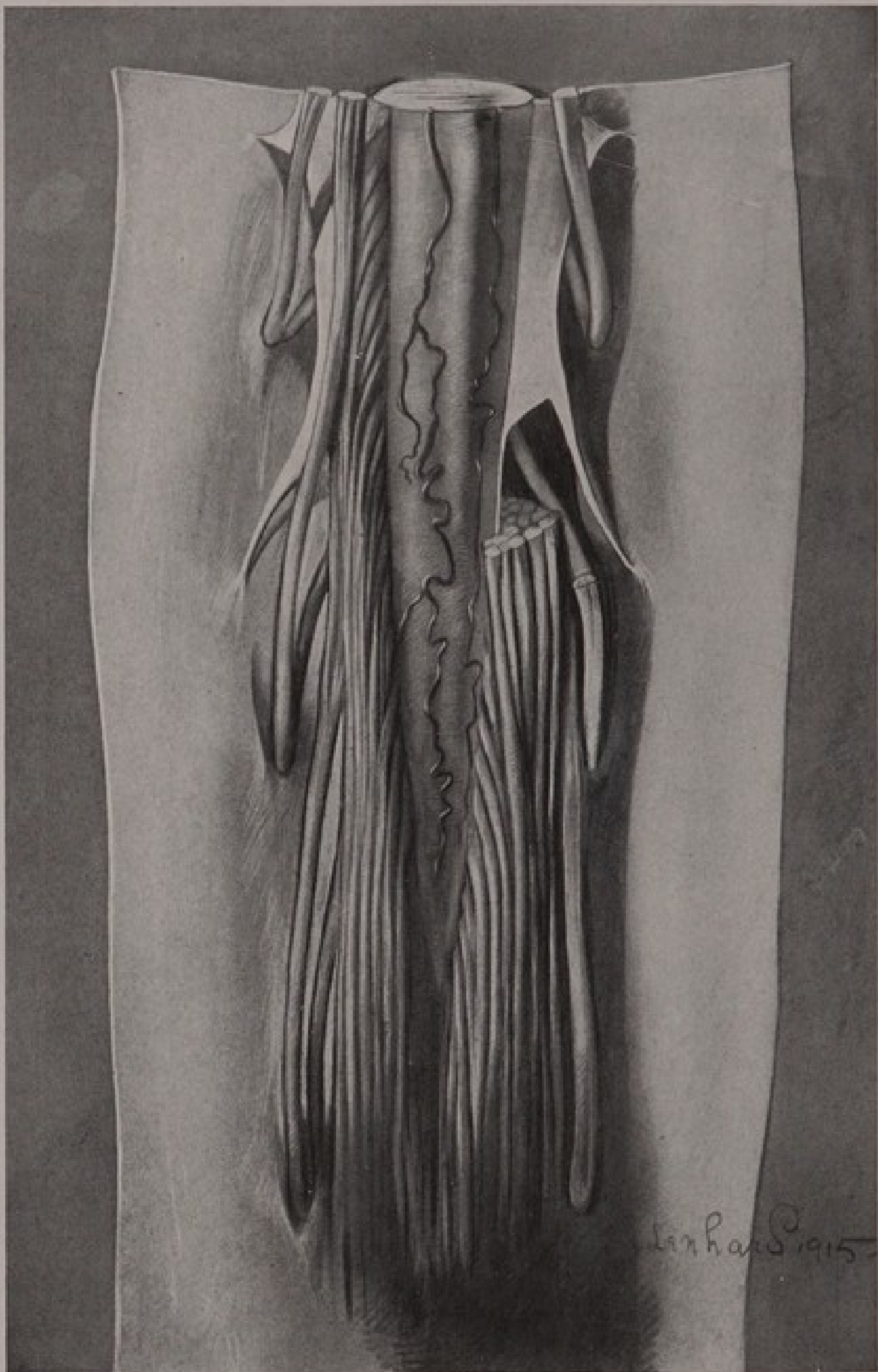


FIG. 14.—The "fork" of the dentate ligament, and its relation to the first lumbar root. On the right side the roots have been cut to show the shape of the fork. × 1½. (From dissection by the author.)

foramen magnum to the level of the first lumbar vertebra. From its attachment to the cord, each ligament extends outward and is attached to the inner surface of the dura by numerous dentations or slips. It is due to this ligament that a tumor which grows on the anterolateral or posterolateral aspect of the cord may press upon only anterior or posterior roots for a long time, and thus give only anterior or posterior root symptoms before the appearance of symptoms of pressure upon the cord itself.

The dentate ligament ends below, at the level of the first lumbar vertebra, in a fork-shaped extremity. The outer prong of the fork is usually about 1 cm. long, and is attached by its end to the inner surface of the dura. Sometimes this prong is 3 to 4 cm. long. The inner prong of the fork is attached to the pia on the lateral aspect of the cord and is prolonged downward along the side of the conus to its tip. The first lumbar posterior root rests upon this fork so that the "fork" may be used as an anatomical landmark for the identification of the first lumbar root (Fig. 14). The posterior roots of the lumbar and sacral nerves are dorsally placed with reference to the fibrous band on the side of the lumbosacral cord and conus derived from the dentate ligament, and can be raised up on a probe. At their origin from the lumbosacral cord the posterior roots lie close together, but when they are raised up with a probe the separate roots can often be recognized. If one begins to count from the posterior root which lies on the fork of the dentate ligament, which is the first lumbar, one can often identify each posterior root.

### THE RELATION OF THE SEGMENTS OF THE CORD TO THE VERTEBRÆ

The relations of the different segments of the spinal cord and of the nerve roots to the spinous processes of the vertebræ can be understood from a study of the accompanying diagram (Fig. 15). In the uppermost cervical region, the origin of the nerve roots from the cord is on the same level as their point of exit from the spinal canal. The lower the nerve root, the greater the distance between its point of origin from the cord and its point of exit from the spinal canal.

In general, the lower boundary of the cervical cord (the level of the eighth cervical nerve) corresponds to the interspace between the fifth

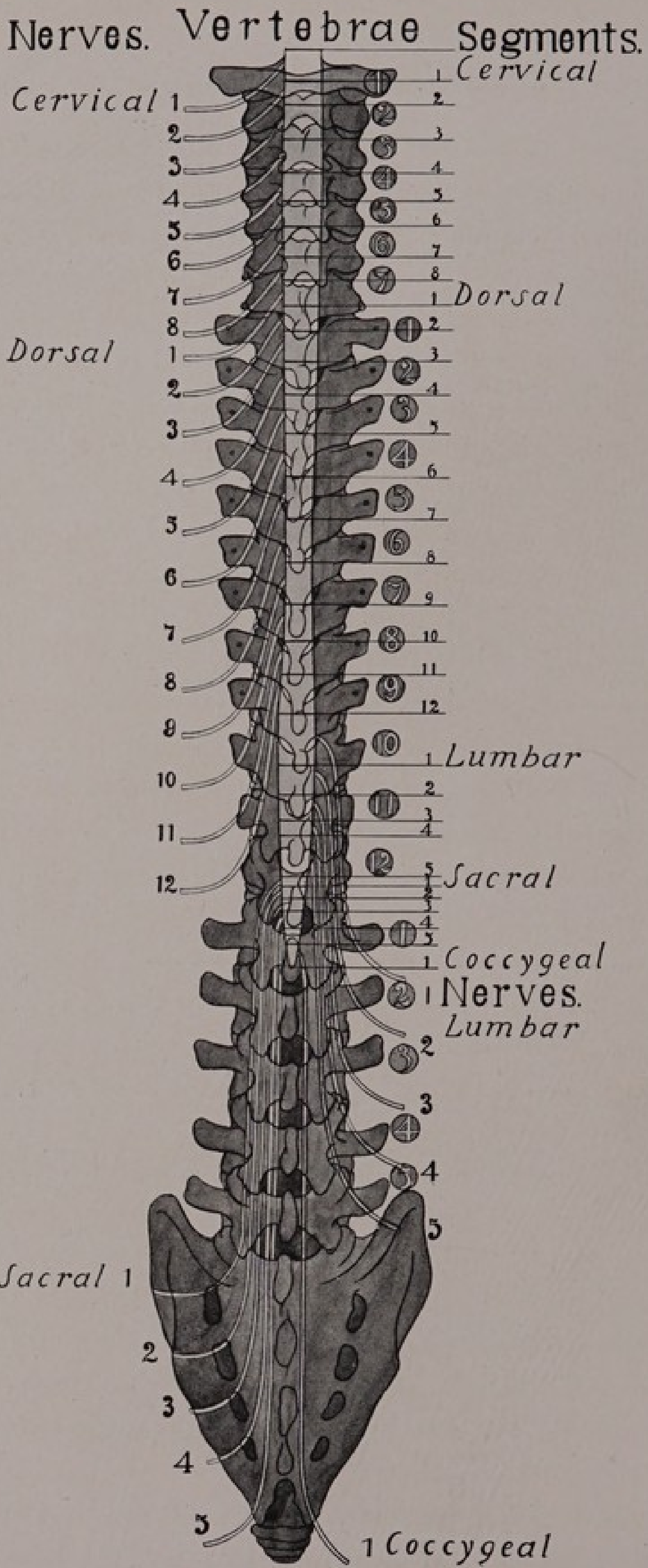



FIG. 15.—The relation of the segments of the cord and of the spinal roots to the vertebræ. The vertebral column is viewed from the back and the spinal cord is seen in the spinal canal. (A composite of ten dissections by the author.)

and sixth cervical spinous processes; the twelfth dorsal segment lies about opposite the ninth dorsal spine; the fifth lumbar segment corresponds to the twelfth dorsal spine. The segments of the spinal cord therefore lie on a higher level than the corresponding vertebræ. The fourth cervical segment lies about opposite the third cervical spine; the fourth dorsal opposite the second dorsal spine; the eighth dorsal opposite the fifth dorsal spine; the twelfth dorsal opposite the ninth dorsal spine; the second lumbar on the level of the tenth dorsal spine; the sacral segments opposite the twelfth dorsal and first lumbar spines. It must be well understood that the lower the level of the segment in question, the greater the distance between it and the correspondingly named spinous process.

### THE BLOOD VESSELS AND THE MAIN FIBER TRACTS OF THE CORD

A superficial account of the anatomy of the spinal cord and the course of its conducting fibers would carry me far beyond the bounds of what is necessary in this volume. Presupposing, therefore, that the reader has a good knowledge of this subject or will obtain detailed information from larger text-books of anatomy and physiology, I shall mention only a few facts of practical importance.

The spinal cord is incompletely divided into two halves by the fissures which pass in from the anterior and posterior surfaces of the cord. The anterior fissure is wider and shorter than the posterior one and reaches to the white commissure. It contains a fold of pia mater and many blood vessels. The posterior fissure or septum also serves to conduct blood vessels to the substance of the cord (Fig. 16). When an incision is made in this septum, considerable oozing of blood is apt to occur, and therefore it is advisable to make the incision rather a little to one side of the septum. There are shallow furrows on each side of the cord in front and behind, corresponding to the lines of attachment of the anterior and posterior roots. Other grooves mark off the mediodorsal or Goll's column and the laterodorsal or Burdach's column. The gray matter occupies the more central parts of the cord, and appears in the form of two irregularly crescentic portions on each side united across the median line by the gray commissure.

The blood supply of the spinal cord is derived from the anterior and

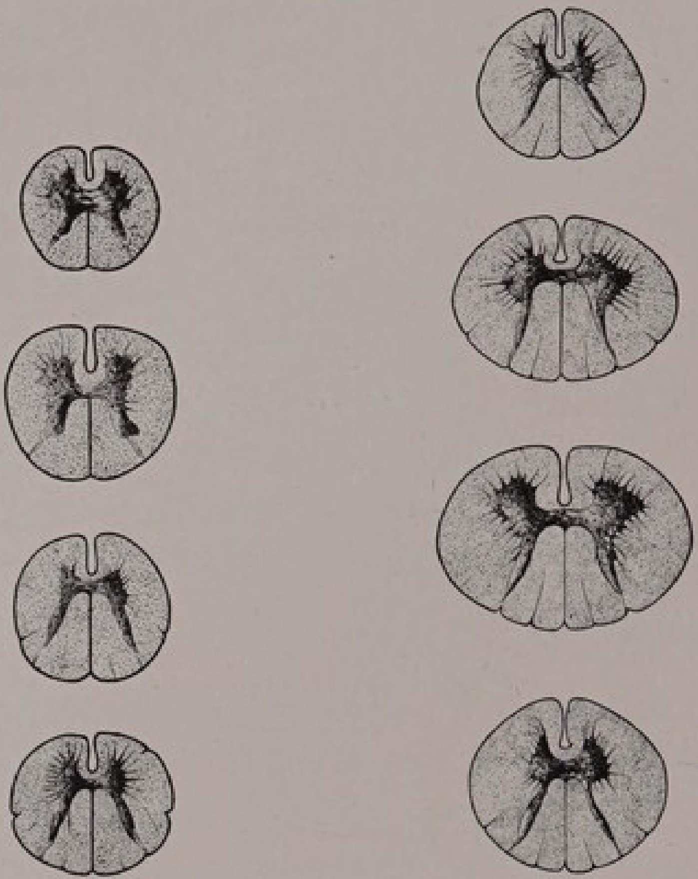


FIG. 16.—Cross sections of the spinal cord, to show the general shape and form of the cord at different levels.

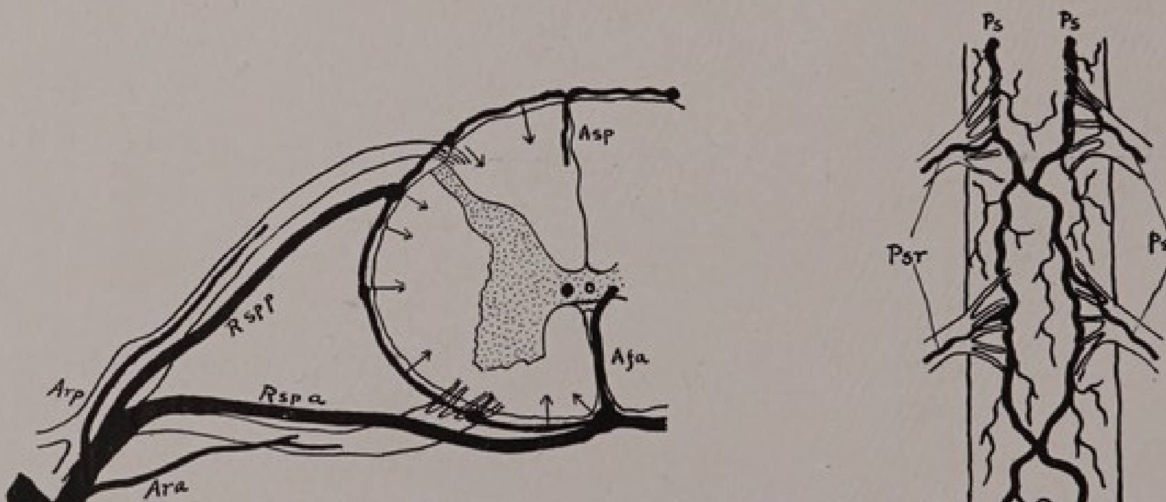



FIG. 17.—The blood supply of the spinal cord. A. Arrangement of the arteries (Ziehen). Afa, artery of the anterior fissure. Ara, artery of the anterior root. Arp, artery of posterior root. Asp, artery of post. med. septum. Rdic, posterior branch of intercostal artery. Rspa, Rspp, anterior and posterior spinal branches.

B. The veins on the posterior surface of the cord. Psr, veins of the posterior roots; Ps, posterior spinal veins.

posterior spinal arteries—branches of the vertebral arteries. The posterior spinal vessels are of special importance because they are the ones that are most often injured in spinal fractures, and because of their position on the posterior aspect of the cord they are in the operative field during laminectomy. The posterior spinal arteries run down on each side of the posterior surface of the cord in front of the origins of the posterior nerve roots. They are more or less tortuous and give off numerous branches which perforate the cord and the posterior median septum. Branches of the posterior spinal veins form a free anastomosis around the dorsal

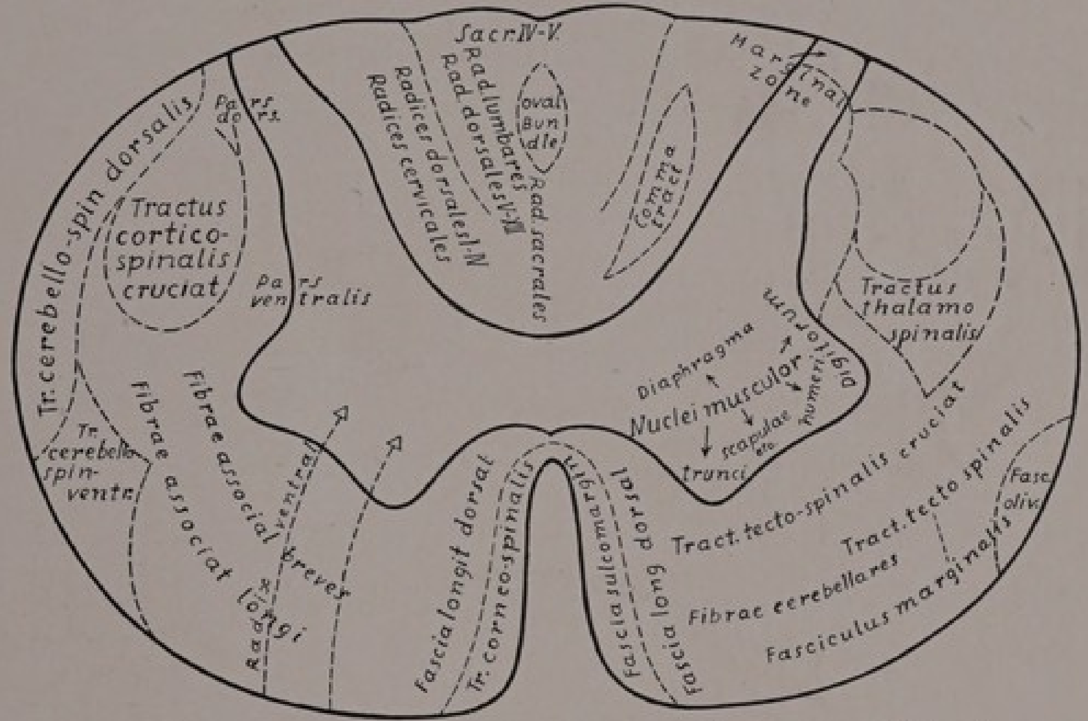



FIG. 18.—Cross section of the cord to show the main fiber tracts (Edinger).

roots of the spinal nerves and accompany each posterior root through the opening in the dura. These branches are sometimes much enlarged so that they cause undue pressure upon the nerve roots and cause root pains. Branches of the two posterior spinal arteries anastomose with each other so that the vessels may be considered as a series of communicating loops (Fig. 17).

The spinal conducting paths are either exogenous, which originate in cells outside of the cord, or endogenous, which originate from cells within the cord substance.

The exogenous fibers are either centrifugal or centripetal. The main fiber tracts are the following:

A. I. CENTRIFUGAL OR DESCENDING (MODIFIED FROM BING) (FIG. 18)

| Name | Origin | Course | Ending |
|---|---|---|---|
| 1. Corticospinal or pyramidal: (*a*) Direct. (*b*) Lateral. | Motor cortex of brain. | (*a*) In anterior columns. (*b*) In lateral columns after decussating in medulla. | In cells of anterior horns. |
| 2. Subcorticospinal: | | | |
| (*a*) Rubrospinal (Monakow's bundle). | Red nucleus. | In lateral columns after crossing. | In cells of anterior horns. |
| (*b*) Thalamospinal. | Optic thalamus. | In lateral columns with rubrospinal tract after crossing. | In cells of anterior horns. |
| (*c*) Tectospinal. | Roof of midbrain. | In lateral columns with rubrospinal tract after crossing. | In cells of anterior horns. |
| (*d*) Vestibulospinal. | Deiter's nucleus. | In anterior columns without crossing. | In cells of anterior horns. |

II. CENTRIPETAL OR ASCENDING

| Name | Origin | Course | Ending |
|---|---|---|---|
| 1. Short fibers from posterior roots. | Spinal ganglia from periphery. | Through marginal zone. | In cells of anterior and posterior horns. |
| 2. Long fibers from posterior roots. | Spinal ganglia from periphery. | Through posterior horns without crossing. | In Clarke's columns. |
| 3. Long fibers. | Spinal ganglia from periphery. | Through posterior columns. | In nuclei of posterior columns and medulla. |

B. I. ENDOGENOUS FIBERS

| Name | Origin | Course | Ending |
|---|---|---|---|
| 1. Spinocerebellar: | | | |
| (*a*) Dorsal (Flechsig). | Cells of Clarke's column. | Lateral column without crossing. | In cerebellum (vermis). |
| (*b*) Ventral (Gower's). | Cells of anterior horn. | Anterior part of lateral column partly crossed, partly uncrossed. | In cerebellum (vermis). |
| (*c*) Spinothalamic. | Cells of posterior horn. | In lateral column after crossing. | In optic thalamus. |
| 2. Association tracts: (*a*) In anterior columns. (*b*) In posterior columns. | | | |
| 3. Root fibers. | Cells of anterior horn. | Peripheral nerves. | |

## CHAPTER II

### THE NORMAL AND PATHOLOGICAL PHYSIOLOGY OF THE SPINAL CORD

The spinal cord is a sensory, motor, vasomotor and trophic organ.

1. It contains fibers for the transmission of various kinds of sensation—tactile, temperature, pain, deep muscle and joint sense. The fibers for touch enter the cord in the posterior roots and pass upward in the posterior columns partly on the same and partly on the opposite side. The fibers from each root lie outside and somewhat superficial to those from

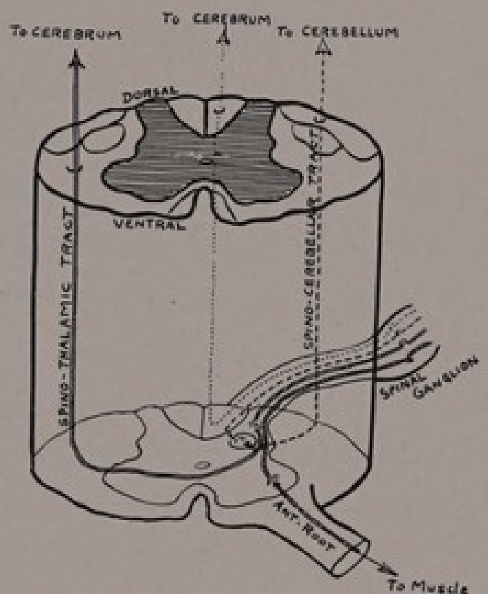



FIG. 19.—The general direction of the fibers which enter the cord through the posterior roots (modified from Bing).

the next lower root. They thus form a series of lamellar tracts, the fibers from each posterior root as they enter the posterior columns crowding the fibers from the next lower nerve root more toward the median line. From this it results that the fibers for tactile sensation from the lumbar and sacral nerves lie nearest the median line, the dorsal more external and posterior, and so on. When one part of the sensory pathway in the cord is interrupted other tracts may take up the transmission of sensations. Although this is probably true for all kinds of sensation, the tactile sensations especially seem to run in a bilateral path and are not so apt to be markedly affected by a purely unilateral lesion.

The fibers for temperature and pain sensation enter in the posterior roots, soon pass into the gray matter of the posterior horns, and crossing over to the other side enter the anterior part of the lateral columns and run upward to the optic thalami (Fig. 19). The fibers for the sensations of temperature do not cross to the other side as quickly as the fibers for pain, but require from two to five segments for their complete crossing.

The fibers for deep muscle sense (postural recognition, spacial discrimination—(bathyesthesia of Oppenheim) in part pass up in the posterior columns; in part they enter the posterior horns, pass outward and then upward in the posterior parts of the lateral columns (lateral cerebellar tracts) to end in the cerebellum.

2. The pyramidal tracts, lying in the lateral and in the mesial parts of the anterior columns, contain the main fibers for the transmission of motor impulses to the muscles through the anterior roots. Interference with these tracts is not always followed by a complete paralysis, because there are a number of secondary tracts which contain fibers from lower centers to the motor nerve cells in the anterior horns which can to a certain extent take up the functions of the pyramidal tract fibers. While destruction of the pyramidal tracts may not cause a complete paralysis, the destruction of the cells in the anterior horns (which are secondary centers for the muscles of the trunk and extremities) will be followed by a complete paralysis and atrophy of the muscles innervated from these cells. Muscle tone and the muscle and tendon reflexes are controlled through the pyramidal tracts and the anterior spinal roots. Muscle tone is controlled through the cells in the anterior gray horns, but these are under the influence of sensory stimuli which are continually passing to the cells from the periphery, both from the skin and from the muscles themselves. The tone of the muscles would be too great and the reflexes too active if it were not for controlling and regulating influences from higher centers which pass down to the cells in the anterior horns through the fibers in the pyramidal tracts. These considerations explain why a lesion of the pyramidal tracts is followed by hypertonus and an exag-

geration of tendon reflexes; a lesion of the anterior spinal roots by a loss, and lesion of posterior spinal roots or posterior white columns by a more or less well-marked diminution in muscle tone and in the tendon reflexes.

3. The cells in the gray horns form the trophic centers for the *motor* nerve fibers which originate from them. Destruction of the cells in the anterior horns is followed by a typical Wallerian degeneration in the nerve fibers from these cells, followed by a degenerative atrophy of the muscles, so that they no longer respond in the normal manner to the electrical current. The typical "reaction of degeneration" consists of (1) a loss of contractility of the muscles when the nerves are stimulated by either the faradic or galvanic current, and (2) a loss of faradic contractility and an increased irritability to galvanism of the muscles themselves. When complete degenerative atrophy has occurred neither nerve nor muscle will respond to faradic or galvanic stimulation. The *sensory* nerves which are continued as the posterior spinal roots will similarly degenerate when they are separated from the spinal ganglia, which are the trophic centers for the peripheral sensory nerves. The central nervous system exercises a trophic influence upon all of the tissues of the body, upon the muscles and bones, as well as the skin and its adnexa. There is no satisfactory evidence that there are special trophic nerves, and most investigators of this subject have concluded that in a way not yet understood the central nervous system—brain and spinal cord—exerts this trophic influence.

4. The spinal cord also exercises a control over the vasomotor system. Lesions of the cord may result in either increased redness and heat of the skin with hyperidrosis, or in cyanosis or pallor, fall in cutaneous temperature and anidrosis. As far as is known, the vasomotor centers lie in the anterior gray horns of the spinal cord.

From what has been stated above, we can in a general way understand the symptoms which will arise from disease or destruction of fibers or cells in the cord. We must next determine what are the functions of the different parts of the cord and of the nerve roots, and what symptoms follow the division of nerve roots or cord tracts.

**The Functions of the Spinal Roots.**—Irritation of a posterior or sensory spinal root will cause pain, hyperesthesia or paresthesia over part or the entire area of distribution of the nerve root. Disease or pressure may affect only a few of the bundles that make up a posterior root; this will occur most often in the cervical region where the nerve bundles originate over a considerable length of the cord and unite only at the dural opening.

If the entire nerve root is destroyed, there may be some sensory disturbances (hypesthesia). According to the so-called "Sherrington's law," each area or zone of the skin is supplied by three spinal roots and anesthesia will occur only when three successive roots have been destroyed.[1] In these cases all kinds of sensation—tactile, pain, thermal, deep muscle—are lost.

Division of a number of posterior roots from an extremity will cause a marked atony and ataxia of the limb. This is due both to the loss of deep muscle sense and to the destruction of the afferent part of the reflex arcs which control the tone of the muscles.

As will be shown in the chapter on spinal localization, root pains and root anesthesias are important in the localization of the level of a spinal lesion.

In the case of the *anterior* roots, the question is a more simple one. Irritation of an anterior root will be followed by muscle spasm or hypertonicity; division of one or more roots will be followed by weakness and loss of tone or paralysis of the muscle or muscles innervated by the root, followed sooner or later by atrophy of the muscles.

**Results of Lesions of the Central Gray Matter.**—In these cases the sensory symptoms are generally of the nature known as dissociated, *i.e.*, there is a disturbance in the thermal and pain senses with persistence of normal or almost normal tactile sense. The disturbance in thermal sensation is usually incomplete unless parts of the lateral white columns are also affected, and warm is sometimes better felt than cold, or vice versa. At other times there may be a perversion of the temperature sense, so that cold is felt as warm, and warm as cold. The sensory disturbance may occur over large or small areas.

[1] Sherrington's law holds good in almost all instances. Undoubted cases are on record, however, in which anesthesia occurred when only two roots were divided, and in several instances no loss of sensation occurred where four successive roots had been divided.

The motor symptoms consist of weakness or paralysis of the muscles whose centers lie within the affected area, followed by rapid degenerative atrophy.

**Division of the Posterior White Columns.**—If the posterior white column of one side alone is divided, there is no sensory disturbance at all or only some diminution of deep muscle sensibility on the same side. If both posterior columns are divided, there will be a diminution or loss of tactile and deep muscle sensation below the level of the lesion. In unilateral division of the posterior column there may also be slight disturbance in pain and thermal sensibility on the side opposite to the lesion, if the marginal root area has been injured (injury to root fibers in the marginal root zone).

**Division of a lateral white column** will cause a paresis or paralysis of all the muscles supplied below the level of the lesion on the same side, associated with a marked increase of tone of the muscles (spasticity) and an increase of muscle and tendon reflexes. Vasomotor disturbances are sometimes observed. The sensory changes affect the thermal and pain senses on the opposite side. Homolateral and contralateral ataxia have also been observed.

**Division of One-half (Hemisection) of the Cord.**—The symptoms which follow present a well-recognized picture known as the Brown-Séquard syndrome, from the author who was the first to make a careful study of the symptoms. In the typical cases there are motor paralysis, superficial hyperesthesia, loss of deep muscle sense and vasomotor disturbances on the side of the lesion, and loss of tactile, pain, and temperature sense on the opposite side.

**Complete transverse division of the cord** is followed by a loss of all motor and sensory power below the level of the lesion, with loss of superficial and deep reflexes and paralysis of the bladder and rectum. Occasionally, slight reflexes will persist for a short time, but in the majority of instances the loss is immediate and complete. The symptoms of an incomplete transverse lesion of the cord will be considered in another chapter.

### THE SENSITIVENESS OF THE CORD AND MEMBRANES

Although our knowledge of this subject is still meager, investigations I have made, which substantiate the results of others, have led me to the following conclusions: The outer surface of the dura is insensitive while its inner surface is very sensitive. When the inner surface of the dura is scratched or rubbed a distinct pain referred to the back is complained of by the patient. The pia arachnoid and the dentate ligament are not sensitive. A slip of the ligament may be grasped with a forceps and divided with scissors without pain.

The cord tissue itself is not sensitive to pain, as far as I have been able to determine during my operations under local anesthesia and in experiments on animals. When an incision is made in the posterior columns near the origin of the posterior roots, however, the patient will complain of a peculiar burning pain which may be referred to an extremity, although often the patient will declare that he feels pain but is unable to localize it.

The posterior spinal roots are very sensitive in their entire course, the painful sensations being referred to the periphery. In one or two instances I have gained the impression that the anterior nerve roots were not entirely insensitive, but I am in some doubt as to the correctness of these observations.

# CHAPTER III

## THE LOCALIZATION OF MOTOR, SENSORY AND REFLEX FUNCTIONS IN THE DIFFERENT SEGMENTS OF THE SPINAL CORD

The spinal centers for the muscles of the trunk and extremities lie in the cells of the gray matter of the cord. Most of the muscles have a plurisegmental innervation and there is no evidence that, as in the brain, distinct nuclei for single muscles or even for muscle groups exist.

With few exceptions the muscles are innervated from groups of cells which extend over several segments. Muscles with different functions may be innervated through the same anterior root (Forgue and Lannegrace, Martin, Sherrington). According to Herringham, of two muscles, both of which receive their nerve supply from cells in several segments, the one nearer the head, the one nearer the long axis of the body, or the one of the two that is more superficially placed, will be supplied by the uppermost of the segments in question.

If the general facts just given be kept in mind, the localization of the centers for the muscles will be easily understood. The following table has been modified from that of Flatau (Handbuch der Neurologie, Vol. I, Part II, pages 659 to 661), to which I have added the main function of each muscle or muscle group.

### THE SEGMENTARY LOCALIZATION OF THE MUSCLES

**A. Muscles of the Head and Trunk.**

I. *Muscles of the Back.*

| | | |
|---|---|---|
| Trapezius | C 2–4 | Rotation of scapula, raises shoulder, moves head to side. |
| Latissimus dorsi | C 6–8 | Adducts and rotates arm inward, draws arm backward, raises ribs. |
| Rhomboid | C 4–5 | Rotates and moves scapula backward. |
| Levator anguli scapulæ | C 3–5 | Raises angle of scapula. |
| Serratus posticus superior | D 1–4 | Respiration. |
| Splenius capitis | C 2–8(?) | Rotates head and draws it to side. |
| Paravertebral muscles | C 1–S 3 | Movements of vertebral column. |
| Rectus capitis major | C 1–2 | Rotate head and draw it back. |
| Rectus capitis minor | C 1 | |
| Obliquus capitis superior | C 1 | Rotate head and draw it back. |
| Obliquus capitis inferior | C 2 | |

II. *Muscles of Neck, Chest and Abdomen.*

| | | |
|---|---|---|
| **Muscles of the neck:** | | |
| Platysma | C 3 | Depresses lower lips and angle of mouth, wrinkles skin of neck. |
| Sterno-mastoid | C 2–3 | Rotates and draws head to shoulder, muscle of inspiration. |
| Sterno-hyoid | C 1–3 | Depress larynx and hyoid bone, control movements of thyroid cartilage. |
| Omo-hyoid | C 1–3 | |
| Sterno-thyroid | C 1–4 | |
| Thyro-hyoid | C 1–2 | |
| Longus colli | C 2–8 | Flex and rotate cervical vertebral column. |
| Longus capitis | C 1–4 | |
| Rectus capitis anticus | C 1 | Flexes and rotates head. |
| Scalenus anticus | C 4–7 | Raise ribs for inspiration. |
| Scalenus medius | C 2–8 | |
| Scalenus posticus | C 5–8 | |
| **Muscles of the chest:** | | |
| Pectoralis major | C 5–6 | Adduction, downward and forward movement of arm. |
| Pectoralis minor | C 7–8(D1) | |
| Subclavius | C 5–6 | Depresses shoulder. |
| Serratus anticus | C 5–7 | Fixes scapula. |
| Levatores costarum | C 8–D 11 | Fix ribs. |
| Intercostals | D 2–11 | Inspiration. |
| Triangularis sterni | D 3–4 | Expiration. |
| Diaphragm | C 3–5 | Respiration. |
| **Muscles of abdomen:** | | |
| Rectus abdominis | D 5–12 | Constrict cavity of abdomen, assist expiration, rotate trunk, move pelvis. |
| Pyramidalis | D 12–L 1 | |
| Obliquus externus | D 5–12 | |
| Obliquus internus | D 8–L 1 | |
| Transversalis | D 7–L 1 | |
| Quadratus lumborum | D 11–L 2 or L 1–4 | Moves pelvis and trunk, inspiration. |
| Coccygeus | S 3–5, C | Supports coccyx. |

**B. Muscles of the Extremities.**

I. *Muscles of the Upper Extremities.*

| | | |
|---|---|---|
| **(*a*) Shoulder:** | | |
| Deltoid | C 5–6 | Abduct arm to horizontal, abduct and rotate arm outward. |
| Supraspinatus | C 5 | |
| Infraspinatus | C 5–6 | |
| Teres minor | C 5 | Rotates arm outward. |
| Teres major | C (5), 6, (7) | Rotates arm inward. |
| Subscapularis | C 5–6 | Rotates arm inward. |
| **(*b*) Arm:** | | |
| Biceps | C 5–6 | Flexes and supinates forearm. |
| Coraco-brachialis | C 6–7 | Adducts forearm. |
| Brachialis anticus | C 5–6 | Flexes forearm. |
| Triceps | C 6–7 (8) | Extends forearm. |
| Subanconeus | C 7 (8) | Fixation of synovial membrane. |
| **(*c*) Forearm:** | | |
| Pronator radii teres | C 6–7 | Pronates forearm. |
| Flexor carpi radialis | C 6–7 | Flexes and radially flexes hand. |

| | | |
|---|---|---|
| Palmaris longus | C (7), 8, (D 1) | Flexes hand. |
| Flexor carpi ulnaris | C (7), 8, (D 1 | Flexes and ulnar flexes hand. |
| Flexor sublimis digitorum | C 7–8, D 1 | Flexes middle phalanges, 2–5 fingers. |
| Flexor profundus digitorum | C 7–8, D 1 | Flexes last phalanges, 2–5 fingers. |
| Flexor longus pollicis | C 6–7 | Flexes last phalanx of thumb. |
| Pronator quadratus | C 6–8, D 1 | Pronates forearm. |
| Supinator longus | C 5–6 | Flexes forearm. |
| Extensor carpi radialis | C (5), 6–7 | Extends radially, flexes hand. |
| Extensor communis digitorum | C 6–8 | Extension of first phalanges, 2–5 fingers |
| Extensor minimi digiti | C (6), 7–8 | Extension of first phalanx of little finger. |
| Extensor carpi ulnaris | C (6), 7–8 | Extension and ulnar flexion of hand. |
| Supinator brevis | C 5–7 | Supinates forearm. |
| Abductor longus pollicis | C 6–7 | Abducts first metacarpal. |
| Extensor brevis pollicis | C 6–7 | Extension of first phalanx of thumb. |
| Extensor longus pollicis | C 6–7, (8) | Abducts first metacarpal; extension of last phalanx of thumb. |
| Extensor proprius indicis | C 6–8 | Extension of first phalanx of index-finger. |

(*d*) Hand:

| | | |
|---|---|---|
| Abductor brevis pollicis | C 6–7 | Abducts first metacarpal. |
| Flexor brevis pollicis | C 6–7 | Flexes first phalanx of thumb. |
| Opponens pollicis | C 6–7 | Opposition of first metacarpal. |
| Adductor pollicis | C 6–7 | Adducts first metacarpal. |
| Abductor minimi digiti | C 8, D 1 | Abducts little finger. |
| Flexor brevis minimi digiti | C (7), 8, (D 1) | Abducts and flexes little finger. |
| Opponens minimi digiti | C (7), 8, (D 1) | Draws forward 5th metacarpal. |
| Lumbricales | C 7–8, (D 1) | Abduct and adduct fingers. |
| Interossei | C 7–8, (D 1) | Extension of 2d and 3d phalanges. |

II. *Muscles of the Lower Extremities.*

(*a*) Hip:

| | | |
|---|---|---|
| Iliacus | L 2–4 | Flexion at hip. |
| Psoas major | (D 12), L 1–3, (4) | Flexion at hip. |
| Psoas minor | (D 12), L 1–3, (4) | |
| Gluteus maximus | (L 4), 5, S 1, (2) | Extension of thigh. |
| Tensor fasciæ latæ | L 4–5 | Flexion of thigh. |
| Gluteus medius | L 4–5, S 1 | Abduction and internal rotation of thigh. |
| Gluteus minimus | L 4–5, S 1 | |
| Pyriformis | S 1–2 | External rotation of thigh. |
| Obturator internus | L 5, S 1–2 | External rotation of thigh. |
| Quadratus femoris | L 4–5, S 1 | |

(*b*) Thigh:

| | | |
|---|---|---|
| Sartorius | L 2–3 | Internal rotation of leg. |
| Rectus femoris | L 2–4 | |
| Vastus medius | L 2–3 | Extension of leg. |
| Vastus internus | L 2–4 | |
| Vastus externus | L 3–4 | |
| Pectineus | L 2–3 | |
| Adductor longus | L 2–3 | |
| Gracilis | L 2–4 | Adduct thigh. |
| Adductor brevis | L 2–4 | |
| Adductor magnus | L 3–4 | |

| | | |
|---|---|---|
| Obturator externus | L 3–4 | Adduction and external rotation of thigh. |
| Biceps | L (4), 5, S 1–2 | Flex leg. |
| Semitendinosus | L 4–5, S 1 | |
| Semimembranosus | L 4–5, S 1 | |
| (*c*) Leg: | | |
| Tibialis anticus | L 4, (5) | Dorsal flexion and supination of foot. |
| Extensor longus digitorum | L 4–5, S 1 | Extension of toes. |
| Peroneus tertius | L 5, (S 1) | Dorsal flexion and pronation of foot. |
| Extensor longus pollicis | L 4–5 (S 1) | Extension of large toe. |
| Peroneus longus | L 5, S 1 | Dorsal flexion and pronation of foot. |
| Peroneus brevis | L 5, S 1 | |
| Gastrocnemius | L (4), 5, S 1–2 | Plantar flexion of foot. |
| Soleus | L (4), 5, S 1, (2) | |
| Plantaris | (L 4–5, S 1) | |
| Popliteus | L 4–5, S 1 | Flexion of leg. |
| Tibialis posticus | L 5, S 1, (2) | Adduction of foot. |
| Flexor longus digitorum | L 5, S 1–2 | Flexion of last phalanges II to V. |
| Flexor longus pollicis | L 5, S 1–2 | Flexion of last phalanx of large toe. |
| (*d*) Foot: | | |
| Extensor brevis pollicis | L 4–5, (S 1) | Extension of large toe. |
| Extensor brevis digitorum | L 4–5, S 1 | Extension of toes. |
| Abductor pollicis | L 5–S 1 | Movement of toes. |
| Flexor brevis pollicis | L 5–S 1 | |
| Adductor pollicis | S 1–2 | |
| Abductor minimi digiti | S 1–2 | |
| Opponens minimi digiti | S 1–2 | |
| Flexor brevis digitorum | L 5–S 2 | |
| Lumbricales | S 1–2 | |
| Interossei | S 1–2 | |

## THE SEGMENT DISTRIBUTION OF SENSATION IN THE BODY

Anatomical, physiological and experimental investigations have led to the division of the skin of the body into a number of areas or zones (Head, Thorburn, Starr, Mackenzie, Petrèn, Sherren, etc.) in relation to the different spinal segments. These areas are not distinct but overlap each other, so that each area is supplied from three spinal segments (Sherrington) (Fig. 20). This overlapping does not occur to the same extent in all parts of the body; on the chest and abdomen the zones overlap each other only partially while in the hand, for example, each area of skin is supplied by three spinal roots. It is of some practical importance to remember that the overlapping for the sensation of pain is aways less than that for touch.

Notwithstanding the large amount of investigation that has been

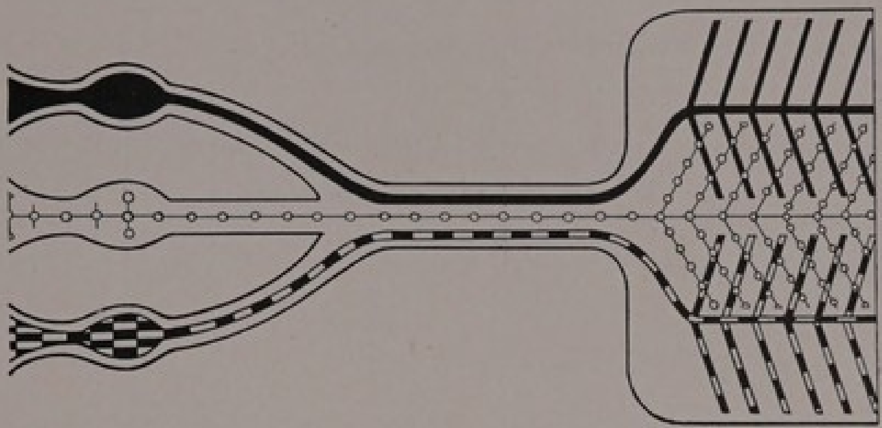


FIG. 20.—The sensory supply of a skin area from three posterior roots.

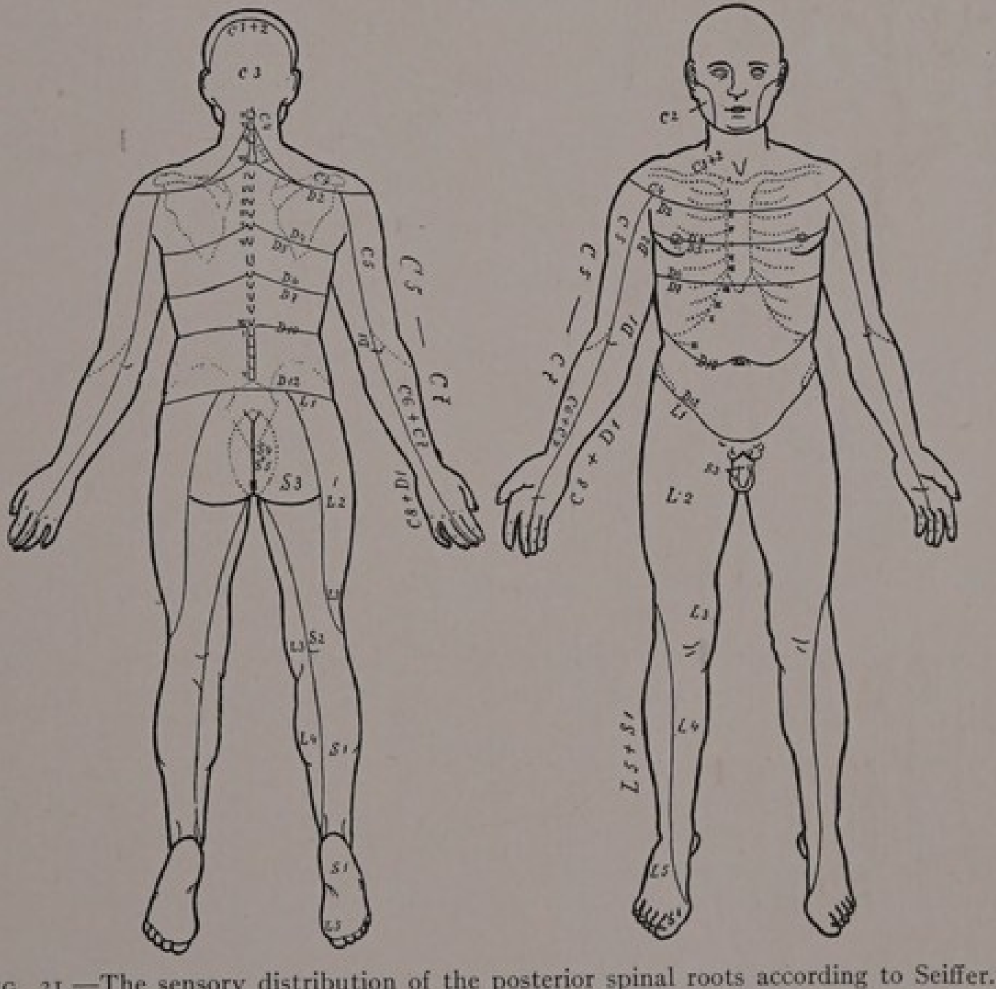


FIG. 21.—The sensory distribution of the posterior spinal roots according to Seiffer.

made, the exact size and shape of the areas supplied by the several spinal roots have not been determined with certainty. Probably considerable variations occur in different individuals.

The accompanying figures give the sensory distribution of the spinal roots according to Seiffer and to Flatau (see Figs. 21 and 22).

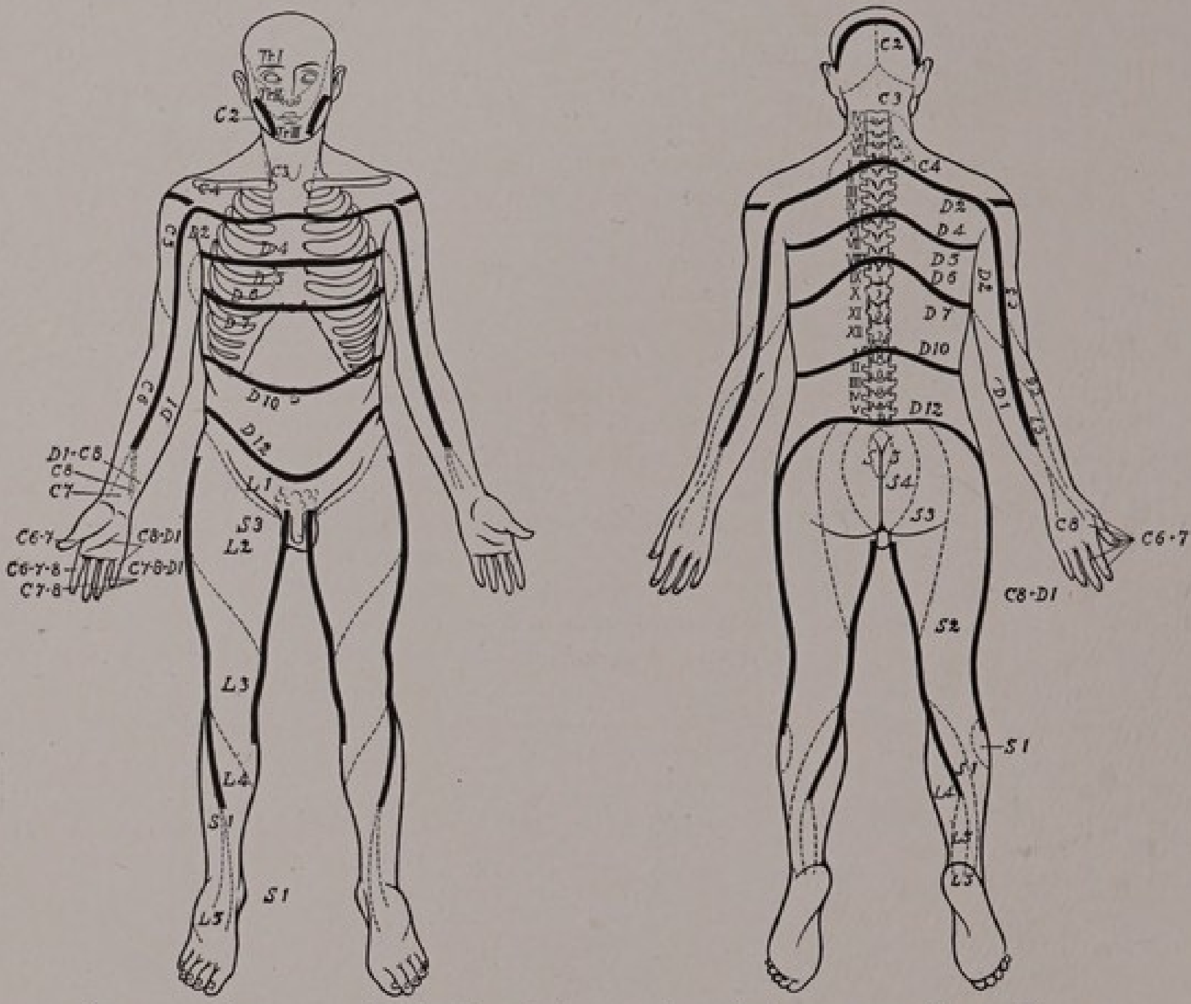



FIG. 22.—The sensory distribution of the posterior spinal roots according to Flatau.

4. In addition to these reflexes, the following centers must be mentioned:

1. The cilio-spinal center........................................ C 8 to D 1
2. The center for the bladder.................................. S 3 – 4
3. The center for the rectum.................................... S 3 – 4
4. The center for the sexual organs............................ S 2 – 3
5. The spinal respiratory center (phrenic nerve).................. C 3 – 5

Further information concerning these centers will be found in Chapter V.

## THE CENTERS FOR THE SKIN AND TENDON REFLEXES IN THE SPINAL CORD (ACCORDING TO BING)

| Tendon reflex | Skin reflex | Elicited by | Result | Localization |
|---|---|---|---|---|
| | Scapula reflex. | Irritation of skin over scapula. | Contraction of muscles of shoulder blade. | C 5–D 1 |
| Biceps reflex... | .................. | Blow on tendon of biceps. | Flexion of forearm. | C 5–6 |
| Triceps reflex.. | .................. | Blow on tendon of triceps. | Extension of forearm. | C 6–7 |
| Scapulo-humeral reflex. | .................. | Blow on lower inner angle of scapula. | Adduction of arm. | C 6–7 |
| Radius reflex.. | .................. | Blow on styloid process of radius. | Supination of forearm. | C 7–8 |
| | Palmar reflex. | Irritation of palm of hand. | Flexion of fingers. | C 8–D 1 |
| | Epigastric reflex. | Irritation of lower part of chest. | Contraction in epigastric region. | D 7–9 |
| | Upper abdominal reflex. | Irritation of skin over upper abdomen. | Contraction of abdominal muscles. | D 8–9 |
| | Lower abdominal reflex. | Irritation of skin of lower abdomen. | Contraction of abdominal muscles. | D 10–12 |
| | Cremaster reflex. | Irritation of region over adductor muscles. | Elevation of testis. | L 1–2 |
| Patellar reflex. | .................. | Blow on tendon of quadriceps. | Extension of leg. | L 2–4 |
| | Gluteal reflex. | Irritation of skin of gluteal region. | Contraction of gluteal muscles. | L 4–5 |
| Achilles reflex.. | .................. | Blow on Achilles tendon. | Extension of foot. | S 1–2 |
| | Plantar reflex. | Irritation of skin of sole. | Flexion of toes. | S 1–2 |
| | Anal reflex. | Pricking of perineum. | Contraction of sphincter ani. | S 5 |

## CHAPTER IV

### THE SYMPTOMATOLOGY OF SPINAL DISEASE

The symptoms of a spinal disease, whether or not that disease is amenable to surgical treatment, will depend upon the nature of the disease and the part of the spinal cord and nerve roots that have become affected. Some diseases attack particular tracts or groups of nerve cells; others are destructive in nature—cells, fibers or entire tracts being destroyed; in still others the functions of cell groups and conducting fibers are inhibited by pressure and in the early stages little or no actual injury occurs. It is characteristic of all of these varieties, however, that sooner or later secondary destruction—ascending or descending degeneration—occurs. The early symptoms will depend mainly upon the parts of the spinal cord first affected. Thus diseases which cause a localized increase of pressure will often give early anterior or posterior root symptoms, either spasms or weakness or paralysis of muscles, or pain or other sensory disturbances. Associated with these early symptoms there is usually more or less rigidity of the spinal column. The stiffness of the back is generally a defensive phenomenon because the pain is generally made worse by movements of the back or by sudden shocks to the spine, as occur in sneezing and coughing. The scoliosis which is often seen in spinal compression due to tumor is also to be explained as a defensive phenomenon.

After the root symptoms have existed for a certain time (and the period may extend over months or many years), symptoms referable to the cord appear. These are either weakness or paralysis of groups of muscles or of entire extremities, and sensory disturbances due to interruption of centripetal fibers in the white columns or gray matter of the cord. The progression of symptoms is sometimes very slow, extending over months or years, with frequent remissions, or it is more rapid, sensory and motor loss becoming marked and extensive within a short time. These are soon followed by disturbances in the functions of the bladder and rectum, and, finally, with marked trophic disturbances, decubitus and edema of the extremities.

The above is the general course of symptoms when the spinal cord is subjected to a gradually increasing pressure from without. When, on the other hand, the disease originates within the cord substance itself, the progression of symptoms is usually a somewhat different one. While pain may be an early symptom, it is generally absent in the early stages of intramedullary disease. The first symptoms are generally motor—weakness and atrophy of muscles or muscle groups with gradual extension until more or less of one or of several extremities is affected. With these early motor symptoms there are sensory disturbances of the dissociated type, or sensation remains normal. The patients often complain of a feeling of numbness or cold in the limbs.

In the first variety of disease, *i.e.*, in which pressure upon the cord from without occurs, the sensory and motor symptoms sooner or later have a distinct level character; in the primary intramedullary disease there may be the same evidence of a level lesion. In many cases of intramedullary disease, however, the affection spreads upward (and downward) in an irregular way, affecting parts of the various fiber tracts so that no distinct level can be recognized. If a level of the disease is observed, it may be shifted upward by the gradual advance of the disease. Similarly, in some extramedullary diseases (leptomeningitis, pachymeningitis) the level of the disease may be slowly shifted upward with the advance of the inflammatory process.

From what has been said, it is clear that the recognition of the *sequence* of the symptoms is very important for the diagnosis and correct valuation of the symptoms of spinal diseases.

1. **The sensory disturbances due to spinal disease** affect the three elementary sensations—touch, pain, and temperature. In lesions within the substance of the spinal cord, pain or temperature sense (if affected at all) is diminished or lost, but it is the entire pain or the entire temperature sense. In root lesions, on the other hand, we regularly observe the peripheral type of sensory disturbance described by Henry Head. When a posterior root lesion is suspected we must examine separately for super-

ficial and deep pain sense disturbance, and for disturbances in the protopathic (above 45° and below 20°C.) and the epicritic (between 25° and 40°C.) temperature sense. In the peripheral nerves there is a close connection between the sensation of pressure, of painful pressure, and the power of recognition of the position of the limbs, or of passive movements, while (according to Head) in spinal disease the power of recognizing the direction and nature of passive movements and of the sense of pressure may be distinct from deep muscle sense.

The sensory symptoms are either subjective or objective. Under the first heading are included pain and paresthesia; under the second, a great variety of disturbances of sensation discovered by physical examination.

The pain of spinal disease may vary much in its intensity. Disease of or pressure on posterior spinal roots will cause typical root pains usually referred to the periphery—down one or the other limb, to part of the chest or abdomen. The so-called intercostal neuralgia is most often a real root pain and recent investigations, have demonstrated that some, at least, of the indefinite abdominal disturbances complained of by patients are due to sensitive cutaneous areas on the abdominal wall. In the so-called "neuritis" of one of the extremities, unless its cause has been determined, we must always be on the lookout for a possible spinal root lesion. Many patients with spinal lesions, especially with intradural newgrowths, complain of pain in the back which is different from root pain and which is, I believe, due to irritation of the sensitive inner surface of the dura mater.

When paresthesiæ are complained of there is usually a "pin and needle sensation," a feeling of numbness or coldness, or burning sensations. These paresthesiæ are sometimes referred to particular nerve areas, but more often are referred to the peripheral parts of extremities. In the former case their localization has considerable diagnostic value, especially when an objective sensory disturbance is found over the same area.

Objective sensory disturbances mainly consist of increase, diminution or disappearance over definite areas of one or more of the three main forms of sensation—touch, pain or temperature. In complete destructions of the cord at any level, there is a total loss of all sensation below the affected level. In partial lesions of the cord the sensory disturbance will depend upon the level of the lesion and the tracts affected.

A hypersensitiveness to touch, pain or heat and cold often occurs at the level of a spinal lesion and is probably due to irritation of posterior spinal nerve roots at that level. If the function of a posterior nerve root at the level of the disease is totally interfered with, there may be an anesthesia over the area of distribution of the root, but this rarely occurs unless three roots at least are affected. Hence we may find at or above the general level of the sensory disturbances a hyperesthesia or an anesthesia which is radicular in character, and when this occurs on one side of the body only, we may be certain that the lesion—if a localized one—is on that side of the spinal cord.

The amount of disturbance of sensation below the level of the lesion will depend upon the degree of interference with fiber tracts. The amount of tactile disturbance is not apt to be as marked as that of the other sensations for reasons that have been explained elsewhere, for tactile sensation is lost only when there is extensive disease of the cord. Loss of tactile sense does, however, occur alone, although in most cases it is associated with changes in the pain and temperature senses.

Disturbances in tactile and deep muscle sensation will regularly follow a disease of both posterior white columns of the cord, but numerous cases are on record where disease of one posterior column did not cause any tactile disturbance. This can only be understood on the basis that the fibers for tactile sensation run in a bilateral path and that one tract can take up the functions of the other, if necessary. Recently, Head and Thompson have claimed that the power of discrimination between two points on the skin is diminished or lost in posterior column disease, and that if only one posterior column is affected, this diminution or loss will be found only on the affected limbs of that side. If the statements of Head and Thompson are correct (as they seem to be), the diminution or loss of the power of discrimination is a valuable diagnostic symptom.

Loss of the sense of vibration (pallanesthesia of Oppenheim) may be an early symptom of sensory disturbance in tumors, compression paraplegia, multiple sclerosis and syphilis of the spinal cord.

In the beginning of pressure upon fiber tracts of the cord there may be very slight sensory disturbance, which can be discovered only by the most careful examination. If the posterior columns are most affected, the sensory loss will involve mainly tactile (hypesthesia or anesthesia) and deep muscle sense. If the lateral columns are also affected, pain (hypalgesia or analgesia) and temperature sensation are also involved.

Usually the temperature and pain senses are equally affected; occasionally the one or the other sensation is preserved. Sometimes the recognition of cold is preserved while that of warm is lost, or vice versa; at other times there is a perversion of sensation, heat being felt as cold and cold as heat. Instead of pain, there may be a burning or itching sensation. This dysesthesia was first described by Charcot; it has often been observed in stab wounds of the cord.

When the disturbances of the pain and temperature senses are due to a lesion of the lateral white columns, an ataxia of the affected limbs is often observed (spinocerebellar tracts in lateral columns).

Marked disturbance of the pain and temperature senses with little or no affection of the tactile sense is known as "dissociation of sensations," and is especially frequent in disease of the gray matter of the cord (syringomyelia, hematomyelia, central tumors of the cord). Until recently it was believed that this dissociation of sensibility always signified central disease of the cord, but we now know that it may occur in disease of a lateral column and is not so very rare in extramedullary tumors of the cord which cause the Brown-Séquard symptom complex (see chapter on spinal newgrowths). When these dissociated sensibility disturbances are associated with early muscular paralyses and early wasting of special muscles or groups of muscles, the diagnosis of central disease of the cord is more probable.

Finally, the physician must never forget that severe disease of the cord may exist without any sensory disturbance; that, for example, a tumor on the anterior surface of the spinal cord may not cause any objective sensory disturbances for a long time.

2. **Interference with the pyramidal tracts** in any part of their spinal course will cause motor symptoms whose character will depend upon the

amount of the interference. Thus there may ensue paresis or paralysis with or without spasticity, changes in the cutaneous muscle and tendon reflexes or disappearance of reflexes. The amount of paralysis will depend upon the degree of interference with the conducting fibers in the pyramidal tracts. Although many writers have attempted to formulate a general plan of arrangement of the fibers for the different parts of the limbs in the columns of the cord, there is, as yet, little unanimity on this subject.

Lesions of the pyramidal fibers will cause an increase in the reflexes below the level of the lesion in most (but not all) instances. The reflexes are either cutaneous, tendinous or periosteal.

In the upper extremities, the important reflexes which become exaggerated when there is a lesion in the pyramidal tracts above the level of the reflex centers in the spinal cord (except in the instances to be mentioned later) are: the triceps, biceps and radial periosteal reflexes.

The most important abdominal reflexes are the upper and lower abdominal and, in the male, the cremasteric reflexes These may become exaggerated with pyramidal tract disease, or may be diminished or absent under conditions which will be spoken of in the next chapter.

In the lower extremities, compression or a lesion of the pyramidal tracts will cause an exaggeration of the patellar or quadriceps tendon and the Achilles tendon reflexes. As explained in a preceding chapter, the pyramidal fibers have a kind of inhibitory effect on muscle tone and hence upon tendon reflexes, and fibers from the posterior nerve roots and also fibers in the cerebellospinal tracts exert a stimulating influence upon the cells in the anterior horns and hence upon muscle tone.

Therefore the patellar reflexes (and in a similar manner other tendon reflexes) are increased by irritative conditions of the posterior spinal roots, disease in the pyramidal tracts and by diffuse affections of the spinal cord. The knee jerks are diminished or disappear in disease of the anterior spinal roots, in complete destruction of the posterior roots and posterior columns, in disease of the gray matter at the level of the cells which form part of the reflex arc, in complete destruction of the cord above this level and in deep coma and deep anesthesia.

Marked increase of any one of these may result in clonic contractions.

In general, Achilles tendon or ankle clonus is most frequent. Lesions of the tracts under discussion may also cause the appearance of pathological reflexes, the Babinski phenomenon (dorsal flexion of great toe when sole of foot is stroked); "Mendel-Bechterew" (plantar flexion of second to fifth toes, frequently with separation of toes, when the region of the fifth metatarsal bone is tapped); "Chaddock" (dorsal flexion of large toe upon irritation of the inner or outer side of foot below the inner or outer malleolus); "Oppenheim" (dorsal flexion of the large toe when the muscles of the calf of the leg are grasped with the hand and massaged in a downward direction); "Gordon" (when the muscles of the calf are suddenly squeezed with the fingers of one hand), etc.

The extensor reflex of the large toe, named "Babinski," after its discoverer, is most often present in spinal disease; the "Mendel-Bechterew" is very frequent, especially when there is marked spasticity.

The tibial periosteal reflex, which consists of a contraction of the adductors of the thigh when the inner surface of the tibia is tapped with a percussion hammer, is regularly exaggerated with pyramidal tract lesions. Sometimes the adductors of the opposite (affected) limb will contract when the patellar tendon of the normal side is tapped (contralateral adductor reflex). This reflex is due to irritation of the uncrossed pyramidal fibers and is very often to be obtained. The Réflexe de défense, to which Babinski has recently again called attention, is an expression of the automatism of the spinal cord when freed from the influence of higher centers. Defensive movements due to automatic spinal activity have been long known to physiologists. It remained for Babinski to demonstrate their value in spinal localization. In paraplegia from compression of the spinal cord, for example, when a systematic examination of these defensive reflexes from the lower extremities upward is made, part of the cord beyond which no réflexe de défense occurs corresponds to the lower limit of the compression. These reflexes (*e.g.*, dorsal flexion of foot, flexion at knee and at hip when plantar surface of foot of paralyzed lower extremity is irritated, flexion at wrist and elbow on irritation of dorsum or plantar surface of hand, etc.) are especially present in level lesions such as transverse myelitis or compression paraplegia due to fracture of the spine, extramedullary tumors, etc. The contralateral plantar reflex (slow dorsal flexion of the toe of the paralyzed leg on irritation of the sole of the healthy foot) is sometimes observed, when all other signs of pyramidal tract lesion are wanting. I have twice observed this crossed toe reflex among the early signs of spinal compression.

3. **Bladder and rectal disturbances** are very frequent in diseases of the spinal cord. The gray matter of the sacral cord and conus terminalis contains centers for the bladder, rectum, and sexual apparatus. The control of the bladder is due to the tonic contraction of the vesical sphincter. If the bladder is distended, the sensory nerves are irritated and stimuli are carried to the spinal centers and through the third and fourth anterior sacral roots to the bladder muscle. There is an antagonism between the sphincter and the detrusor of the bladder, and it is probable that stimulation of the sphincter is regularly associated with an inhibition of the detrusor, although both are controlled by centers in the brain and by volition.

Disturbances of the bladder may therefore result from disease of any part of the spinal cord. If the disease is located above the spinal centers for the bladder, the control of higher centers is cut off, the patient may lose volitional control, the bladder empties itself reflexly as soon as it is distended, or it becomes overdistended and overflow occurs. If the centers in the cord are destroyed, all control is lost and there is incontinence of urine. The rectum is controlled by a similar nervous mechanism. The earliest bladder and rectal symptoms of spinal disease are generally retention or difficulty in starting the expulsion of the urine, and constipation. Complete incontinence of urine may occur without rectal disturbance, but constipation is more frequent. Finally, incontinence of urine and of feces occurs as a regular symptom of advanced lesion of the spinal cord at any level. Disturbances of the sexual organs are frequently associated with bladder and rectal disturbances.

The changes that occur in the cerebrospinal fluid, and the alterations in the form of the vertebræ shown by X-ray examinations, will be considered in Chapters VII and IX.

# CHAPTER V

## THE SYMPTOMS OF SPINAL DISEASE AT DIFFERENT LEVELS AND IN DIFFERENT REGIONS OF THE CORD

Because of the existence, at different levels of the spinal cord, of centers for particular and peculiar functions—the control of the dilator of the pupil, of the bladder, the rectum, the sexual function, etc.—it follows that disease in different segments of the cord will be characterized not only by motor and sensory symptoms from interference with cells in the gray matter and with ascending and descending fiber tracts, but also by disturbances in these peculiar functions.

Thus disease in the cervical region will cause pupillary symptoms, and hence such pupillary disturbances have great importance for spinal localization. If the spinal disease exists in those segments of the cord in which lie the reflex centers for the cutaneous abdominal reflexes, these will be lost, and this loss of one or other abdominal reflex will indicate the level of the disease to which all the other symptoms and signs have to be correlated.

Although a disease in any part of the cord may cause vesical and rectal disturbances, it is especially in conus and cauda equina diseases that early interference with the emptying of the bladder and rectum occurs, and hence early loss of one or both of these functions has diagnostic significance.

Similarly, a disease at the level of the reflex centers for the patellar or the ankle jerks may cause an isolated loss of the one or the other on one or both sides, and the diagnostic importance of such a loss must not remain unrecognized.

The motor and sensory symptoms due to a lesion of the cord vary within wide limits, and depend upon the amount of white and of gray matter affected. In the cervical and lumbar cord, the gray matter occupies a considerable part of the cord, hence in these parts of the cord early muscle atrophies are frequent.

From what has been stated in the preceding chapters, it should be possible for the physician to determine the location of a spinal disease from the symptoms and signs presented. In the present chapter, certain peculiarities fo symptoms at different levels of the cord will be described.

1. **Disease in the upper cervical** (**from the first to the fifth cervical**) **segments** is sometimes rapidly fatal, but life may be sufficiently prolonged to observe oculo-pupillary, respiratory and cardiac symptoms. The cilio-spinal center lies in the gray matter of the eighth cervical and first dorsal segment; it exercises a control over the cervical sympathetic ganglia and is itself controlled by higher centers. When any part of the sympathetic oculo-pupillary innervation is interfered with, a paralytic miosis (in which the pupil will no longer dilate in the dark and a difference between the two pupils (anisokoria) occurs), a narrowing of the palpebral fissure and a moderate degree of enophthalmus (sinking back of the eyeball), results. Respiratory disturbances due to interference with the centers for the phrenic nerve and diaphragm (C 3–C 5) has been frequently observed. These respiratory disturbances are frequently caused by a combination of phrenic nerve and medullary lesions. In several instances, however, I have noted that the diaphragm was not paralyzed in spite of extensive disease in the third to fifth cervical segments. It seems to me probable that the diaphragm receives some innervation from still higher centers.

Slowing and irregularity of the pulse is characteristic of high cervical lesions, and is probably due to disturbances in the medulla oblongata, as are also the very high temperatures (103° to 106°F.) that are often observed.

In these high cervical lesions, vasomotor symptoms with disturbances of sweating of the face (Horner's symptom complex) frequently occur. There may be early spastic hemiplegia of an upper and lower extremity with partial loss of sensation on the other side. There may be neuralgic symptoms referable to the occipital minor and major, supraclavicular and auricularis magnus nerves, and atrophy of the sterno-mastoids, trapezii and other superficial and deep muscles of the neck.

2. **Lesions between the Sixth Cervical and First Dorsal Segments.**— In these there is frequently, but not always, a difference between the size

of the two pupils (anisokoria) due to a miosis on the side of the lesion, with a diminution or loss of the triceps reflex on one or both sides, marked weakness of the triceps muscle and sensory disturbances, especially on the radial side of one or both upper extremities. The presence of the radius reflex (blow on the styloid process of the radius causing supination of forearm) with absence of triceps reflex is especially characteristic of a lesion at the sixth cervical segment, and I have frequently seen this combination in extramedullary tumors at this level. The sensory and motor symptoms may affect one or both upper extremities, or in addition one or both lower extremities. In the so-called Dejerine-Klumpke paralysis the lesion is at the level of the eighth cervical and first dorsal roots, and the small muscles of the hands and the flexors of the forearm are especially affected. Oculo-pupillary symptoms are frequent.

3. **Lesions between the eighth and twelfth dorsal segments** are characterized by absence of the abdominal reflexes, and by root anesthesias over the abdomen. Sometimes the upper abdominal reflex on one or both sides is absent while the lower is preserved, and vice versa, and by this means it has often been possible for us to more exactly localize the lesion of the cord at the level of the centers for the upper (D 8 to D 9) or the lower (D 10 to D 12) abdominal reflexes. The abdominal muscles may not be paralyzed, even though a complete transverse lesion above the eighth dorsal segment exists. I have under my care, at the present time, a patient with a complete crush of the cord at the level of the second dorsal segment, in whom the abdominal muscles are not paralyzed. Hypotonia or paralysis of the abdominal muscles is sometimes a valuable level sign of spinal disease. When the patient coughs, the bulging of the abdominal muscles on either side is very evident. Sometimes, even if there is no paralysis of the abdominal muscles, the difference between the reaction of the muscles to the faradic current on the one or the other side will be very distinct. Girdle pains are most frequent in the middorsal region.

4. **Lesions in the lumbar cord** are characterized by diminution or loss of the patellar tendon reflex on one or both sides if the disease be at the level of or below the second lumbar segment and is frequently asso-

ciated with early disturbances in the functions of the bladder and rectum. On account of the small size of the lumbar and sacral segments of the cord, disease most often affects a large part of the lumbosacral cord, and it is often difficult to differentiate between the symptoms of this part of the spinal cord and those of the cauda equina. The paralysis is usually of the flaccid type with marked atrophy of muscles. The knee jerks and the cremasteric reflexes are usually lost, while the ankle jerks remain active or are exaggerated, perhaps with ankle clonus.

**5. Lesions of the Epiconus.**—Minor has attempted to distinguish the epiconus, in which he includes the fourth and fifth lumbar and the first and second sacral segments. The prominent symptoms of an epiconus lesion are, according to Minor, a degenerative paralysis of the glutei muscles with especially early loss of power in the peronei muscles. The tibialis anticus is usually not affected; the ankle jerks and plantar reflexes disappear early while the knee jerks persist. It is very rare, however, that a pure epiconus lesion can be diagnosticated from the signs and symptoms.

**6. Lesions of the Conus and Cauda Equina.**—Clinically we are accustomed to include in the conus the three lower sacral and the coccygeal segments—that part of the cord which lies behind the twelfth dorsal and the first lumbar vertebræ. Disease of this portion of the cord can frequently not be distinguished from an affection of the cauda equina. Disease of the conus is characterized by retention or incontinence of urine, constipation or incontinence of feces, impotence, anesthesia over the sacrum and around the anus and genitals, without any motor or reflex disturbances in the lower extremities.

In disease of the cauda equina, on the other hand, pain in the small of the back, extending into the perineum, the genitals, and often down the posterior surfaces of the thighs into the areas of distribution of the peroneal nerves, is far more frequent. The sensory loss is often asymmetrical, extending down the posterior surfaces of the thighs and outer aspects of the legs.

The lower the disease of the nerves of the cauda equina, the smaller the number of roots that are affected and the smaller is the area of sensory

FIG. 23.—To explain the sensory disturbances in the Brown-Séquard syndrome (Brissaud). On the side and at the level of the lesion, a band of anesthesia (in white); above and below this, a band of hyperesthesia (in black). On the opposite side, a band of hyperesthesia (in black), and below this, loss of sensation (in white).

disturbance, but there are diseases which affect both conus and nerves of the cauda equina (soft newgrowths) in which there is very little sensory loss. The characteristic sensory loss in conus and cauda affections varies within wide limits; sometimes characteristic segment loss occurs, at other times the sensory disturbances are very irregular. In both conus and cauda equina lesions, weakness of dorsal flexion of one or both feet with more or less complete dropped foot occurs. This drop-foot may be the only evidence of a motor disturbance in the lower limbs.

The characteristic symptoms of conus and cauda lesions are pain in the back, rectal and vesical disturbances, diminution or loss of sensation over the areas of distribution of the sacral nerves, loss of ankle jerks and dropped foot on one or both sides with sensory disturbances in the lower lumbar and sacral root areas, flaccid paralyses and atrophy of the muscles of the posterior surface of the thigh, of the leg and the foot.

The anesthesia extends over the mucous membrane of the rectum, bladder, scrotum and penis (vulva in women), around the anus, over root areas down the back of the thigh, etc.

## THE BROWN-SÉQUARD SYNDROME (Fig. 23)

The most frequent combination of symptoms in spinal cord disease is the Brown-Séquard syndrome, in which motor symptoms occur on the same side of the body below the level of the lesion, and sensory disturbances on the other side. The Brown-Séquard symptom complex occurs where one-half of the diameter of the cord is affected, and in its typical form presents the following:

I. On the same side as the lesion:

(*a*) Motor paralysis or paresis, due to the interference with the pyramidal tracts.

(*b*) Vasomotor disturbances due to interference with the homolateral vasoconstrictor fibers in the lateral columns.

(*c*) Disturbances in deep muscle sense (bathyanesthesia of Oppenheim), with ataxia due to interference with the posterior columns and spinocerebellar tracts.

(*d*) Superficial cutaneous hyperesthesia.

II. On the opposite side:

(*a*) Disturbances of sensibility, especially those for pain and temperature (often also tactile).

In addition, on the side of the lesion there are girdle pains and hypo- or anesthesia due to the nerve roots that are involved, so that (on the side of the lesion) the sensory disturbance is on a somewhat higher level than on the opposite side.

If the lesion involves one-half of the cord in the lumbosacral regions, the motor and the sensory loss are usually on the same side, because at this low level few sensory fibers have already crossed to the other side.

The Brown-Séquard syndrome is most frequently observed after injury of the cord due to fractures of the vertebræ or to bullet and stab wounds. It also occurs in spinal tumors and spinal syphilis, and (rarely) in myelitis and in multiple sclerosis. The typical Brown-Séquard symptoms are, however, rarely observed; there is usually a preponderance of motor symptoms on one and sensory symptoms on the other side as an indication of the Brown-Séquard symptom complex.

In some cases of spinal tumor I have observed a reverse condition, motor symptoms on the contralateral and sensory symptoms on the homolateral side. The explanation for this will be given in the chapter on spinal tumors.

Dissociation of the syringomyelitic character is often observed with spinal symptoms of the Brown-Séquard type; on the side of the sensory symptoms tactile sensation is normal or only slightly disturbed, while the pain and temperature sense is markedly affected or completely lost.

# CHAPTER VI

## METHODS OF EXAMINATION

It is only by careful, thorough and repeated examinations that a correct diagnosis can be made and the exact localization of a spinal disease determined. We can not but impress upon those who are interested in this line of work the importance of thoroughness, and the advisability of taking nothing for granted. For those who have not had much experience in spinal diseases, the following résumé is given as a general guide for their examination of the patient.

### THE PHYSICAL EXAMINATION

Arranged in the order in which I am accustomed to make it, the examination of a patient with a suspected spinal disease should include, in addition to the general examination, the following:

The patient should be entirely undressed and placed in the recumbent position upon a couch or bed.

*The Cranial Nerves.*

Nystagmus.

Inequality of pupils.

Reaction of pupils to light and accommodation.

Movements of the tongue.

Rigidity of the neck.

*The Upper Extremities.*

Movements, active, against resistance, passive.

Abduction, adduction and rotation at shoulder; flexion and extension at elbow and wrist; movements of fingers.

Hypotonia, spasticity, or ataxia?

Triceps reflex (blow on triceps tendon with arm and forearm at right angle at rest on body causes extension at elbow).

Biceps reflex, limb in extension and at rest by the side of the body (blow on finger placed on biceps tendon just above elbow causes movement of flexion at elbow).

Radius reflex (blow on radial surface of forearm near wrist causes flexion at elbow).

Sense of position, tested by placing fingers or forearm in various positions and asking patient to imitate position with other limb or to describe position of part (eyes of patient closed).

*Chest and Abdomen.*

Are there fibrillary twitchings of muscles?

Type of respiration. Paralysis of abdominal muscles.

Abdominal reflexes, upper and lower. (To compare them on the two sides lightly scratch the skin on each side just below the free costal border and (for the lower) just above Poupart's ligament.)

Cremasteric reflexes (light scratch on inner and upper aspect of thighs causes raising of testicle).

*Lower Extremities.*

Active movements: Can patient raise heels from bed? Flexion at hips and knees. Plantar and dorsal flexion of feet.

Passive movements: Power to raise limbs from bed against resistance. Attempts to flex and extend legs at knee against resistance. Attempts to dorsally flex and extend feet against resistance. Attempts to abduct and adduct thighs against resistance. Movements of toes. Spasticity. Atonia. Ataxia (heel to knee test).

Knee jerks. Reaction of patellar tendon to blow with hammer just above tubercle of tibia.

Patellar jerks. Blow on finger placed transversely at upper margin of patella. Patellar clonus.

Ankle jerks; blow on Achilles tendon.

Ankle clonus. Exhaustible or inexhaustible.

Extensor reflex of large toe ("Babinski"). (Light scratching of sole of foot on inner or outer side causing dorsal extension of large toe and palmar flexion of small toes.) Normally all toes are flexed.

"Oppenheim" reflex (massaging muscles of calves of legs with the fingers in a downward direction causes dorsal flexion of large toe in pyramidal tract lesions).

"Gordon" reflex (sudden squeezing of muscles of calf causes dorsal flexion of large toe in pyramidal tract lesion).

Tibial periosteal reflex (tapping of inner surface of tibia causes contraction of adductors of thigh). Crossed adductor reflex (tapping of patellar tendon with hammer causes contraction of adductor muscles of opposite limb).

The réflexes de défense are tested by scratching the soles of the feet, the abdominal wall, the palms of the hands, etc.

*Sensory Examination.*

It is advisable to test the anterior surface of the body first for disturbances of all sensation, and then the posterior surface, the patient being turned on the abdomen.

Tactile sensation is to be tested with a camel's hair brush or a wisp of cotton; pain, with sharp pin point; temperature, with test tubes of ice and of hot water.

The examination for tactile disturbances is made by lightly touching the skin with the cotton or brush. First the head and neck, then the upper extremities, then the chest and abdomen, and finally the lower extremities are thus examined, areas of changed sensation being marked with an indigo pencil. Especial care must be taken in comparing the sensation of the two sides of the body, of the ulnar and radial aspects of the upper extremities, of the fingers, etc. The upper level of the sensory disturbance must be carefully determined and the examination repeated in various ways. After the areas in which there is increase, diminution or loss of normal sensation have been marked out, a chart is made. Then pain sensation is similarly examined for, care being taken that the patient knows exactly what the examiner is looking for and that he does not confuse the deep or superficial touch with the pain sense.

Disturbances of deep muscle sense in the lower extremities are best tested for by bending the large or one of the smaller toes toward the dorsal or the palmar surface of the foot and asking the patient what is being done. When there is only slight disturbance the patient may sometimes give a correct and at other times an incorrect answer.

The vibratory sense is tested with a tuning fork placed on different parts of the body. Spacial discrimination is tested with a pair of calipers, in order to determine at what distance from each other the two points of the calipers are recognized as separate. Care must be taken that the two points touch the skin at the same time.

After the anterior surface of the body has been tested, the patient is turned upon the abdomen, and the posterior surface examined in the same manner.

In all of these examinations due regard must be paid to the following facts. In many spinal diseases the time reaction of the patient is changed, so that there is an appreciable delay before the patient responds to a given stimulus. Repeated attempts to elicit normal or pathological reflexes may result in tiring out the reflex in question so that it becomes weak or disappears. This is especially the case with the cutaneous reflexes. If this occurs, it may be necessary to desist from the examination for a little time and to return to it later.

The examination for disturbances of temperature sense must include the following: Is hot felt as hot and cold as cold? Is the hot and the cold felt more acutely over some areas or above the level of sensory disturbance? Can the patient distinguish between hot and cold? Is there perversion of sensation—hot felt as cold or cold as hot? Is there thermal hyperesthesia above the level of temperature loss or diminution? If the epicritic and protopathic sensibility is to be tested, tubes of hot and cold water of the proper temperature must be used (see Chapter IV).

When the patient is on the abdomen, the spines of the vertebræ should be examined for possible tenderness. Each spinous process may be lightly struck with the percussion hammer or, better, pressure against the side of each spinous process is made with the thumb of the right hand. It is advisable also to percuss over the spinous processes because occasionally there is dulness on percussion over the region of a neoplasm.

2. An X-ray examination should always be made of the suspected portion of the spine and, whenever possible, both an antero-posterior and

a lateral plate should be obtained. The X-ray examination is usually negative in primary intradural disease. Affections of the bone (tuberculosis, arthritis deformans, neoplasms, fractures) will generally, but not invariably, show changes on the X-ray plate.

3. Examination of the blood and the cerebrospinal fluid for the Wassermann reaction. Microscopic and chemical examination of the cerebrospinal fluid.

4. Electrical examination.

# CHAPTER VII

## THE X-RAY IN SPINAL DISEASE

An X-ray examination of the spine should always be made before a patient is subjected to an operation for spinal disease or injury. In a large number of cases—intradural spinal newgrowths, syringomyelia, etc.—the X-ray findings will be entirely negative, and the fact that the bony framework of the spine is normal gives support to the diagnosis that has been made. On the other hand, the X-ray plates may show that there exists a disease of the bony spine, an arthritis, periarthritis, etc., which may or may not have anything to do with the symptoms complained of. Finally, in a large number of patients, the X-ray will demonstrate the nature of the process which is the cause of the spinal symptoms, and will give us information which may either contraindicate operative interference or make it imperative.

Whenever possible, antero-posterior and lateral views should be taken, and plates taken obliquely may be of value. The size and shape of the intervertebral foramina can only be determined by a lateral view of the vertebral column. Stereoscopic plates are always to be preferred, for a stereoscopic examination of the spine will frequently demonstrate lesions which can not be otherwise discovered. A large number of X-ray exposures may have to be made before a satisfactory picture is obtained, and I have more than once clearly seen evidence of vertebral disease in one X-ray plate when several, previously taken, failed to show any abnormality. That the patient's bowels must be thoroughly evacuated before a plate of the lower dorsal, lumbar, or sacral vertebræ is made is a technical detail which, with many others, comes within the domain of the roentgenologist.

Experience is necessary before one can learn to correctly interpret X-ray plates of the vertebral column, and the surgeon must carefully study the plates of a large number of normal spines. There are, of course, many variations in the size and shape of the vertebræ and their processes, and of the intervertebral foramina, and the differences between what is

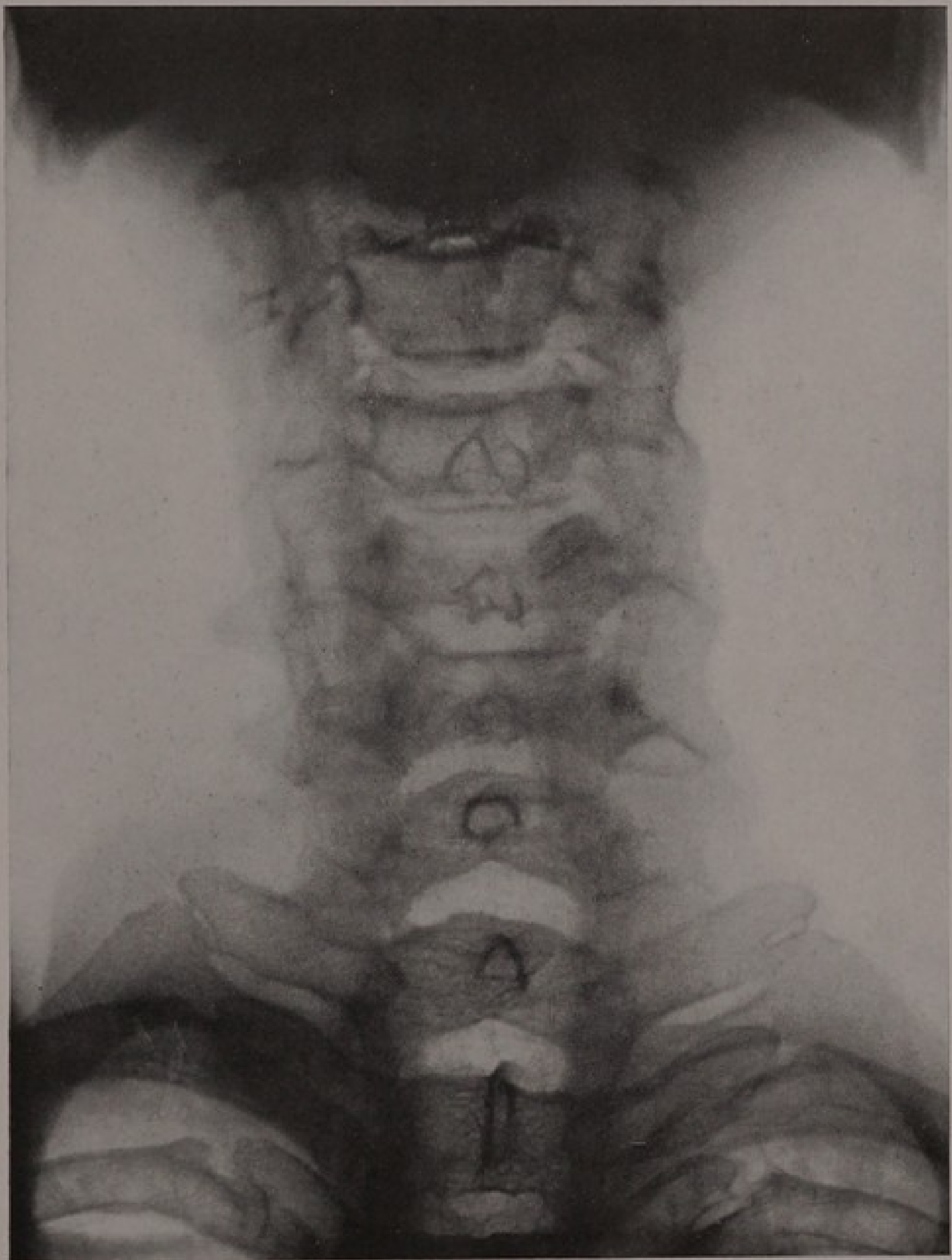


FIG. 24a.—X-ray of normal cervical vertebræ, antero-posterior view.

normal and what must be considered pathological are sometimes very slight.

The interspaces between the cervical vertebræ may be very large and somewhat irregular. Normally there is a long ellipsoid shadow over the cervical vertebræ which is due to the air in the trachea (Figs. 24 and 25).

The upper two-thirds of the dorsal vertebral column are often indistinct

FIG. 24*b*.—X-ray of normal cervical vertebræ, the atlas and axis.

on account of the overlying shadows of the heart and the great vessels. In many plates, however, the outlines of the bodies and processes of the dorsal vertebræ can be clearly distinguished (Figs. 26 and 27).

The spinous processes of the lumbar vertebræ often vary in their direction, so that an antero-posterior view of this part of the spine may show that some of the spines point to one and some to the other side of the median line (Fig. 28). The transverse processes are subject to variations in their size and form. The transverse processes of the fourth and fifth lumbar vertebræ may be very large and the fifth may articulate with or impinge on the ischium (Fig. 29).

Fig. 25.—X-ray of the cervical vertebræ from the side.

Congenital abnormalities of the vertebral column are well shown on the X-ray plate, and in spina bifida the size and extent of the defect can usually be made out without difficulty.

Injuries to the spines and laminæ usually show well. It is surprising how often a fissure or fracture of part of a spinous process or of the tip of a transverse process is discovered in patients who have sustained a very slight injury to the back.

It is unnecessary to give a description of the various pictures obtained

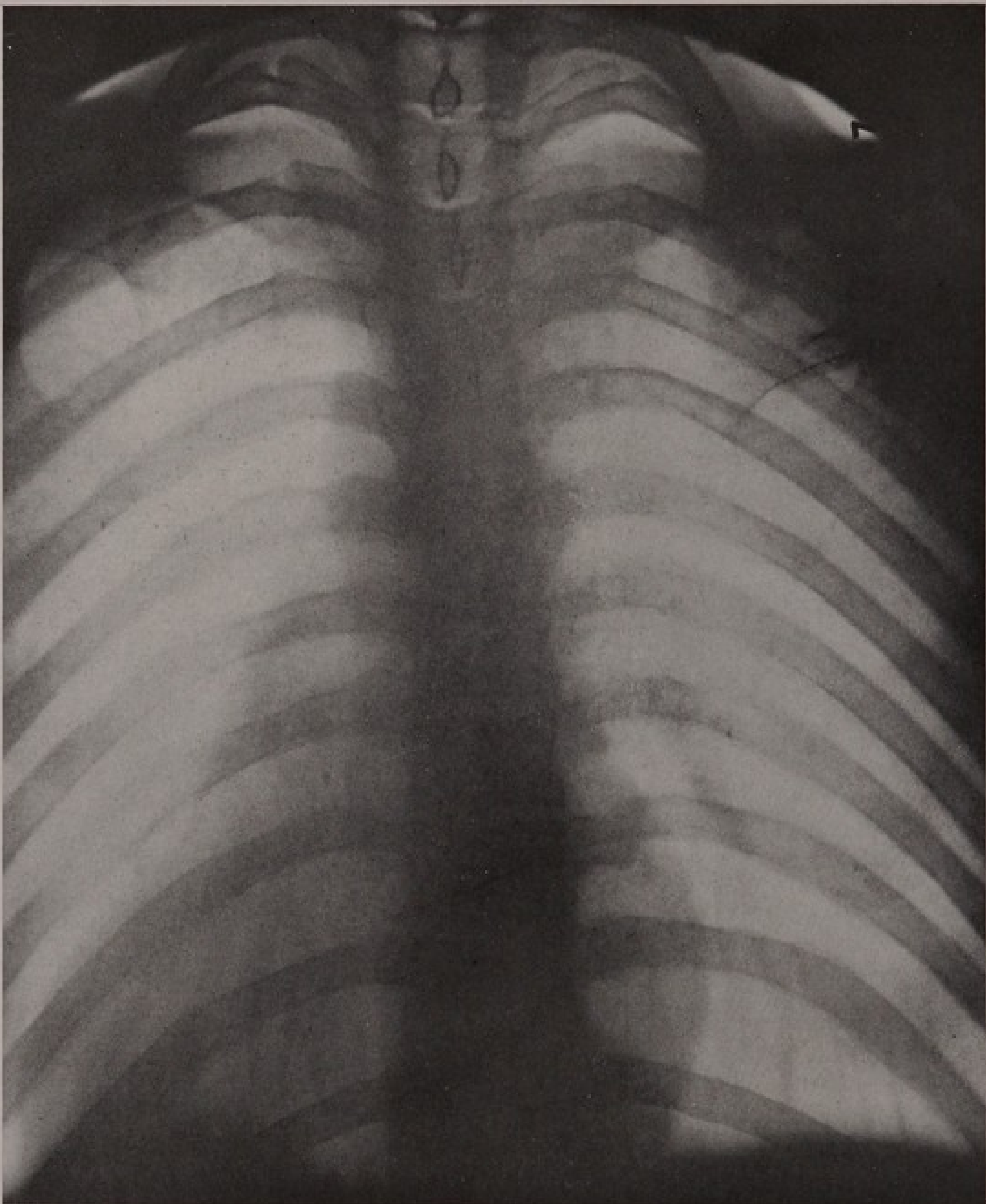


FIG. 26.—X-ray of the dorsal vertebræ from in front.

from patients with fractures of the vertebræ, for the X-ray findings are as varied as the injuries themselves. In some instances, as I have before

Fig. 27.—X-ray of the dorsal vertebræ from the side.

stated, the diagnosis of fracture can only be made by the X-ray; in most of the patients the main value of the examination lies in the information obtained as to the exact location of the injury and as to the presence of pressure upon the cord or nerve roots and deformation of the spinal canal by crushed or dislocated bones or free fragments (Figs. 30–33).

In old fractures of the spine, as well as in deforming bone disease

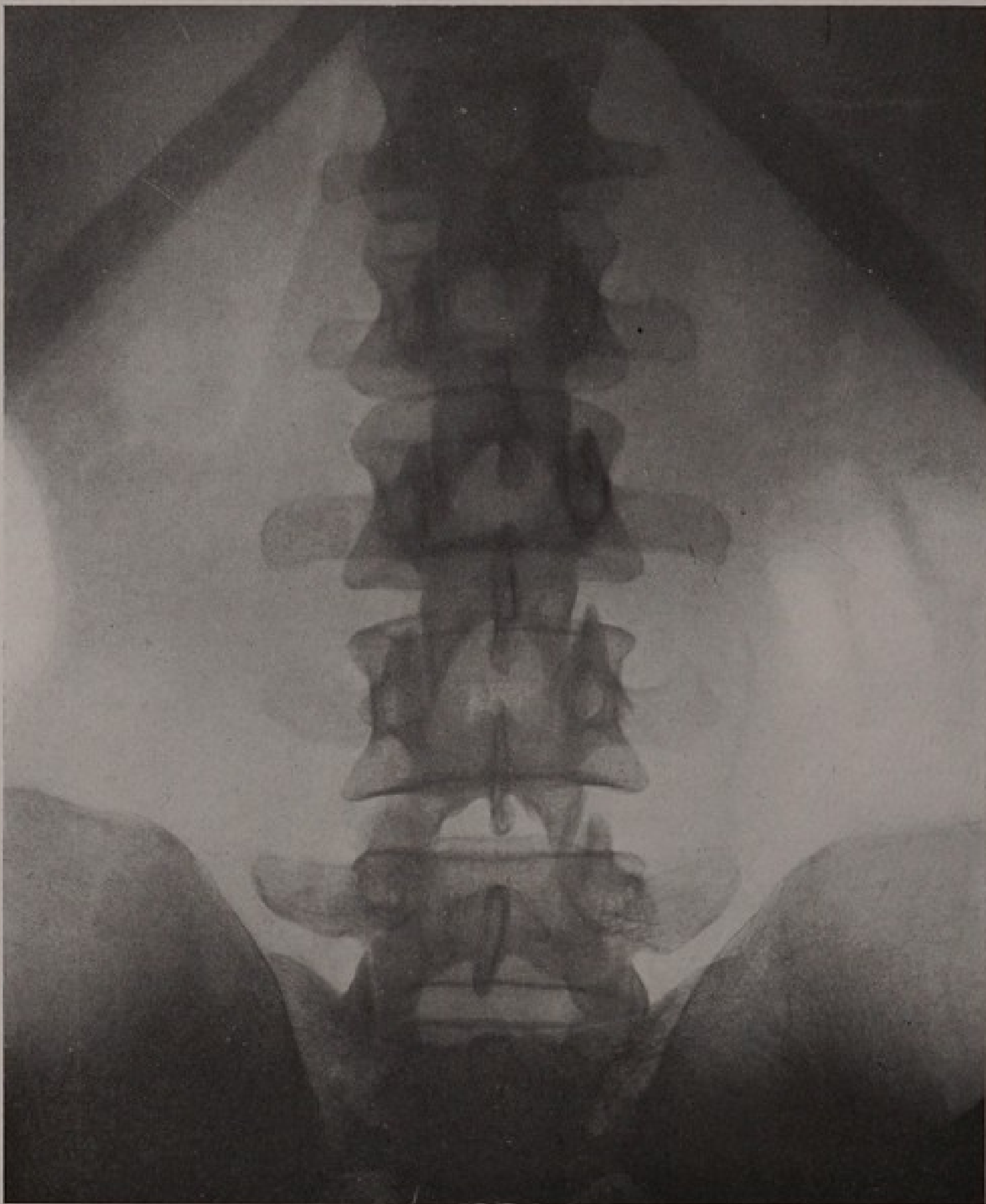


FIG. 28.—X-ray of the lumbar vertebræ.

(arthritis deformans, spondylitis, spondylose rhizomélique, etc.) changes in the bony framework, which cause pain and stiffness of the back or pressure upon the nerve roots or the spinal cord and symptoms therefrom, are usually well shown in the X-ray picture. Proliferation of bone from the bodies of the vertebræ, from the capsules of the joints, from the periarticular structures, etc., is easily demonstrable. The vertebral bodies

FIG. 29.—The lumbar vertebræ, showing a marked transverse process of the fifth lumbar vertebra. A moderate degree of "sacralization" of the last lumbar vertebra.

may be hypertrophied or there may be marked atrophy of the bodies and osteoporosis, so that the shadows of the bodies of the vertebræ are pale while their margins are distinct. The intervertebral discs may appear thinned or they may be replaced by solid bone. The X-ray may give us definite evidence of malignant disease of the bodies of the vertebræ, or the changes may be so slight that even those most expert in the interpretation of the plates may fail to find anything pathological. Sometimes small irregularities in the outlines of the bodies or the arches will suffice to substantiate a clinical diagnosis of malignant vertebral disease, although it may be impossible to differentiate the changes from those of tubercular disease of the spine. If the X-ray shows changes in other

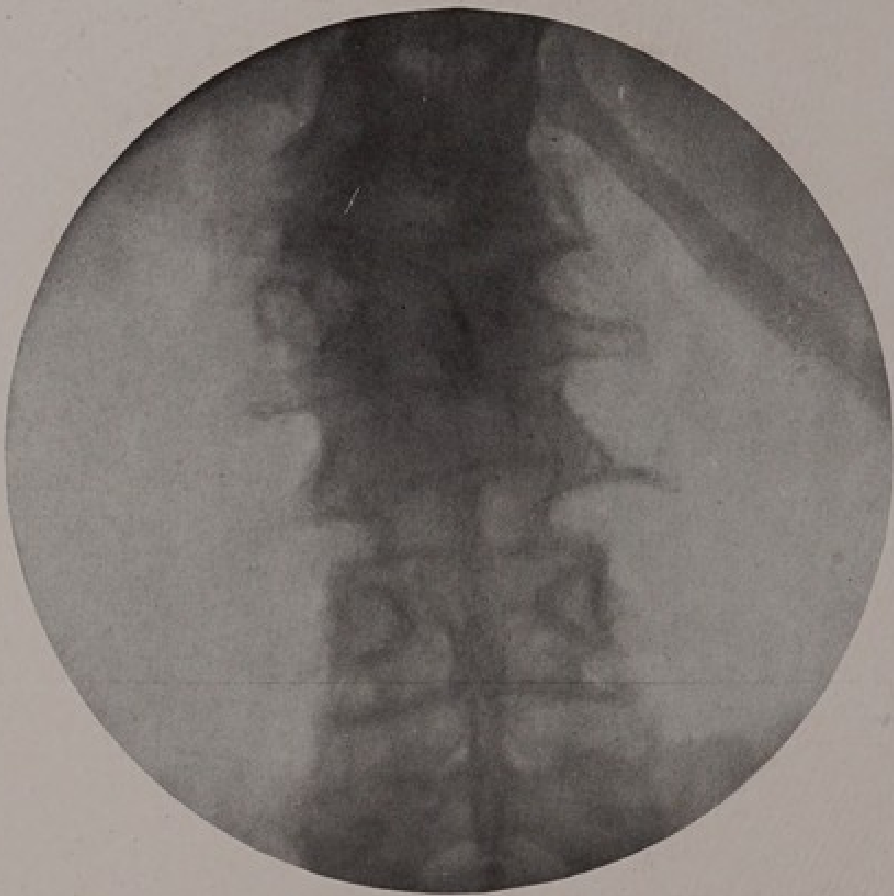


FIG. 30.—X-ray of fracture of the first and second lumbar vertebræ (N. Y. Neurological Institute).

bony structures, in the ribs or the long bones, the changes in the vertebræ can be given their proper valuation.

Some extradural tumors cause a localized bone absorption, so that the X-ray picture shows a rounded area of bone atrophy which is very characteristic. This is most often found in malignant disease of the bone, but it may occur in benign extradural disease; I have twice removed an extradural fibroma from patients who were suspected of malignant disease on account of a localized area of bone absorption.

Benign newgrowths occur at all ages, so that they may be met with in individuals past middle life. In these patients there may be spondylitic changes which have no connection with the newgrowth. We must be careful, therefore, not to give too much importance to an X-ray report of "spondylitis" in a patient with the symptoms of a well-localized spinal disease. In a number of instances I have removed spinal-cord tumors from patients in whom surgical intervention had been long

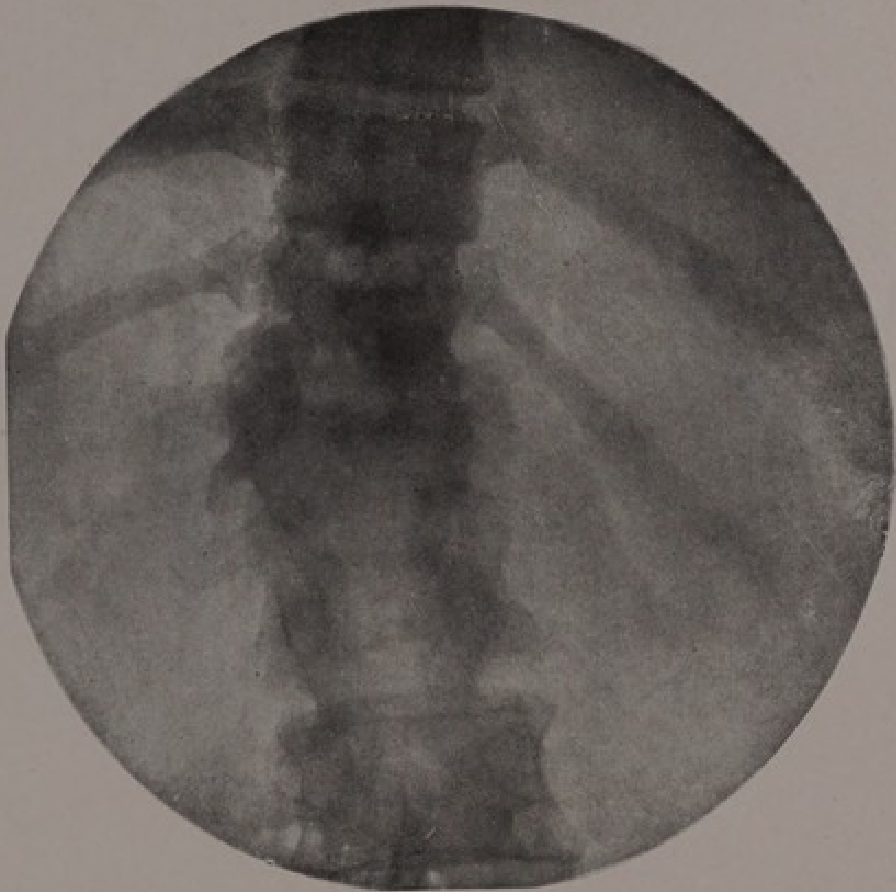


FIG. 31.—X-ray of fracture of the first and second lumbar vertebræ after decompressive laminectomy (N. Y. Neurological Institute).

delayed on account of an X-ray report of "spondylitis." I know of several patients who were treated for considerable periods for Pott's disease on account of X-ray findings which actually had nothing to do with the spinal cord disease.

Figures 34–45 illustrate some of the changes in the bones and ligaments of the vertebral column which may be observed on the X-ray plate and will serve to illustrate what I have said in this chapter.

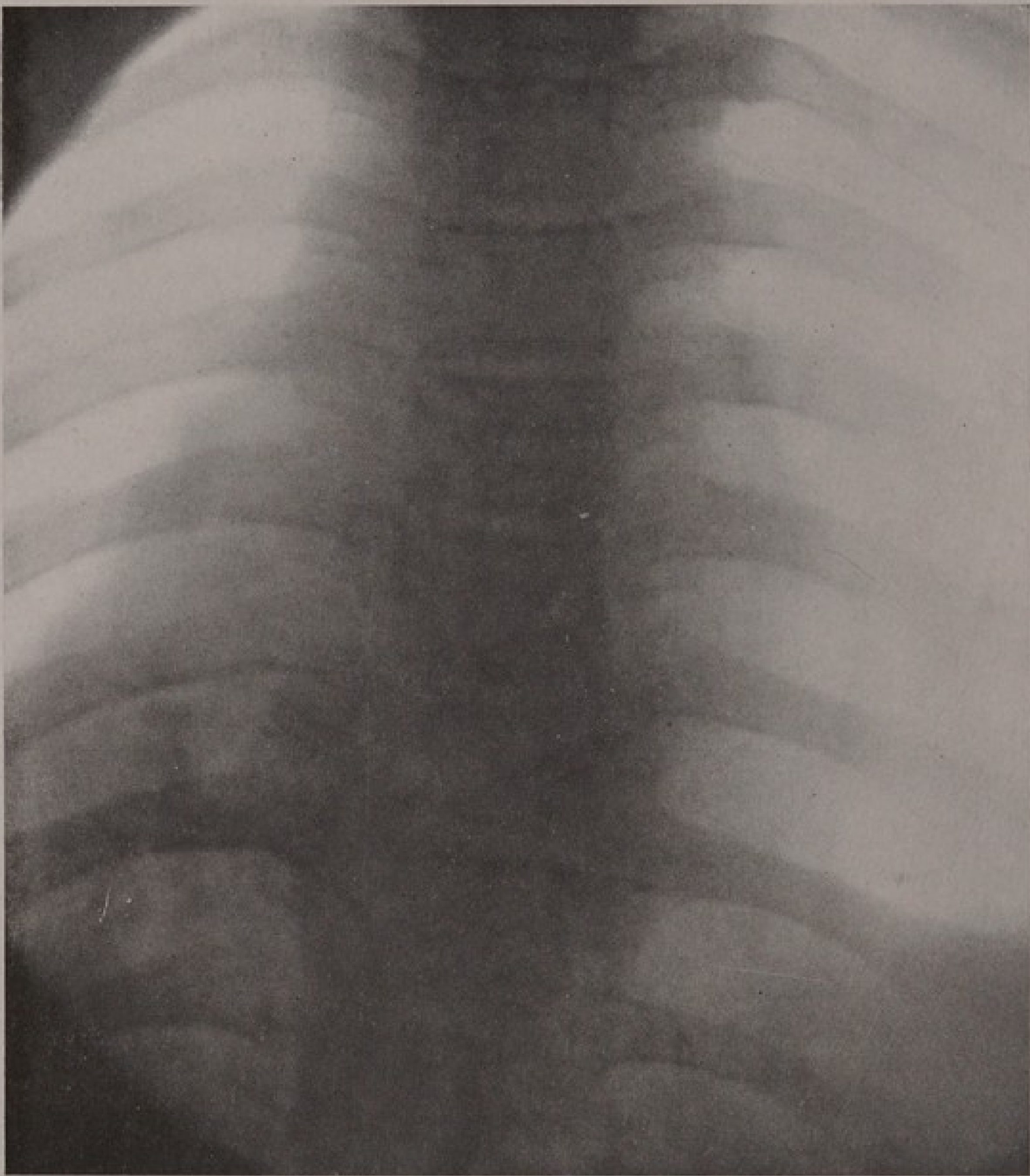


FIG. 32.—X-ray of fracture of the eighth and ninth dorsal vertebræ eight years after the injury.

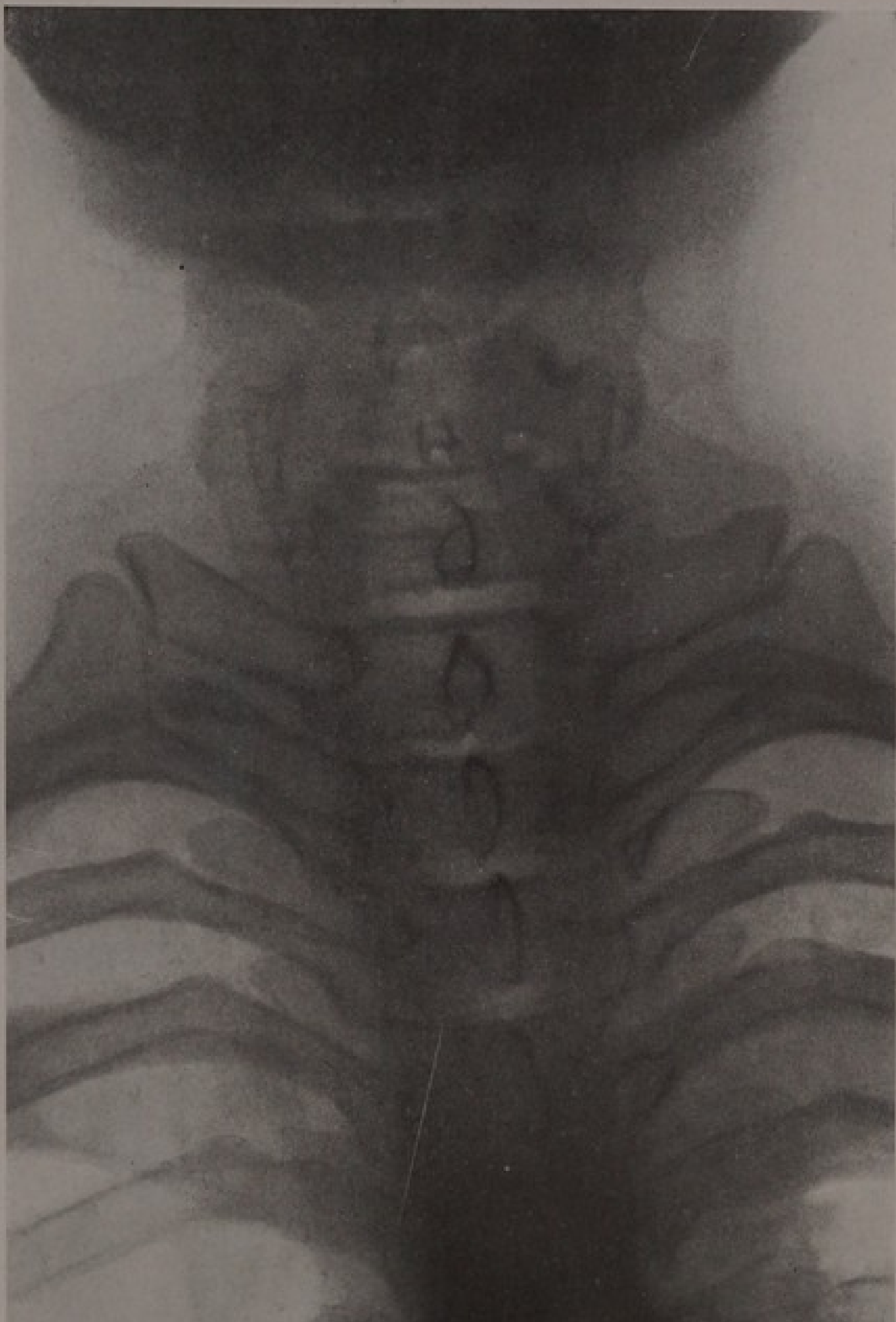


FIG. 33.—X-ray of crushing fracture of the third, fourth, fifth and sixth cervical vertebræ.

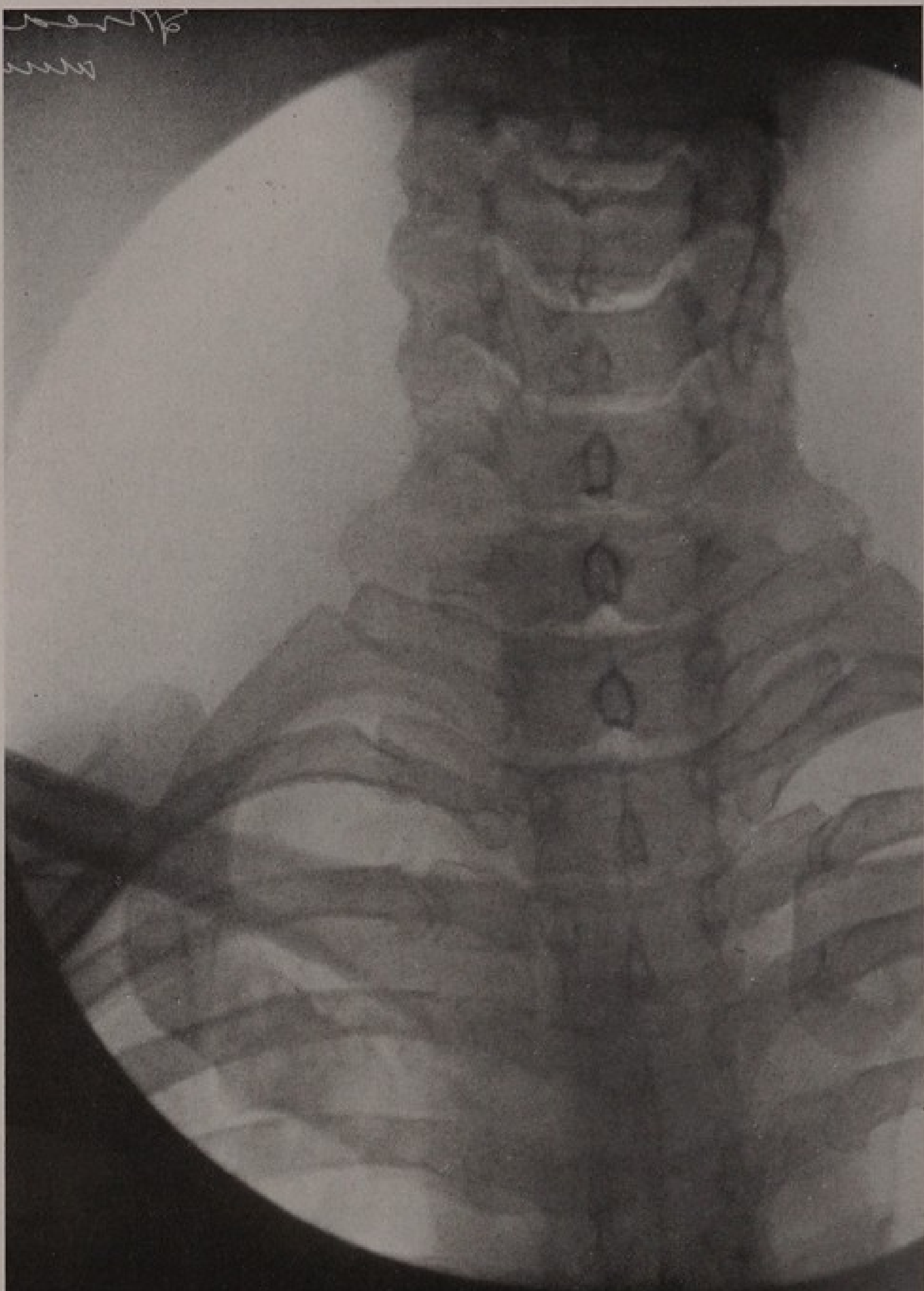


FIG. 34.—Arthritis of the cervical vertebræ in a patient with cervical spinal tumor. The outlines of the bodies are irregular and several of the bodies are united by bone.

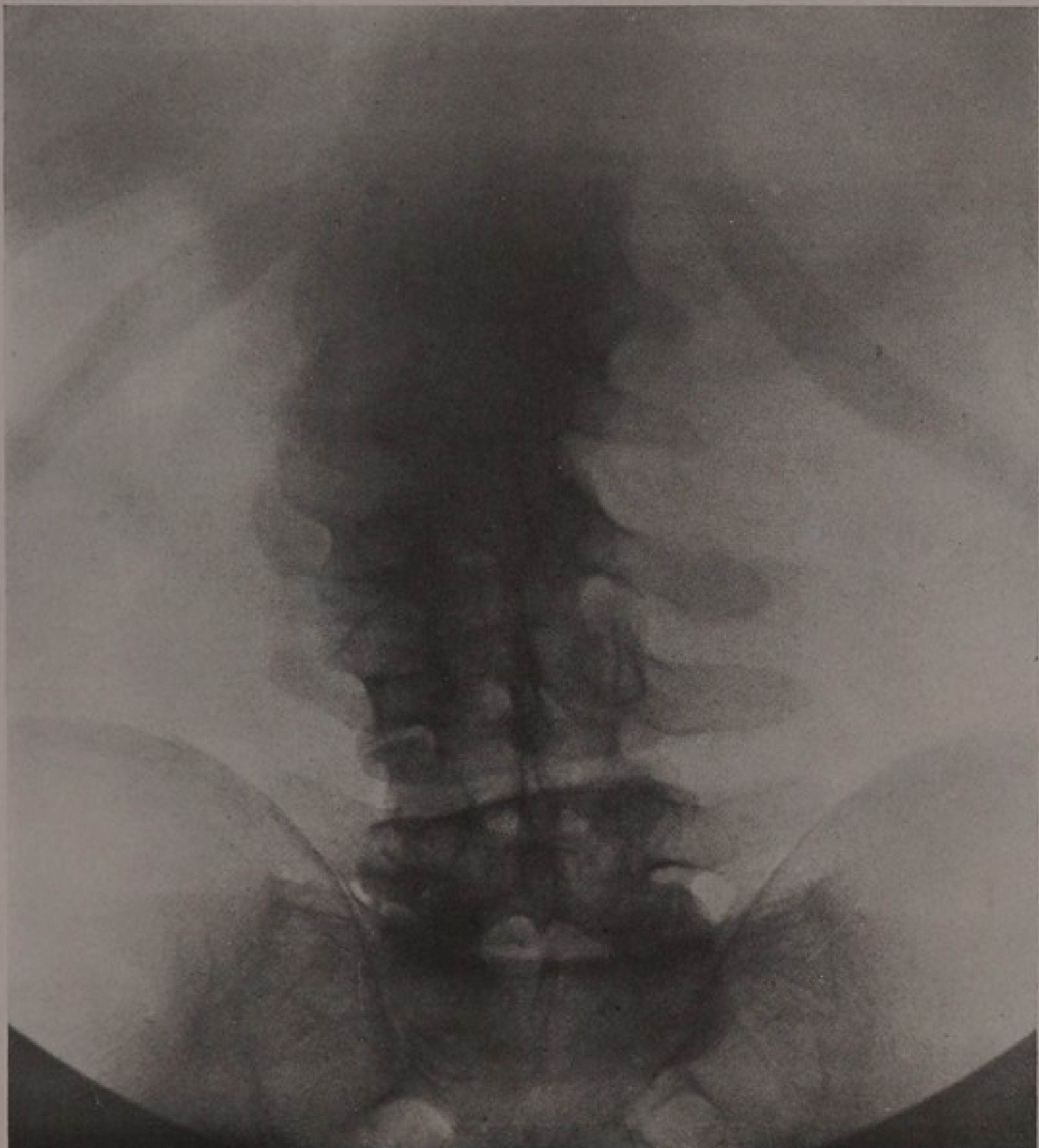


Fig. 35.—Healed tubercular spondylitis of the upper lumbar vertebræ.

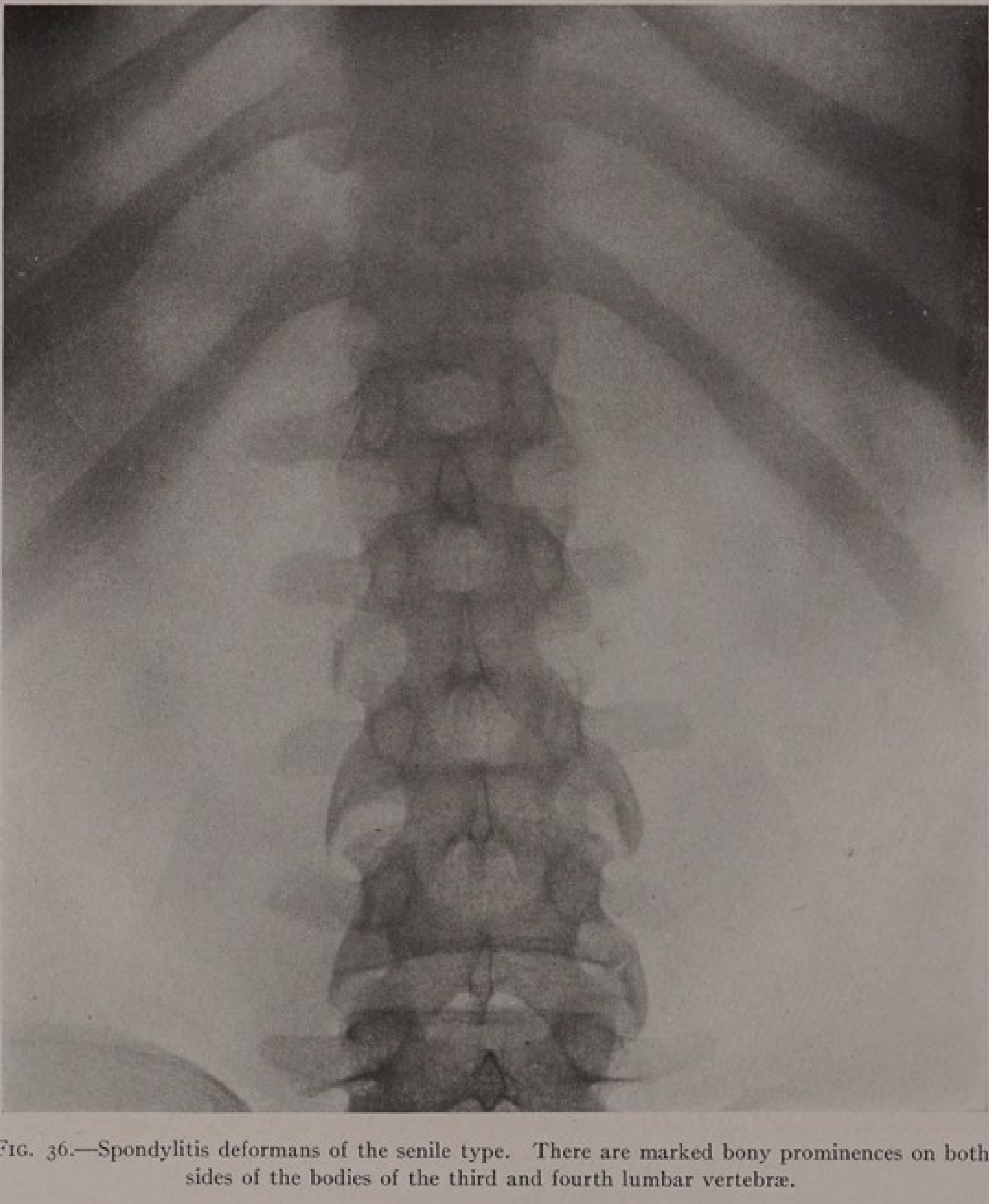


FIG. 36.—Spondylitis deformans of the senile type. There are marked bony prominences on both sides of the bodies of the third and fourth lumbar vertebræ.

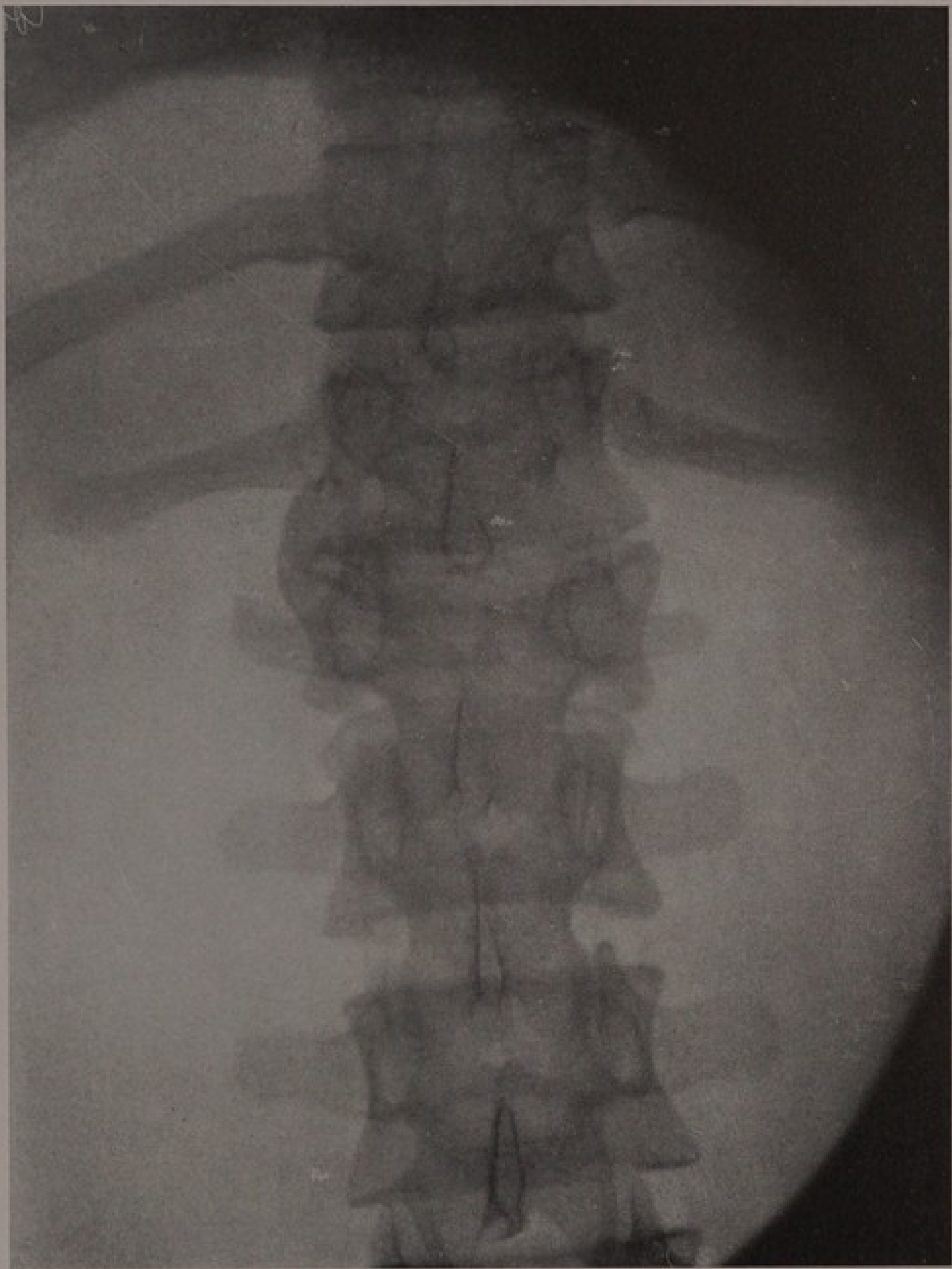


FIG. 37.—Spondylitis. Bony union has taken place between the twelfth dorsal and first lumbar vertebræ on the right side.

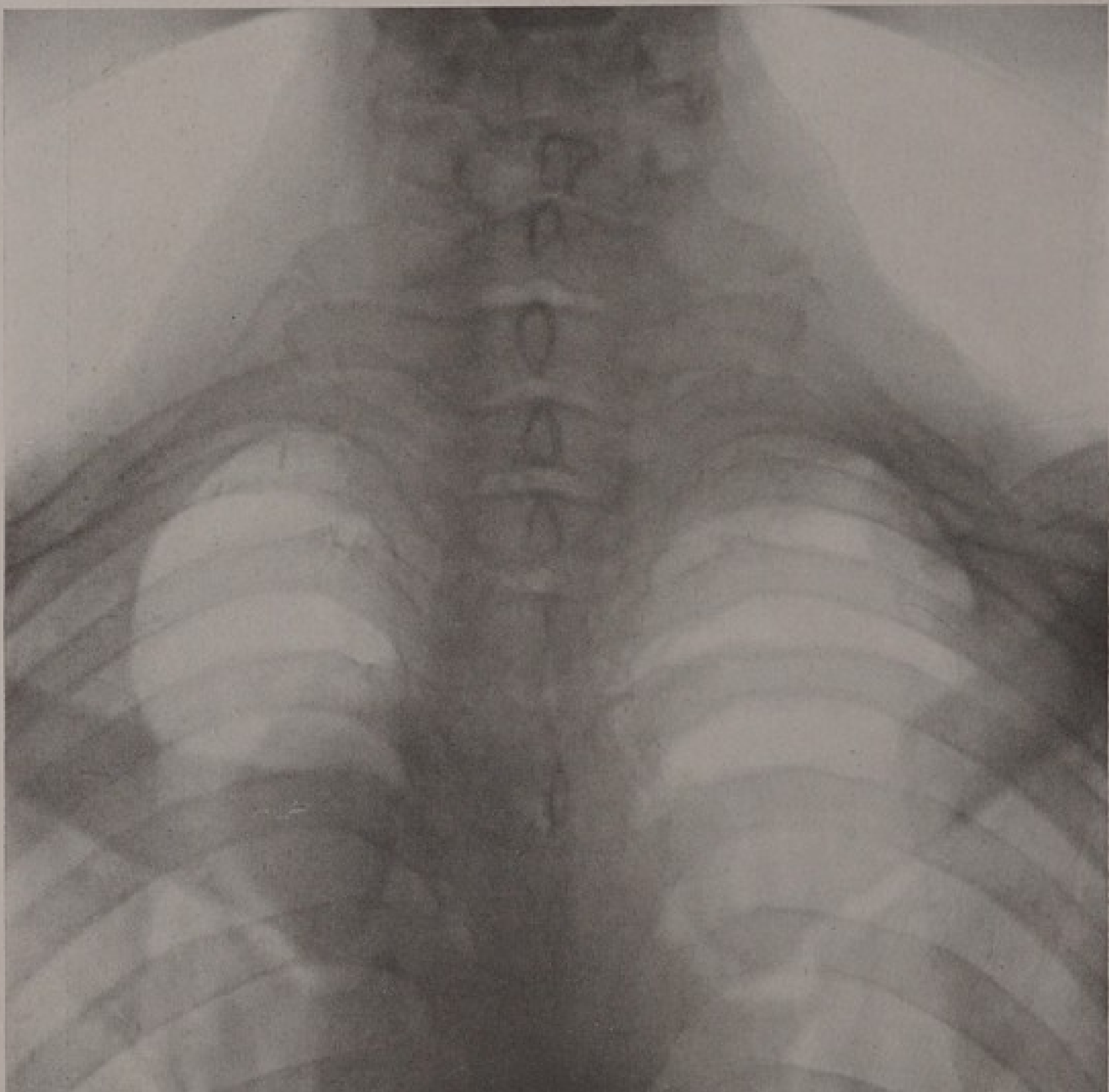


FIG. 38.—Spondylitis of the cervical and dorsal vertebræ. (From a patient with an extramedullary spinal tumor.) The X-ray findings were confusing, but did not cause the patient's symptoms.

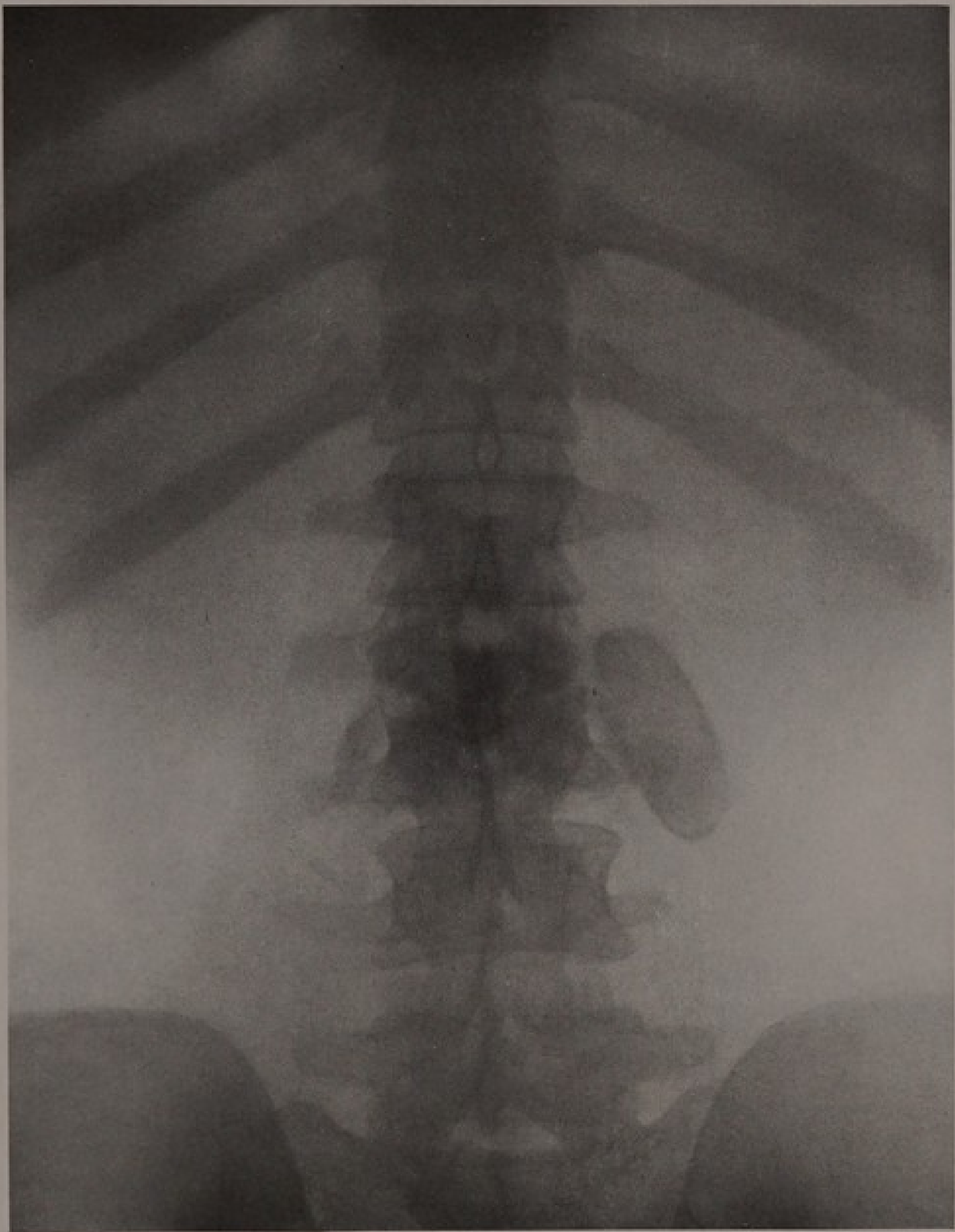


FIG. 39.—Tubercular spondylitis of the second and third lumbar vertebræ with calcareous cold abscess.

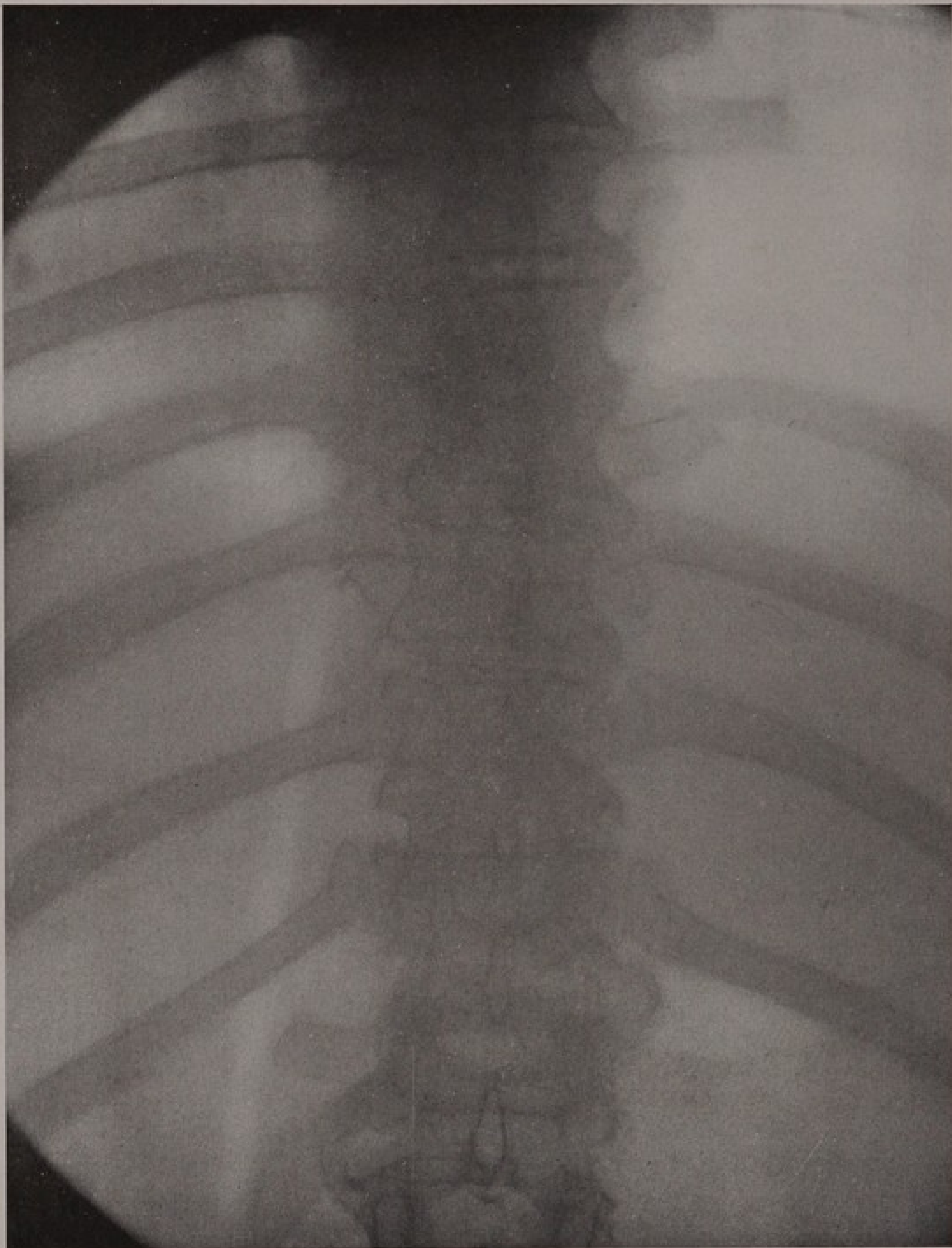


FIG. 40.—Spondylitis of the dorsal and lumbar vertebræ. This X-ray appearance is often presented by patients with a spinal tumor.

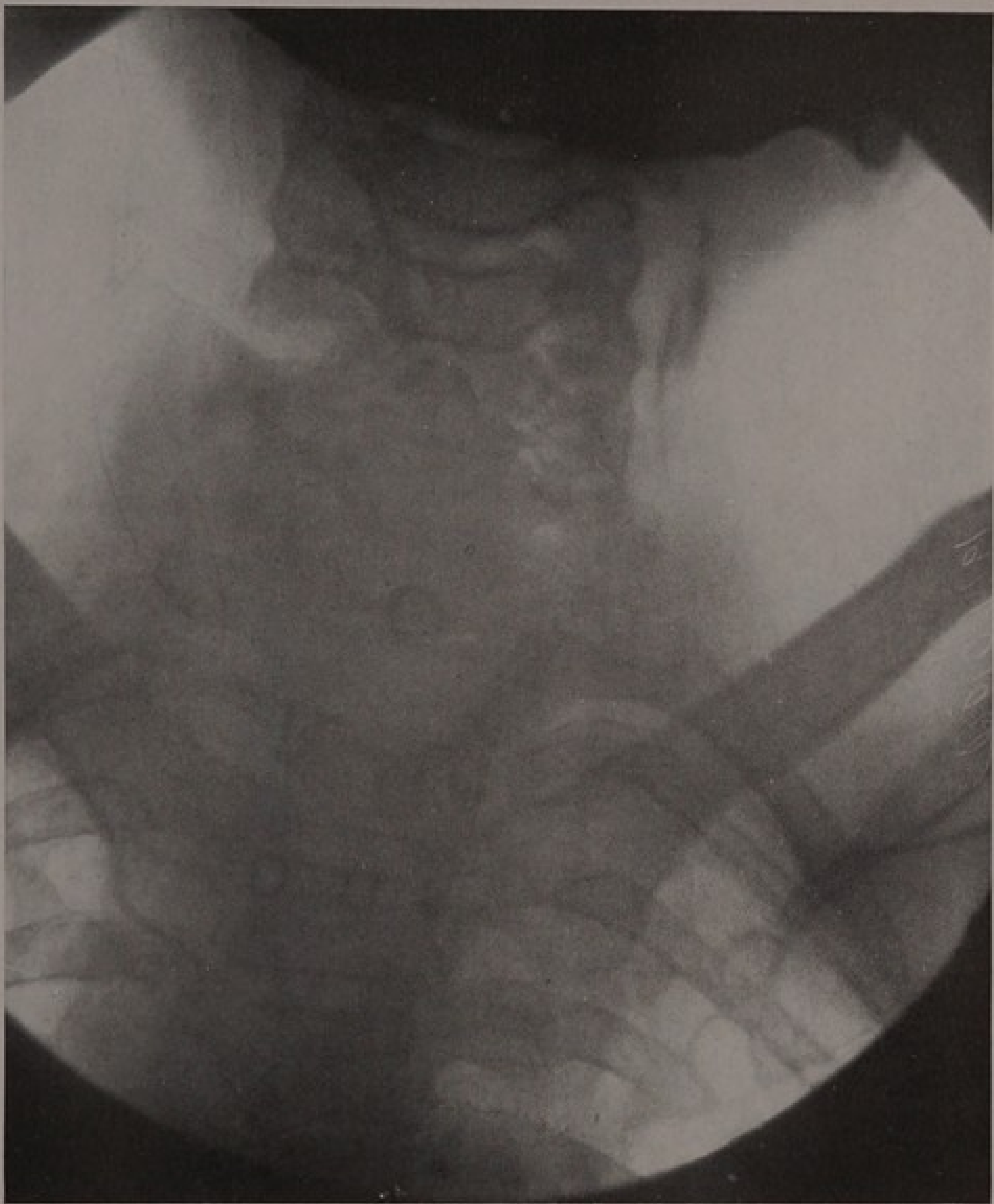


Fig. 41.—Metastatic carcinoma of the cervical vertebræ. The "bitten out" appearance is well marked.

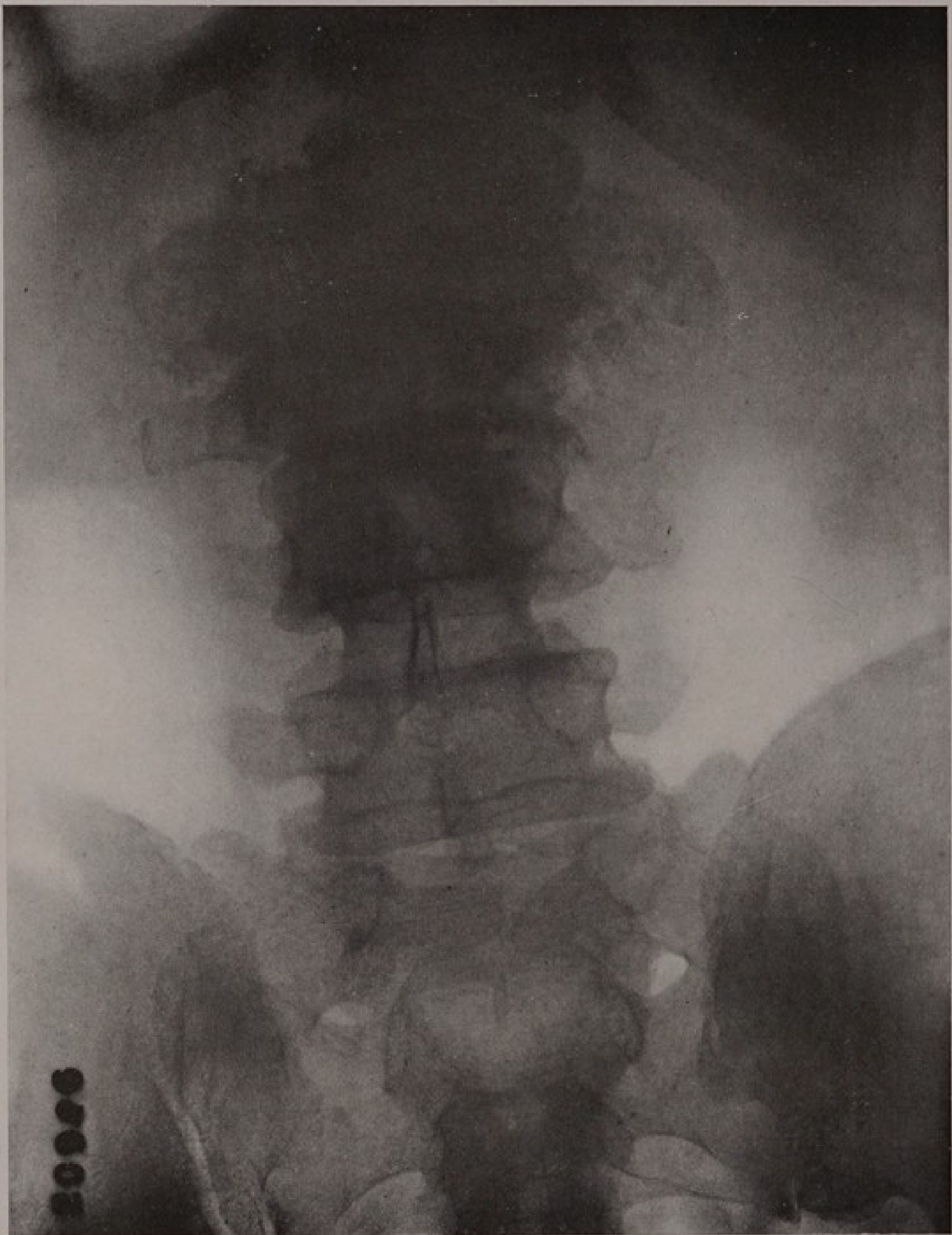


FIG 42—Osteosarcoma of the first and second lumbar vertebræ.

FIG. 43.—Spondylitis with marked atrophy of the vertebral bodies. Bony union has occurred on the right side between the second and third lumbar vertebræ.

FIG. 44.—Lumbar spina bifida.

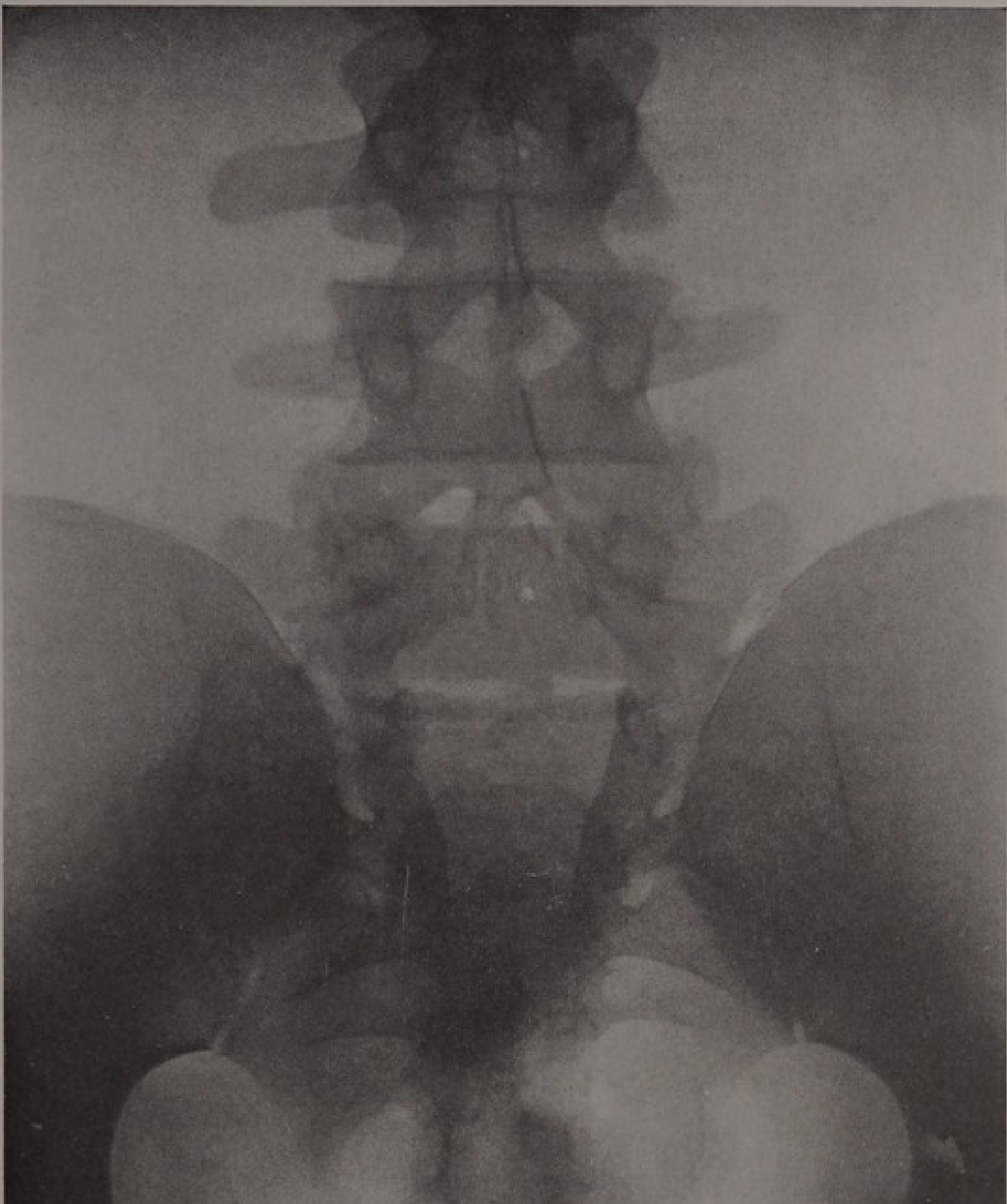


Fig. 45.—Spina bifida occulta. There is a large median defect in the last lumbar and in all of the sacral vertebræ.

# CHAPTER VIII

## THE DIFFERENTIAL DIAGNOSIS OF SURGICAL SPINAL LESIONS

The diagnosis of the location and the nature of a spinal lesion amenable to surgical treatment can often be made with certainty. For such a diagnosis, however, a broad viewpoint of spinal anatomy, physiology and symptomatology must be taken. The possible significance of the slightest symptom must not be underestimated. It is important for the surgeon—in order that he may do his work well—to obtain a careful history of the patient so as to learn the *earliest* symptoms and the *progression* of the symptoms.

The surgeon should be able to visualize the condition of affairs (as far as it is possible with our still limited knowledge). Then it will be possible for him to understand the exact relations of a pathological process. If the patient is under observation for a long period of time before he is subjected to operative interference, it is often possible to state, from the progression of the symptoms, in what direction the disease is advancing, and to prophesy what fibers will be next affected.

For a long time, a painless beginning of the symptoms was believed to occur in intramedullary rather than in extramedullary disease, but very many cases have been reported[1] (and I have seen quite a number) in which pain was a prominent symptom in intramedullary affections (see spinal tumors, etc.). On the other hand, extramedullary disease may run its course with little or no pain. Marked root pains are, however, much more frequent in diseases on the outside of the spinal cord (fractures of the vertebræ, pachymeningitis, tumors). Of greater importance for the diagnosis of an intramedullary disease is the early atrophy of muscles or muscle groups.

Localized spinal disease often presents definite symptoms and signs, so that the upper level of the cord lesion can be determined with accuracy.

[1] See particularly a very interesting paper by Pearce Bailey in the Journal of the A. M. A. for 1914.

The lower level of a localized disease can, however, rarely be diagnosticated with certainty. When several posterior spinal roots are affected, one may be able to gain a general idea of the extent of the lesion. In intramedullary disease, isolated palsies of muscles or groups of muscles with degenerative atrophy may give us an indication of the number of segments of the cord that have been invaded by the disease. The extent of the réflexes de défense will sometimes give one a valuable hint as to the lowest extent of the cord lesion (Babinski), but conclusions as to the lower level of the lesion must always be accepted with hesitation. Intramedullary disease of the cord often extends over many more segments than the symptoms indicate. In the future we shall surely have better methods for the accurate determination of the lower as well as of the upper level of a localized spinal lesion.

There is seldom any difficulty in distinguishing between spinal and intracranial diseases. The only diseases in which difficulties may arise are some, like multiple sclerosis, in which there may be both cerebral and spinal lesions, and in trauma of the brain and cord, where the brain symptoms may overshadow and to a certain extent hide the spinal symptoms.

The differentiation between spinal diseases which can be relieved by surgical interference and those which, due either to their location, extent or nature, are outside of the domain of surgery will depend upon a number of factors. Thus the spinal symptoms may be due to diffuse extramedullary disease (multiple tumors, tuberculous masses, diffuse extramedullary growth) or to degenerative processes, in which operative interference is hopeless; or the spinal lesion is entirely secondary to another disease (malignant disease of the bodies or arches of the vertebræ, meningomyelitis in the course of infections or blood diseases). The field for spinal surgery is rapidly being enlarged, however, and diseases which were considered hopeless only a few years ago can now be safely attacked by the surgeon. I need only mention the removal of intramedullary growths and the drainage of hydromyelia cavities, in which modern spinal surgery has made much progress.

### THE DIAGNOSIS OF THE NATURE OF THE DISEASE

While, in rare instances, an operable spinal disease begins acutely, the course of the disease (before its recognition becomes possible) is usually much prolonged. For many months or years the patients are treated for a variety of symptoms—attacks of "neuritis" or rheumatic pain in one or more limbs or the back, vague abdominal symptoms, indefinite disturbances of the bladder and rectum. Therefore, if the history of the patient is of short duration, with marked symptoms from the very beginning, it is improbable that the affection is a remediable one. In both intramedullary and extramedullary spinal tumors, in syringomyelia and hydromyelia, the history is usually one dating back months or years, while myelitis and other degenerative processes often begin acutely. In secondary malignant disease of the spine, the cord symptoms are apt to begin suddenly and to advance rapidly, so that the limbs are completely paralyzed within a few days. The same is the case in toxic myelitis, whether it be due to an unknown cause or to some general disease such as pernicious anemia, leukemia, the acute infectious diseases, in the course of bacteriemia, syphilis, tuberculosis, etc. There are undoubted cases, however, in which the symptoms of a spinal tumor begin very suddenly and advance very rapidly. Sensory level symptoms occur in newgrowths in and around the cord, in pachymeningitis, in localized tubercular or syphilitic lesions, in tubercular processes in the vertebræ and in fractures, dislocations and other injuries of the spine. In the traumatic lesions there is the history of the trauma; in tubercular disease due to caries of the vertebræ the X-ray picture will usually show evidence of bone disease. In pachymeningitis there is often a marked increase of the number of cells in the cerebrospinal fluid, while syphilitic disease gives a positive Wassermann. We must never forget, however, that a newgrowth or other disease may exist with syphilis. In most instances, newgrowths of the vertebræ or of the surrounding muscles with secondary bone invasion give evidence of their presence and nature on the X-ray plates. This is not always the case, however, for I have seen several instances of sarcoma of the arches of the vertebræ, with secondary involvement of the cord, in which the X-ray examination failed to show any bone disease.

The X-ray will also show a defect of the spine in spina bifida and spina bifida occulta.

In trauma of the cord, from fractures or dislocations of the vertebræ, bullet and stab wounds, etc., the question frequently arises whether the injury to the spinal cord is an irremediable one. I shall consider this question in some detail in a later chapter, but must state in this place that our knowledge in this respect is still defective. When all motor and sensory power and all the reflexes below the level of the lesion have been lost, the diagnosis of complete transverse lesion of the cord is justified and operative interference contraindicated. I have seen several cases, however, in which there were at first the symptoms and signs of a transverse lesion, but in which there was great improvement after some time, as evidence that we did not have to deal with a complete transverse lesion. Where the pressure upon the cord has occurred more slowly, as in extramedullary tumors, and the paraplegia has not been complete (with loss of all reflexes) for a long period of time, the removal of the growth may be followed by a return of reflexes, etc., because the symptoms may be, to a great extent, due to pressure upon rather than destruction of the fiber tracts.

Notwithstanding that our knowledge of spinal diseases has made great progress and that in very many cases an exact diagnosis can be made with certainty, there still remains a large number of cases in which the possibility of a remediable spinal disease can not be excluded, and in which, therefore, an exploratory operation may be justified.

# PART II

# OPERATIONS UPON THE SPINE, SPINAL CORD AND NERVE ROOTS

## CHAPTER IX

### LUMBAR PUNCTURE

Lumbar puncture was first performed by Leonard Corning, but the development of the operation followed upon the researches of Quincke (1891) and a large number of investigators who followed him. The operation is based upon two facts: that there is a flow of cerebrospinal fluid from the ventricles of the brain through the foramen of Magendie and the foramina in the lateral recesses of the fourth ventricle into the subarachnoid space of the spinal canal; and secondly, upon the anatomical facts that the bony wall of the spinal canal is not a complete one, and that the spinal cord extends only to the body of the first lumbar vertebra, while the dural sac ends at the second or third sacral vertebra. The lower part of the spinal canal contains only nerve roots, small blood vessels and cerebrospinal fluid, so that a needle can be introduced into the spinal canal between the arches of the vertebræ without great danger of injury to any nerve structures.

**Anatomy.**—For the details of the anatomy of the spinal canal and cord, the reader is referred to Chapter I in Part I. The nerves of the cauda equina are arranged in such a manner that a space 2 to 5 mm. in width is left in the middle between the roots of each side, and it is into this space that the needle used for lumbar puncture should penetrate.

The spaces between the arches of the third and fourth and fourth and fifth lumbar vertebræ are very large (Fig. 46), so that through one of these a needle can be passed into the spinal canal. A line which unites the highest parts of the iliac crests will generally pass over the fourth lumbar spine, which is a favorite site for the introduction of the needle

(Fig. 47). From without inward, the parts that are penetrated are the skin and subcutaneous tissue, spinal muscles, the interspinous ligament,

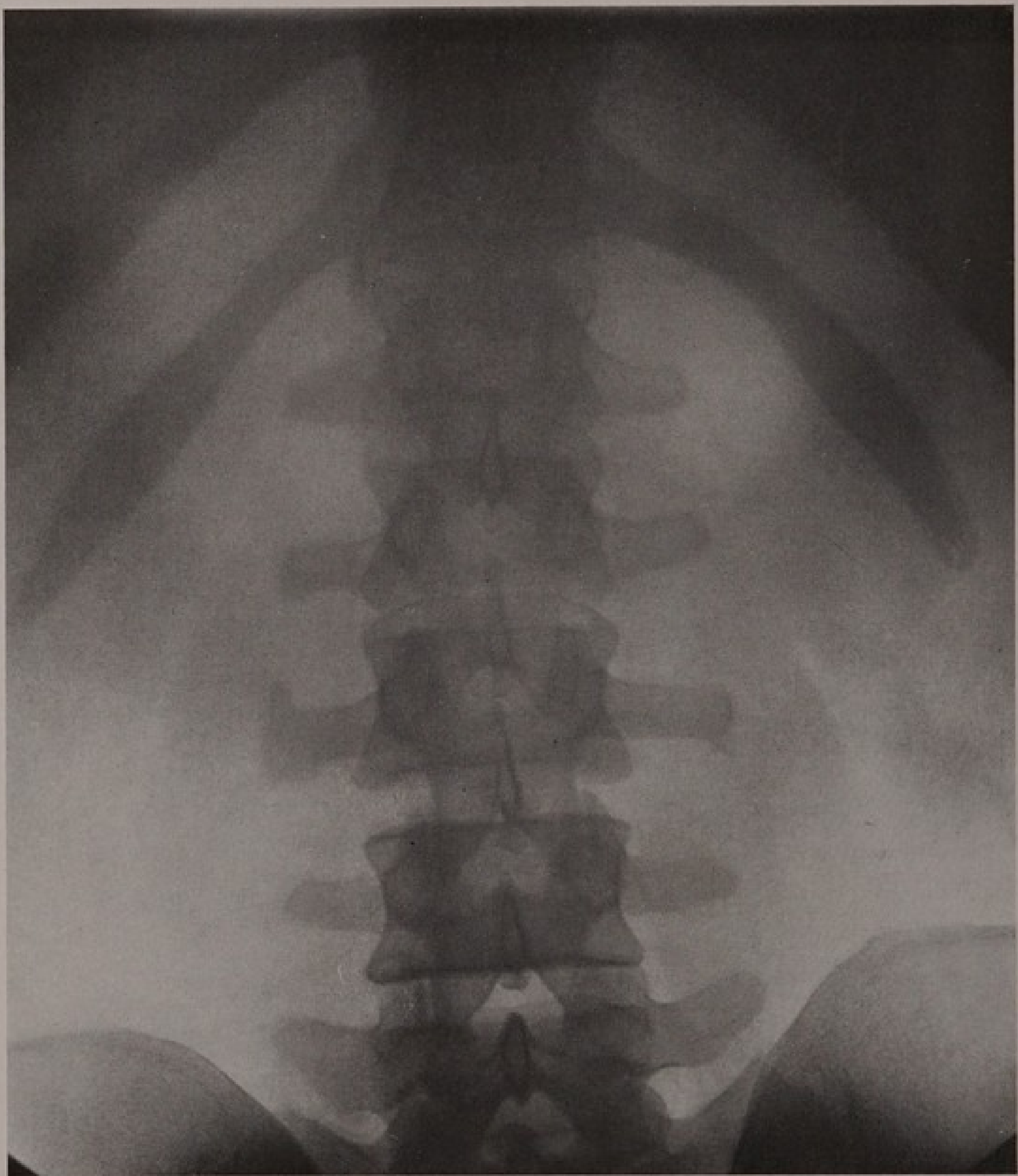


FIG. 46.—X-ray of the lumbar spine to show the size of the opening between the fourth and fifth vertebræ through which lumbar puncture is ordinarily performed.

the ligamentum flavum, the dura and the arachnoid. If the lumbar puncture is done to one side of the middle line, the interspinous ligament is avoided (Fig. 48).

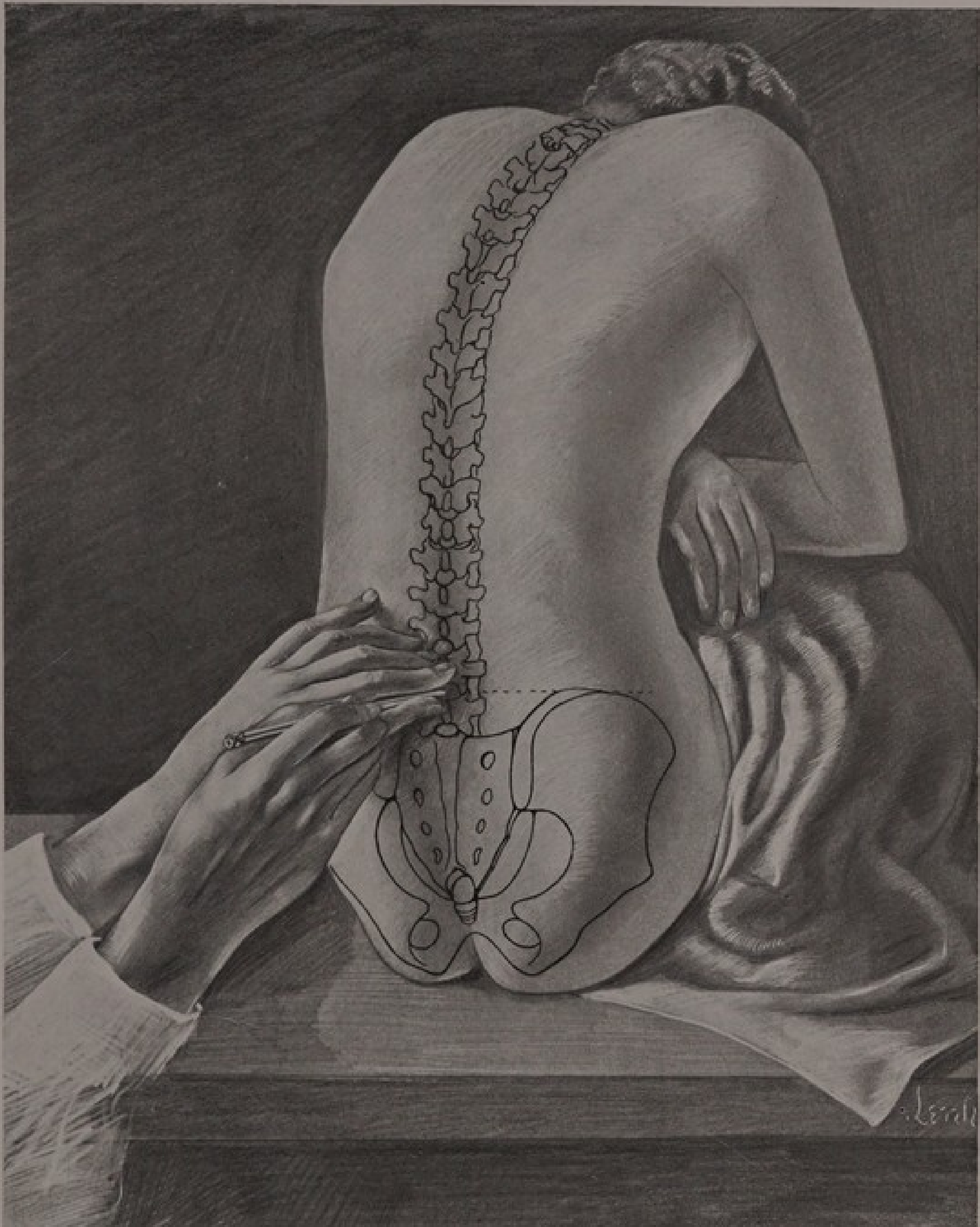


Fig. 47.—The method of locating the space between the arches of the fourth and fifth lumbar vertebræ.

**Technic.**—The depth to which the needle has to be passed before the subarachnoid space is penetrated varies with the age and the size of the patient. In infants and young children fluid will often be obtained 1 cm. from the skin, in adults about 4 to 6 cm. deep, but in very muscular and very fat individuals the needle may have to be pushed in 8 to 10 cm. before fluid escapes.

Various needles have been recommended for lumbar puncture, but a simple needle without an acute point, marked off in centimeters and with

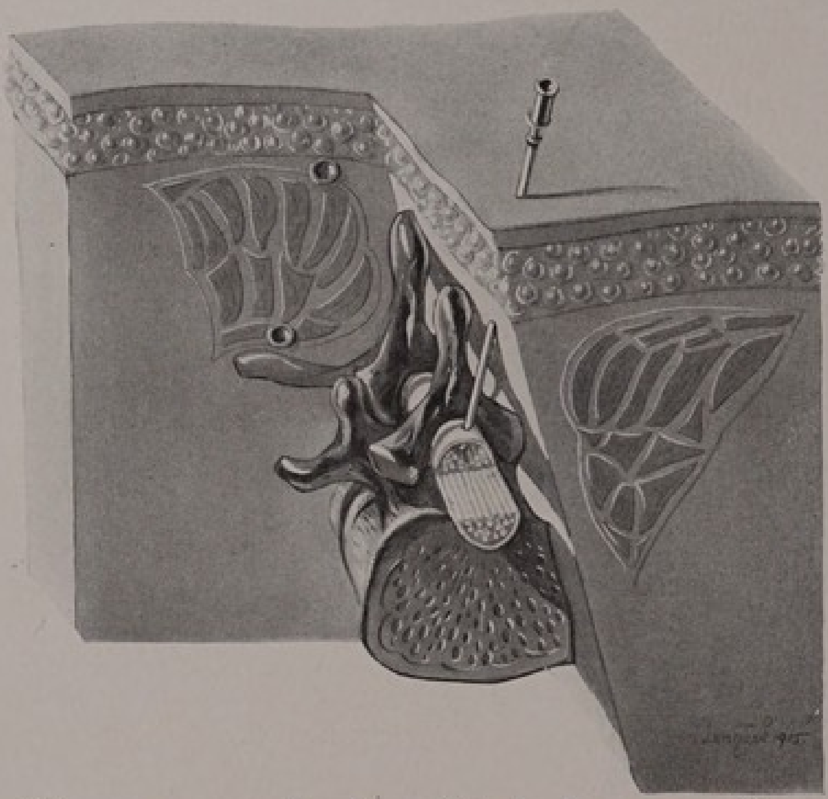


Fig. 48.—The parts penetrated by the needle in lumbar puncture (diagrammatic).

a well-fitting stilet (Fig. 49), will suffice for all purposes. If it is desirable to measure the pressure under which the fluid escapes, this can be done with any of the apparatuses on the market. A simple one is of the form and style described by Frazier (Fig. 50), which contains a tube for manometric pressure.

For the little operation the patient should either be in the recumbent position with the head flexed on the chest, the body flexed on the pelvis and the knees drawn up against the body, or he may be seated at the edge of the bed in a similar position (Figs. 51 and 52). In either case the body should be well bent so as to separate the vertebral arches as much as possible from each other. The skin is sterilized (washing with alcohol, tincture of iodine) and the needle is introduced in the median line (in children) or about 1 cm. outside of the mid-line (in adults) and pointed slightly medianward and toward the head of the patient. The needle is then pushed deeper until the resistance of the ligamentum flavum has been overcome and the dural sac has been entered. As soon as the resistance of the ligamentum flavum has been overcome, it is advisable

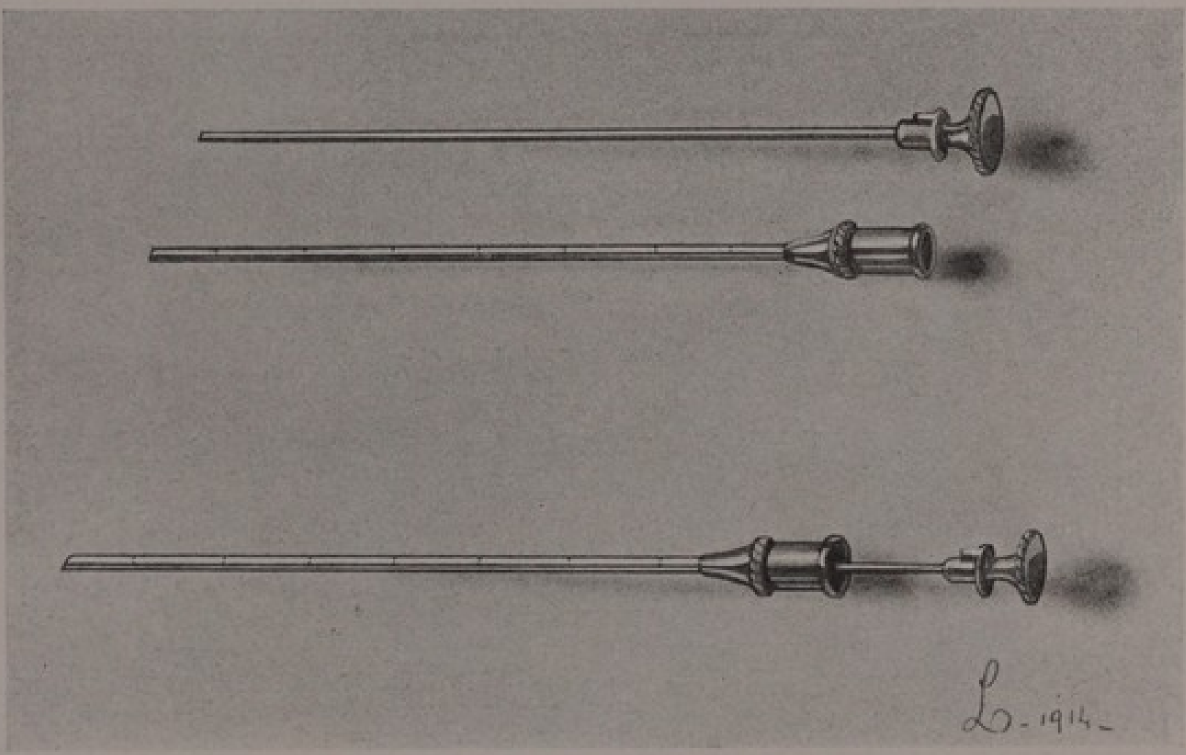


FIG. 49.—The needle for lumbar puncture.

to withdraw the stilet, and the escape of fluid drop by drop is an evidence that the needle is in the proper place. If a bony resistance is felt, the needle is either gently moved around until the space between the laminæ is found, or the needle is partly withdrawn and again pushed forward in a slightly more oblique direction.

If the pressure of the fluid is to be measured, the attachment for the manometer tube is now connected with the apparatus. Otherwise, the fluid is allowed to run into a sterile test tube, the degree of pressure with which it escapes being noted. As soon as the desired amount of fluid has been collected, the needle is withdrawn and the opening covered with a small piece of sterile gauze held in place by adhesive plaster straps.

**Difficulties and Dangers of the Operation.**—The little operation is seldom, if ever, difficult and is practically without danger if not too much fluid is allowed to escape. The patient should usually remain in bed for twenty-four hours after the puncture.

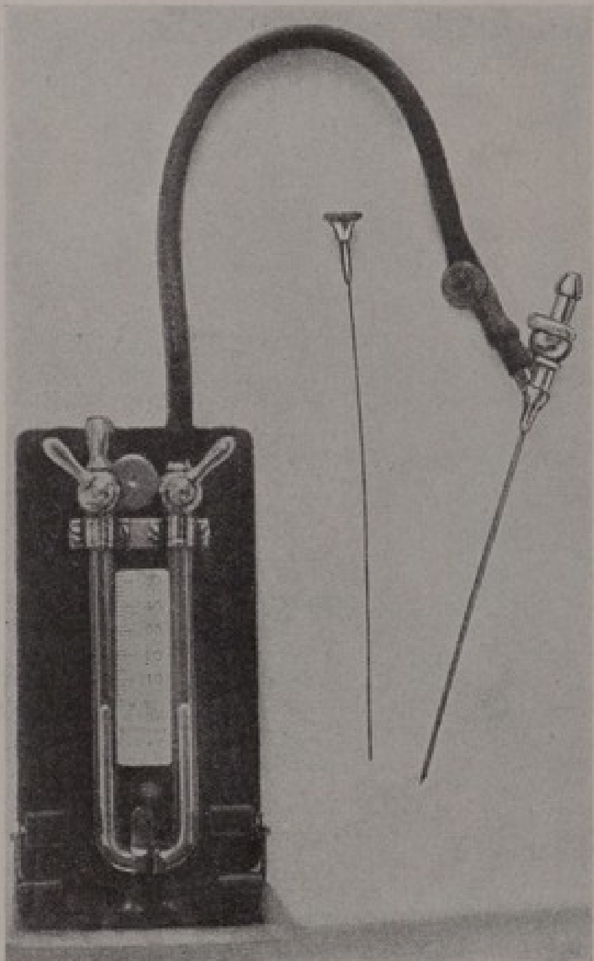


FIG. 50.—Frazier's pocket mercurial manometer attached to canula. When folded up the U-tube is protected and the mercury is prevented from escaping by closing the cocks.

If the needle is introduced in the right direction, fluid should be obtained in the large majority of instances. Occasionally the needle must be pointed very obliquely upward in order to avoid the bone. If no fluid is obtained the needle should be partly withdrawn, and reinserted with the stilet in place. In most instances a "dry tap" is due to obstruction of the needle by tissue, or to the fact that the needle has not perforated the dura but has pushed the dural sac in front of it, or that the needle has slid along by the side of the dural sac. In the latter instance there is apt to be an escape of a few drops of blood from the needle on account of injury of small veins on the inner surface of the spinal canal. If this happens, the needle should be withdrawn, washed out with sterile solution and reinserted. If the patient complains of severe pain in one leg, as the dural sac is penetrated, it is probable that one of the roots of the

Fig. 51.—The sitting position for lumbar puncture.

cauda has come in contact with the needle; the pain usually disappears within a moment and the occurrence has no significance.

If asepsis is perfect, little immediate harm can be done to the patient, but more than 20 to 50 c.c. of cerebrospinal fluid should never be removed at one time. Lumbar puncture should never be done when there is an expanding lesion in the posterior cranial fossa, on account of the danger of herniation of the cerebellum into the foramen magnum and sudden medullary death. This has occurred within a few hours of the operation in a number of instances.

After lumbar puncture the patients often suffer for hours or for a number of days from headache and dizziness, which may be so distressing that they are unable to lift the head from the bed. Severe pain in the back may be complained of. Attacks of syncope have also followed the operation.

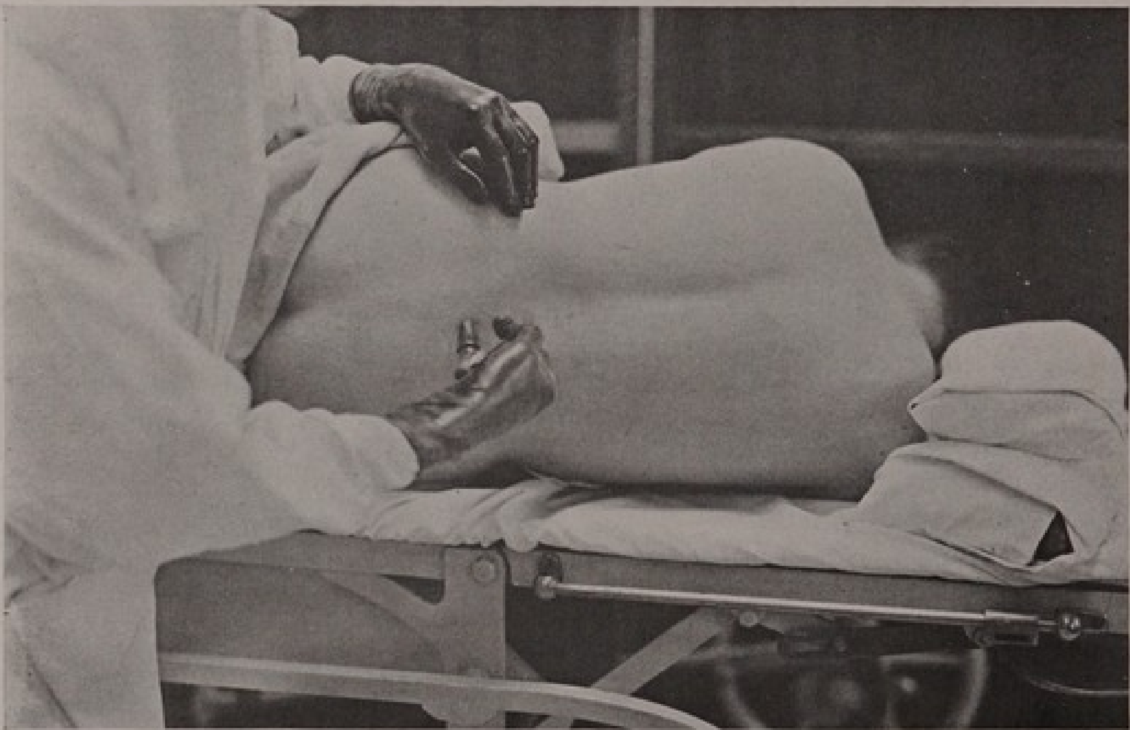


FIG. 52.—The recumbent position for lumbar puncture.

Care must always be taken that the patient does not suddenly straighten out his spine while the needle is in place. In several instances I have been called in to remove a piece of a needle, a sudden movement of the patient having caused the needle to break. If this accident should occur, an X-ray picture should first be taken (unless the needle can be plainly felt beneath the skin) and then the needle removed under local or general anesthesia. In two of the patients from whom I was asked to remove a broken fragment, the needle could only be found after one spinous process had been removed.

**Indications for and Value of Spinal Puncture.**—The spine is punctured for either diagnostic or therapeutic purposes. In the first instance, the object is to determine the pressure under which the fluid escapes and to obtain a specimen for examination. For this latter purpose, it is advisable to allow the first few drops of the fluid to escape as there is often microscopically a little blood mixed with the fluid.

Therapeutically, the withdrawal of cerebrospinal fluid by spinal puncture is of value in some cases of posterior basic meningitis in children. In tubercular meningitis, in which disease the fatal outcome is often hastened through the ventricular distension, repeated lumbar punctures may overcome the deleterious effects of the distension. Undoubted cases of recovery from tuberculous meningitis after repeated and long-continued lumbar punctures are on record (Freyhan, Neisser). In chronic hydrocephalus of the non-obstructive variety repeated lumbar punctures are often very useful, and the same is true of the treatment of expanding lesions of the brain, such as tumor, abscess, etc., excepting when the disease is in the posterior fossa. In chronic non-obstructive hydrocephalus lumbar puncture may be done every two to six weeks, no more than 50 c.c. of fluid being removed at one time. The earlier the treatment is begun, the better will be the results. If the brain has been much injured by the long-standing compression, improvement will not occur.

By means of puncture of the arachnoid sac, various drugs and remedies are injected into the spinal canal (Flexner serum in meningitis, magnesium sulphate (Meltzer, Kocher) and antitoxin in tetanus, salvarsanized serum in syphilis, various drugs for spinal anesthesia—cocain, tropa cocain, stovain, etc.). When a drug or fluid of any kind is to be injected into the spinal canal, as much cerebrospinal fluid should be allowed to escape as solution is to be injected.

**The Cerebrospinal Fluid.**—As far as is known, the cerebrospinal fluid is a secretion from the choroid plexuses of the cerebral ventricles (Cushing, Dixon and Halliburton, Frazier and Peet, etc.), its secretion being due to a hormone in the blood itself (Dixon and Halliburton). The fluid is absorbed into the venous system and into the lymphatics within the nerve sheaths.

**Pressure.**—The normal pressure of the cerebrospinal fluid in the recumbent position is between 5 and 7.3 mm. of mercury or 60 to 100 mm. of water. The pressure is raised periodically with the cardiac and respiratory pulsations and during the acts of coughing, sneezing, etc., and it varies directly with the blood pressure. Normally it escapes drop by drop or in a small stream, but the pressure may be much raised in intracranial disease, reaching 300, 500, or even 1000 mm. of water.

The pressure of the fluid is regularly raised with conditions which cause increase of pressure within the cranial chamber—tumor, abscess, meningitis, hydrocephalus, edema of the brain, etc. The pressure of the fluid is diminished in asthenic conditions, tumor in the posterior cranial fossa which obstructs the foramen magnum, spinal tumors which obstruct the spinal canal, etc.

Nonne, Raven, and others believe that marked increase of globulin (precipitation by magnesium sulphate), without or with a slight increase in the lymphocytes, and a yellow color (xanthochromie) of the cerebrospinal fluid is characteristic of compression of the cord. The increase of globulin in the fluid obtained by spinal puncture is caused by the stasis below the site of the compression. The albuminous content of the fluid is increased in inflammatory processes, but there is in addition an increase in the number of lymphocytes. The yellow color of the fluid is due to the presence of changed blood from an old hemorrhage.

Increase of globulin and xanthochromie may occur in intramedullary as well as in extramedullary tumors of the cord, for obstruction to the circulation of cerebrospinal fluid may occur as well when the cord is enlarged by an intramedullary as when it is pressed upon by an extramedullary newgrowth. In some cases, however, no changes have been observed at all, and I have operated upon a number of patients with intra- and extramedullary newgrowths in whom the fluid obtained by spinal puncture was entirely normal.

The number of cells in the cerebrospinal fluid varies with the position of the patient, the location of the puncture, and a number of other factors. Therefore it is advisable to have all lumbar punctures done in one position, and the operator can follow his own choice as to whether he prefers to have the patient in the sitting or in the recumbent position.

Increase of cells, aside from red blood cells and pus cells, is always due to an inflammatory process in or near the meninges. While pleocytosis regularly occurs in a number of the syphilitic and metasyphilitic affections, we are interested only in the changes that occur in the number of cells in certain spinal diseases. Increase occurs in meningitis of all kinds whether intracranial or spinal or both, in abscesses or inflammatory processes in the brain or near the meninges (sinusitis, etc.). According to some authors there is a moderate increase of cells in spinal tumors, but it has been my experience that spinal newgrowths usually give a normal cell count.

Brownish discoloration (xanthochromia) of the cerebrospinal fluid has been frequently described in spinal newgrowths. I have most often seen it in large tumors of the conus and cauda equina that fill up the greater part of the lower end of the spinal canal. The discoloration of the fluid is probably due to old blood. If such a brownish coloration of the fluid is found, the only conclusion justified is that there has been a stasis of the fluid from some cause or bleeding into some part of the subarachnoid space.

The cerebrospinal fluid is examined also for the presence or absence of the Wassermann reaction, presence of bacteria, of other abnormal constituents, etc.

**Intradural and Extradural Injections.**—By means of lumbar puncture drugs can be brought into direct contact with the central nervous system, and this route has been selected in a large variety of diseases. I shall not speak in detail of spinal anesthesia, except to mention that various anesthetic substances have been injected into the spinal canal and a perfect anesthesia of the lower part of the body obtained.

Intraspinous injections of tetanus antitoxin, magnesium sulphate, carbolic acid solution have been used in tetanus; salvarsanized serum and neosalvarsan have been injected in the treatment of syphilis and metasyphilitic diseases. The technic of these injections is like that of lumbar puncture, but it should be a general rule to allow as much cerebrospinal fluid to escape as there is fluid to be injected.

**Sacral Puncture and Epidural Injections.**—In 1903 Cathelin first described a procedure by means of which injections could be made into the sacral epidural space for the relief of nocturnal incontinence of urine

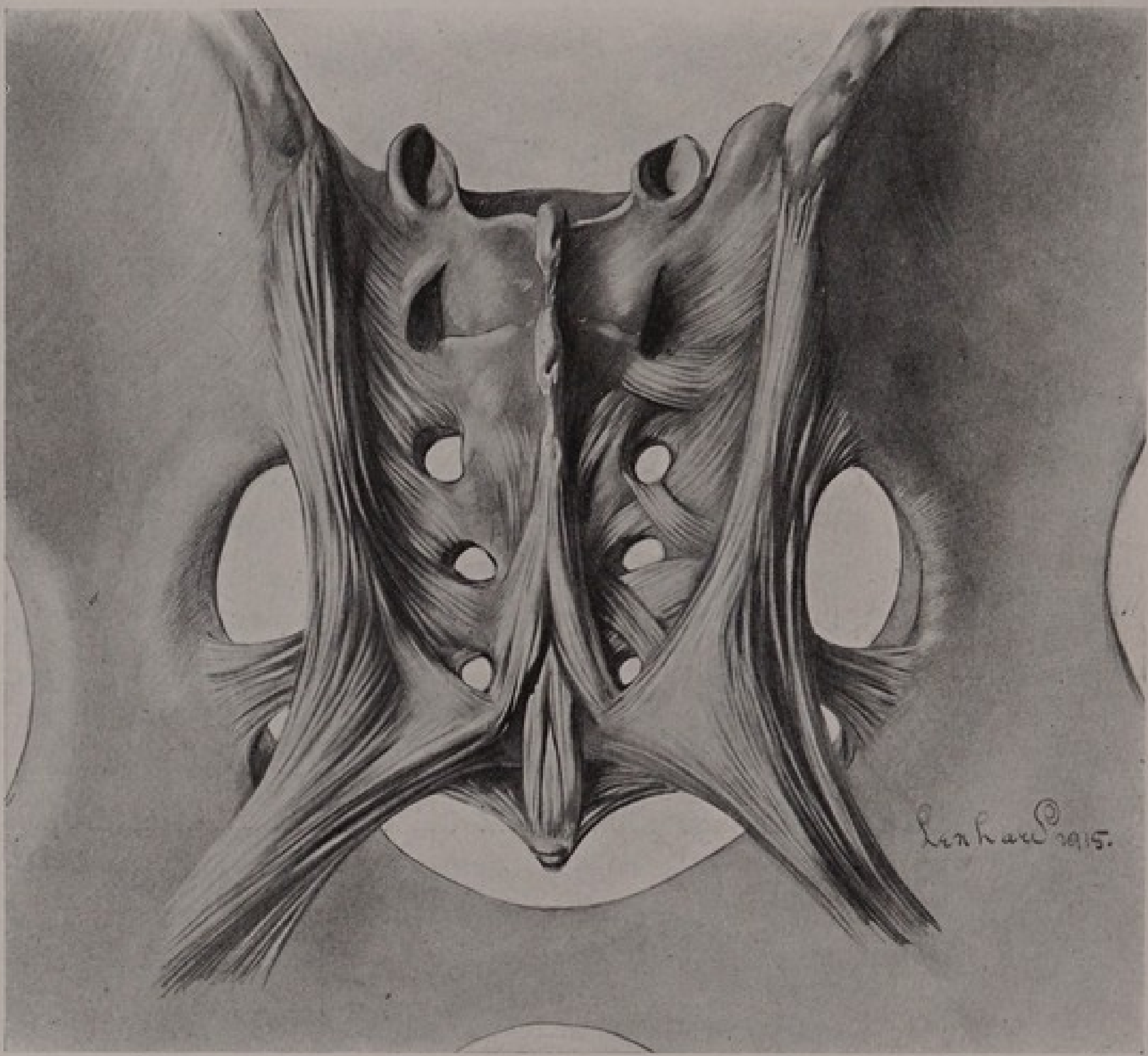


FIG. 53.—The sacrum with its ligaments (from behind) to show the region where the sacral puncture is done.

and of painful inflammatory processes of the lower urinary tract. The method has since been found to be useful in the treatment of lumbago, of the pain of recurrent carcinoma of the rectum, of neuralgic affections of the pelvic viscera, and for sacral anesthesia.

The injections are made into the sacral epidural space through the large triangular opening on the dorsal surface of the lower part of the bone.

As the sacral epidural space is a direct continuation of the epidural space of the general vertebral column, it is even possible if large amounts are injected to force fluid for a considerable distance upward.

The sacral hiatus is closed by a ligament which has to be perforated by the needle. The dura ends at the second or third sacral vertebra, so that there is no danger of penetrating the dura sac unless the needle is pushed upward too far (Fig. 53).

The technic of sacral puncture is the following: The patient is

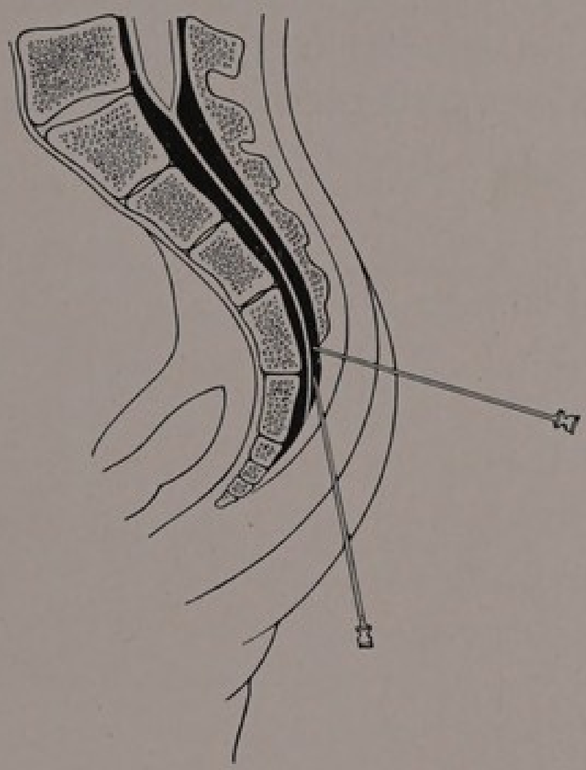


Fig. 54.—The directions taken by the needle in sacral puncture.

placed at the edge of the bed in one of the positions used for lumbar puncture, and the skin sterilized with tincture of iodine. The median vertical crest of the sacrum is palpated with the finger until the large depression of the sacral opening is felt. An ordinary lumbar puncture needle is then introduced directly forward through the skin (which may be previously anesthetized) until the ligamentous tissue which covers the sacral opening has been penetrated. The direction of the needle is then changed so that the end points in the long axis of the body (Fig. 54). The needle is pushed upward for a distance of 5 to 6 cm. and the injection is then made. For sacral anesthesia about 20 c.c. of 1 per cent. novocain solution should be used. In the treatment of nocturnal enuresis, small quantities of liquid vaseline or larger amounts of normal saline solution are recommended.

In thin individuals the injection can be made without any difficulty, but in the very stout it may require much patience to find the proper spot for the puncture of the skin. If the needle has entered the epidural space, no infiltration of the subcutaneous tissues over the sacrum will follow the injection, and it is always a good plan to inject saline solution first in order to determine that the needle is in the proper place. The needle should never be introduced to a depth of more than 6 cm. or the dural sac itself might be entered.

# CHAPTER X

## THE EXPOSURE OF THE SPINAL CORD BY LAMINECTOMY

The structure of the vertebral column should be carefully studied by those who desire to do successful spinal surgery. The many bones connected by numerous ligaments, allowing of marked mobility in many directions, the whole supported by thick muscles, make a remarkable mechanical system. Within this is the spinal canal containing the spinal cord suspended in it, the cord being protected from injury by the fluid which surrounds it.

To open the spinal canal and to expose the cord the posterior wall of the canal must be removed, after the soft tissues have been drawn aside and the ligamentous structures divided. Various methods have been devised to accomplish this end. Osteoplastic methods were once highly recommended (Marion, Cavicchia, Bickham, Arbanz, Mixter and Chase, etc.), but these have not been looked upon with favor, for the operations are too complicated and bloody, and are more time consuming than the simpler procedure soon to be described. The attempt has also been made to popularize the operation of hemilaminectomy (A. S. Taylor, Alessandri, Bonome), but this operation does not give as wide a field of exposure as the complete laminectomy in which the posterior arches are removed entirely, and the consensus of opinion is that the operation of hemilaminectomy is only advantageous where no exploration has to be done. Its main field of usefulness is where nerve roots on one side only have to be divided. As to the claim that the mechanics of the spine are less interfered with when only the laminæ of one side are removed, I shall show that this is only a theoretical advantage. After the complete removal of the spinous processes and laminæ of a number of vertebræ, the functions of the spinal column are soon fully recovered.

**Surgical Anatomy.**—Although in Part I I have given an account of the structure and arrangement of the vertebræ, a few important features must still be mentioned. The spaces between the cervical and between the upper dorsal spinous processes are of considerable size and there is no trouble in removing each spine at its base with appropriate rongeur forceps (Fig. 1, page 18). The middle dorsal spines, however, overlap each other so much that it is not so easy to isolate each spinous process for its removal. In the lumbar region, again, the spines, though very thick and short, are easily removed (Figs. 2 and 3, pages 19 and 20).

The removal of the spinous processes and laminæ in the cervical and greater part of the dorsal regions will lay open the spinal canal widely. In the lowest dorsal and lumbar regions the canal is more deeply placed,

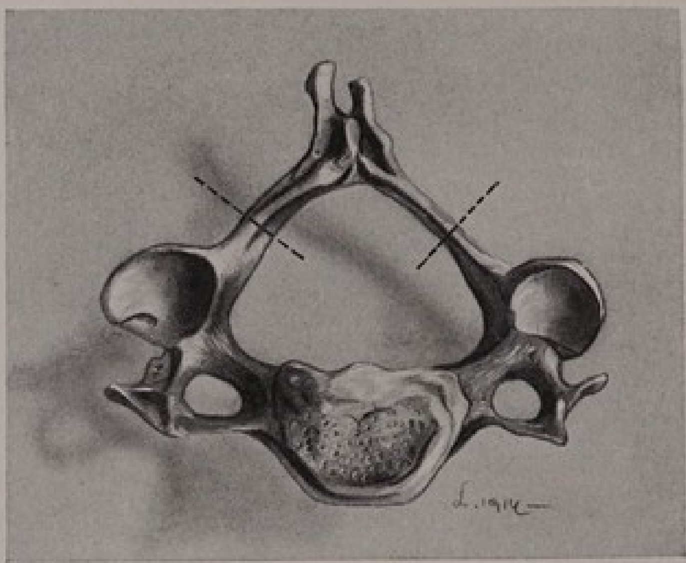


Fig. 55.—A cervical vertebra. The broken lines show the amount of bone removed in order to widely open the spinal canal (compare with Figs. 56 and 57).

and only the removal of the laminæ well out to the articular processes will give a free exposure of the spinal canal and its contents (Figs. 55–57).

The muscles that surround the cervical and dorsal vertebræ are easily separated from the spines and laminæ, but in the lowest dorsal and the lumbar vertebræ the prominences of the transverse processes interfere somewhat with the retraction of the muscles. In the lumbar region, also, the muscles are thicker and more deeply placed between bony prominences (Figs. 58–60).

The ligamenta flava are much thicker in the lower dorsal and lumbar regions and must often be separately excised.

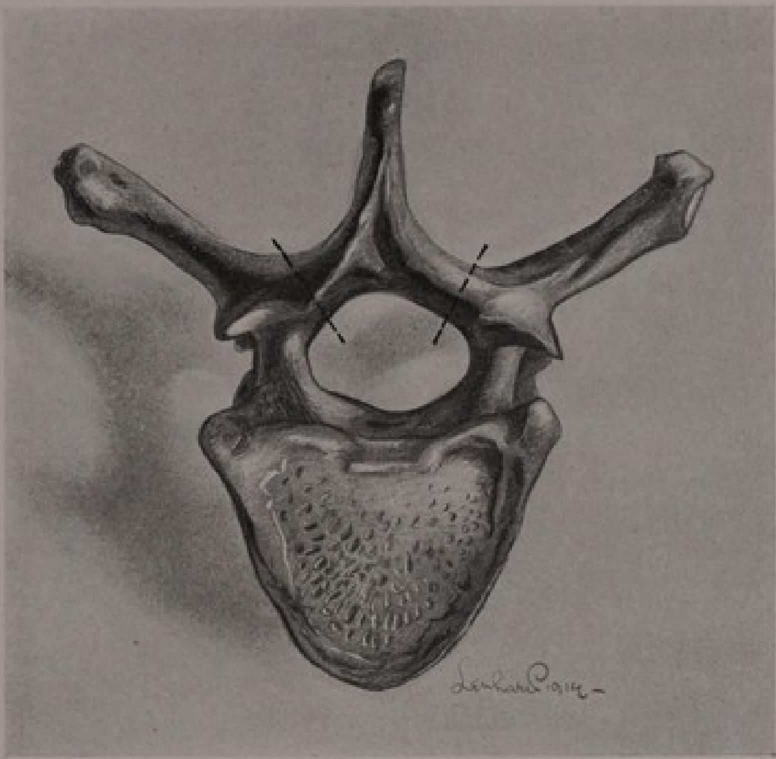


FIG. 56.—A dorsal vertebra (broken lines as in Fig. 55).

FIG. 57.—A lumbar vertebra (broken lines as in Fig. 55)

The outer surface of the dura is covered by a layer of fat which must frequently be stripped off from the membrane and removed before the dura is exposed to view.

**Position of the Patient. The Anesthesia.**—In general, the patient should be placed in the prone position, the chest being raised from the table by means of pillows placed under the shoulders. There are differences, however, in different parts of the vertebral column. When the operation is to be done in the cervical region, the patient is best placed in the position used for suboccipital craniotomy (Fig. 61). The head must rest on an outrigger or extension and be slightly flexed on the chest, so as to make the cervical spine as prominent as possible. The thorax must be raised from the table by means of pillows placed under the shoulders, so that respiration shall not be interfered with.

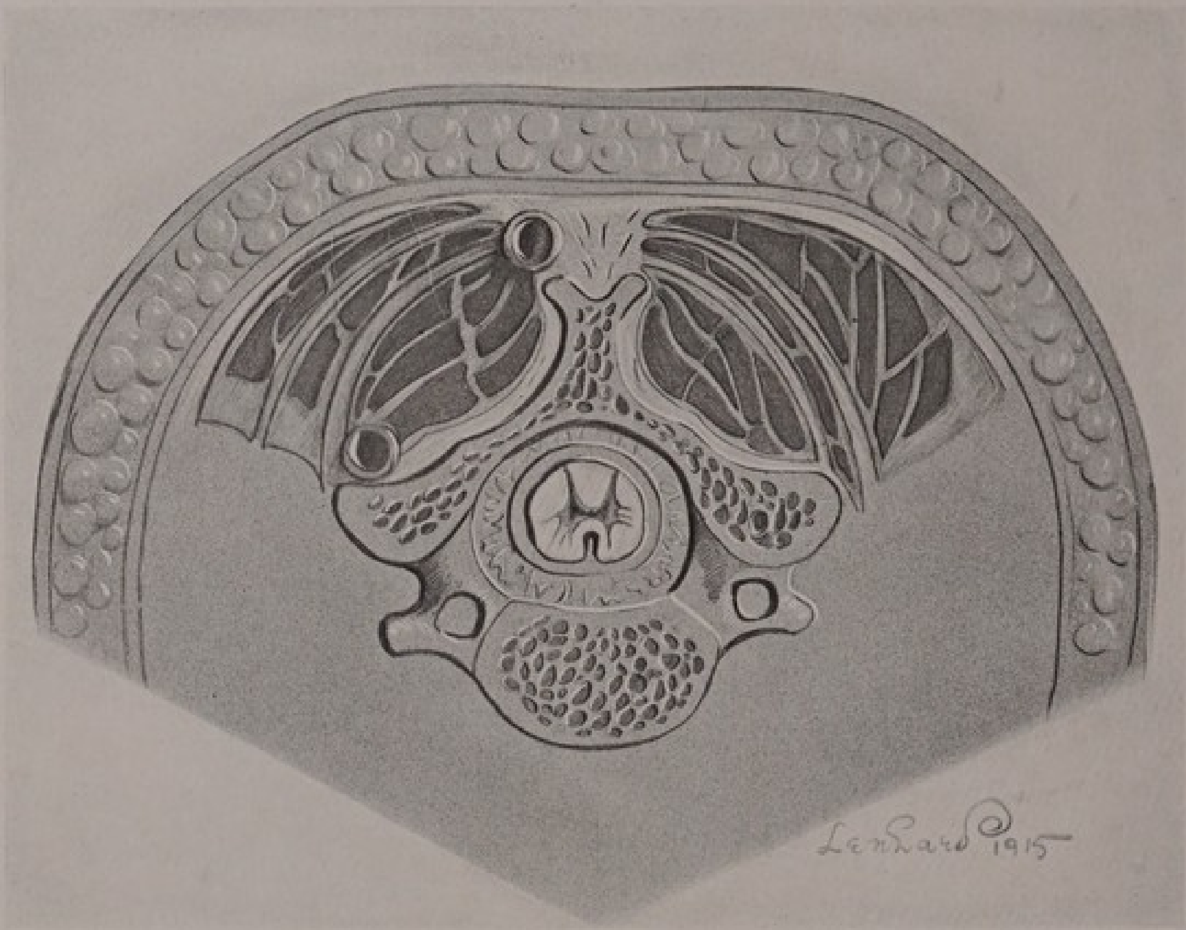


FIG. 58.—Cross section of the back in the cervical region, showing the muscle and fascial layers and the larger blood vessels. The vessels have been drawn very large to show their location.

If the operation is done in the dorsal region, the part to be operated upon must be made prominent by means of pillows placed under the abdomen or chest (Fig. 62). A similar position is useful for operations in the lower dorsal or lumbar regions, but it is usually sufficient to have

Fig. 59.—Cross section of the back in the middorsal region.

the patient in a modified Sims position, the one side of the body being elevated from the table by means of pillows (Fig. 63).

Very frequently the anesthesia can be given in the ordinary way with an open mask or with nasal tubes. If the laminectomy is done in the cervical and upper dorsal regions, however, anesthesia by intratracheal insufflation is the best and simplest method. The advantages of this method of etherization are manifest and well known.

Very rarely a spinal operation may be required in a patient in whom a general anesthetic is contraindicated. In such a case the operation may

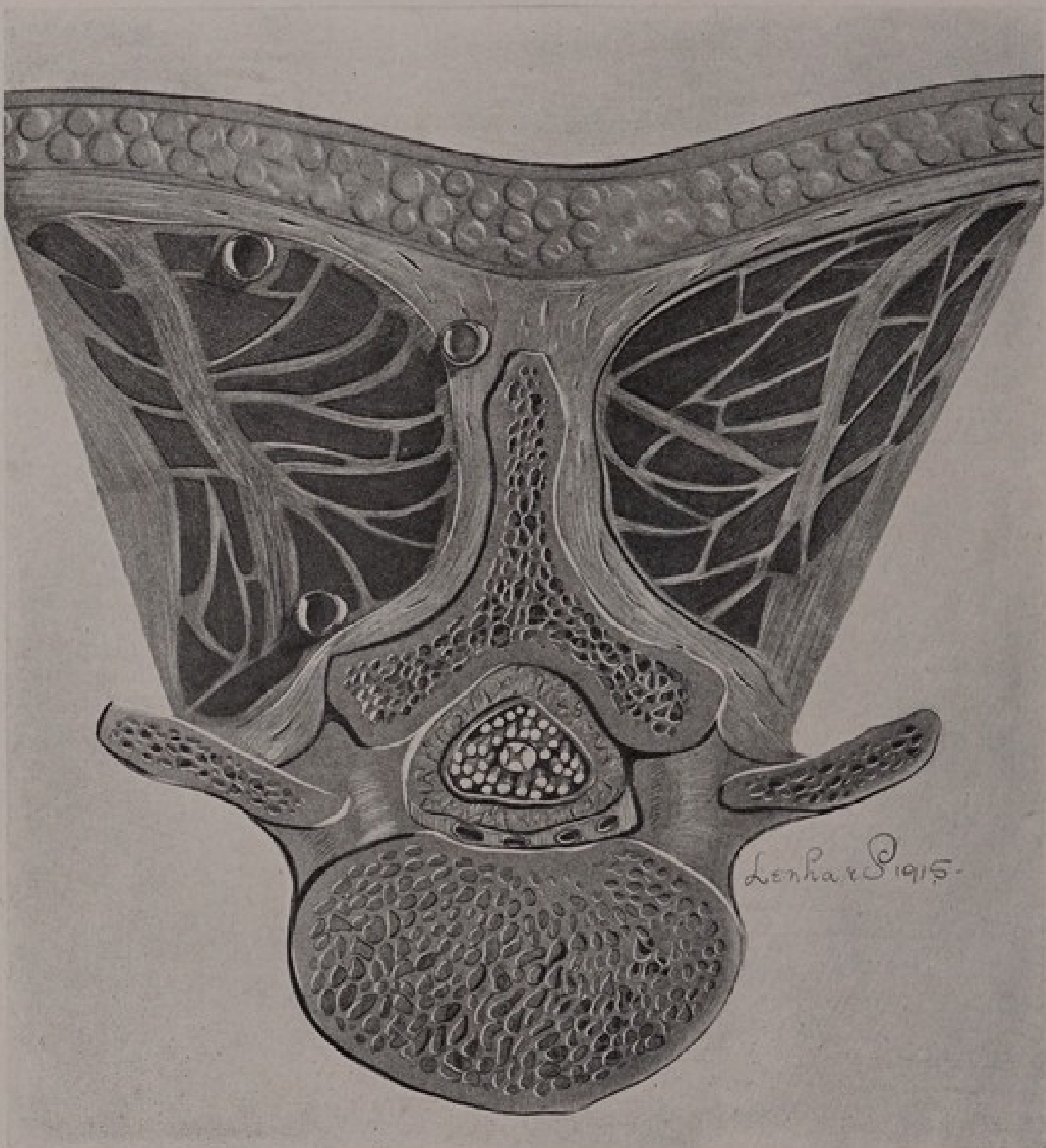



FIG. 60.—Cross section of the back in the lumbar region.

be done under spinal or under local infiltration anesthesia. If the laminectomy is to be done in the lower dorsal or lumbar region, a good anesthesia may be obtained by the injection of stovain or novocain into the spinal sac by lumbar puncture. If the operation is to be done in the cervical or upper dorsal region, the parts must be rendered anesthetic by means of local injections of cocain in the following manner: The patient should be given a full dose of morphine and atropine one hour before the operation. The skin, subcutaneous tissues and muscles should be infiltrated with Schleich solution on both sides of the spinous processes and down to them. After the skin and fascia have been incised, the tissues near the spinous processes and laminæ should be infiltrated with the anesthetic solution, the attempt being made to include also the spaces between the spines.

FIG. 61.—The prone position for cervical laminectomy.

As soon as the spinous processes are exposed, the cocain solution should be injected under the periosteum of the spines and laminæ, the injections being frequently repeated while the spinous processes and laminæ are being removed. As soon as one spinous process has been taken away so that the dura is exposed, a small dose (.02 cg.) of stovain should be injected into the dural sac. The operation should then be interrupted for five to ten minutes until a good spinal anesthesia has been obtained. The anesthetic should not be injected into the dura if the operation is done in the upper dorsal or cervical region, on account of the danger of

Fig. 62.—The prone position for laminectomy in the dorsal and lumbar regions.

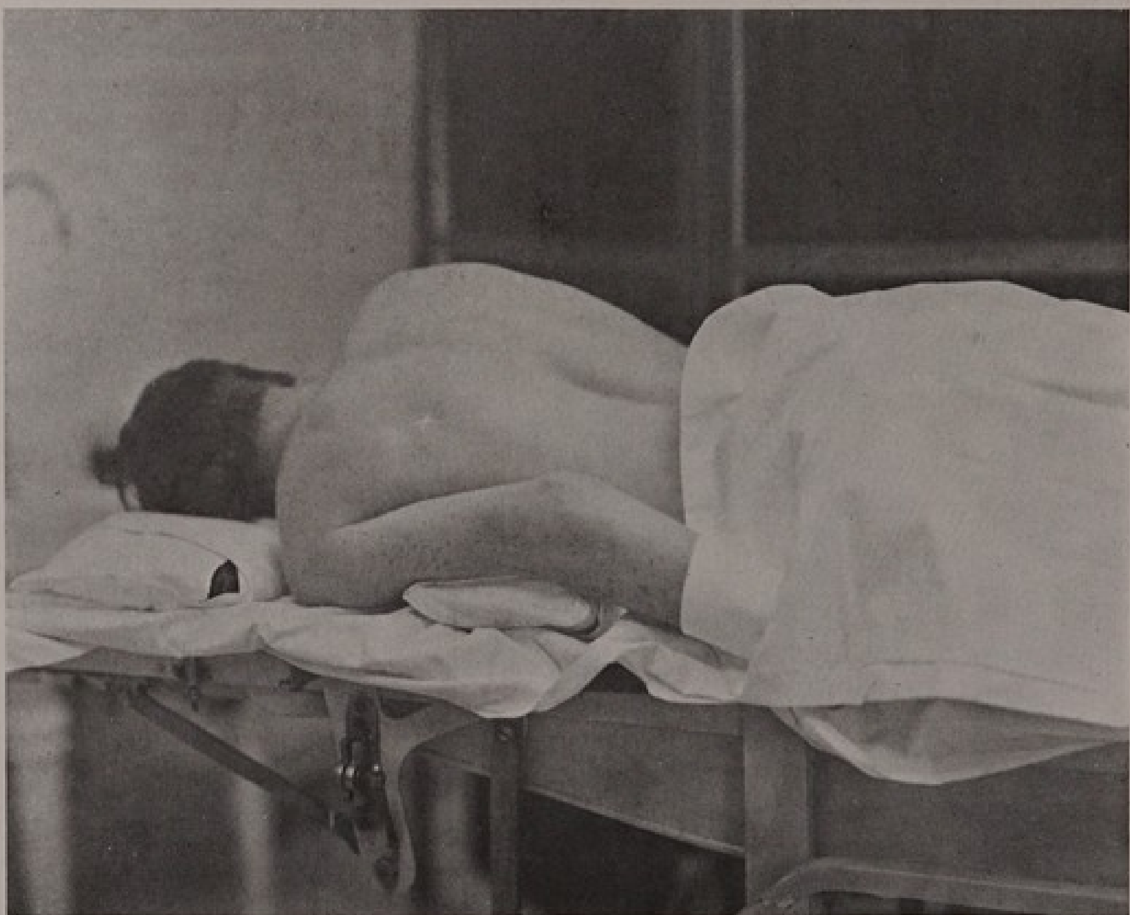


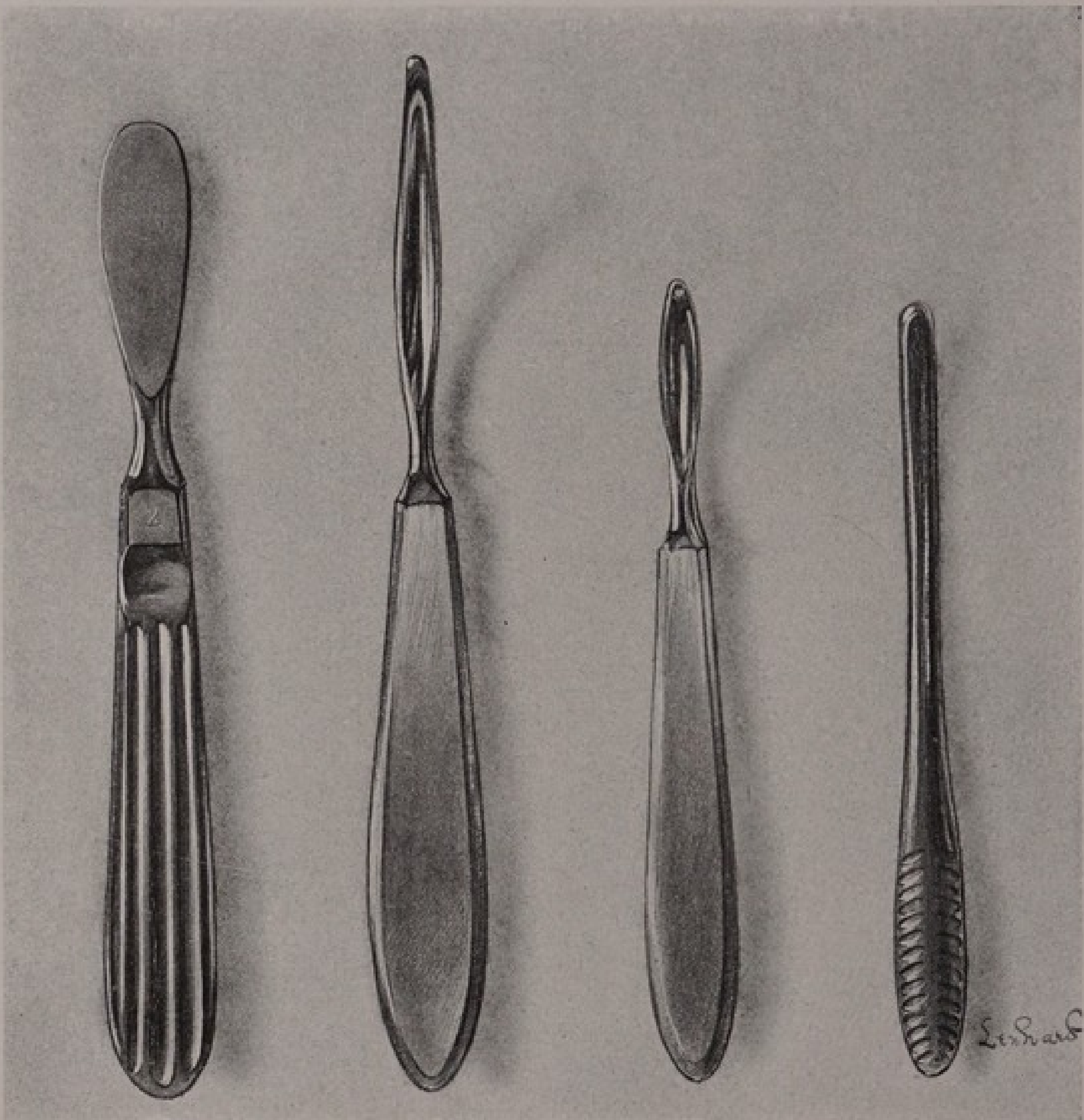
Fig. 63.—The semi-prone position for laminectomy.

respiratory symptoms. From the time that the dura has been widely exposed, frequent applications of cocain on small sponges to the dura, or nerve roots, will contribute to the anesthesia of the parts in the operative field.

The preparation of the patient and the sterilization of the skin are the same as that for any other operation. The skin of the back is washed with alcohol and ether and painted with tincture of iodine.

FIG. 64.—Laminectomy. I. The skin incision.

**The Operation** (Figs. 64 to 82).—Ordinarily it is necessary to remove the arches of at least three vertebræ in order to obtain sufficient exposure, and it is better to take away one arch too much than one too little. The spinous processes desired should first be located both by counting downward from the seventh cervical (vertebra prominens) and by counting upward from the fourth lumbar (on a level with a line connecting the highest parts of the iliac crests). The incision is made over the spines and rapidly deepened on one side of the spinous processes. The scalpel must be kept as close as possible to the spines, so as to divide the muscular attachments near the bone. The separation of the muscles is completed with a broad elevator (Fig. 65) and the oozing controlled by a gauze



A B B B

FIG. 65—A. Broad elevator to separate the muscles from the laminæ. B,B,B. Other elevators that may be required (natural size).

packing. The same procedure is then accomplished on the other side. The bleeding is seldom profuse, rarely requiring the use of artery forceps, and is controlled by the packings. There are a few large blood vessels which must occasionally be caught with forceps. The packings are removed after a minute or two and the wound edges spread apart with an automatic retractor (Fig. 66). The retractor not only controls all

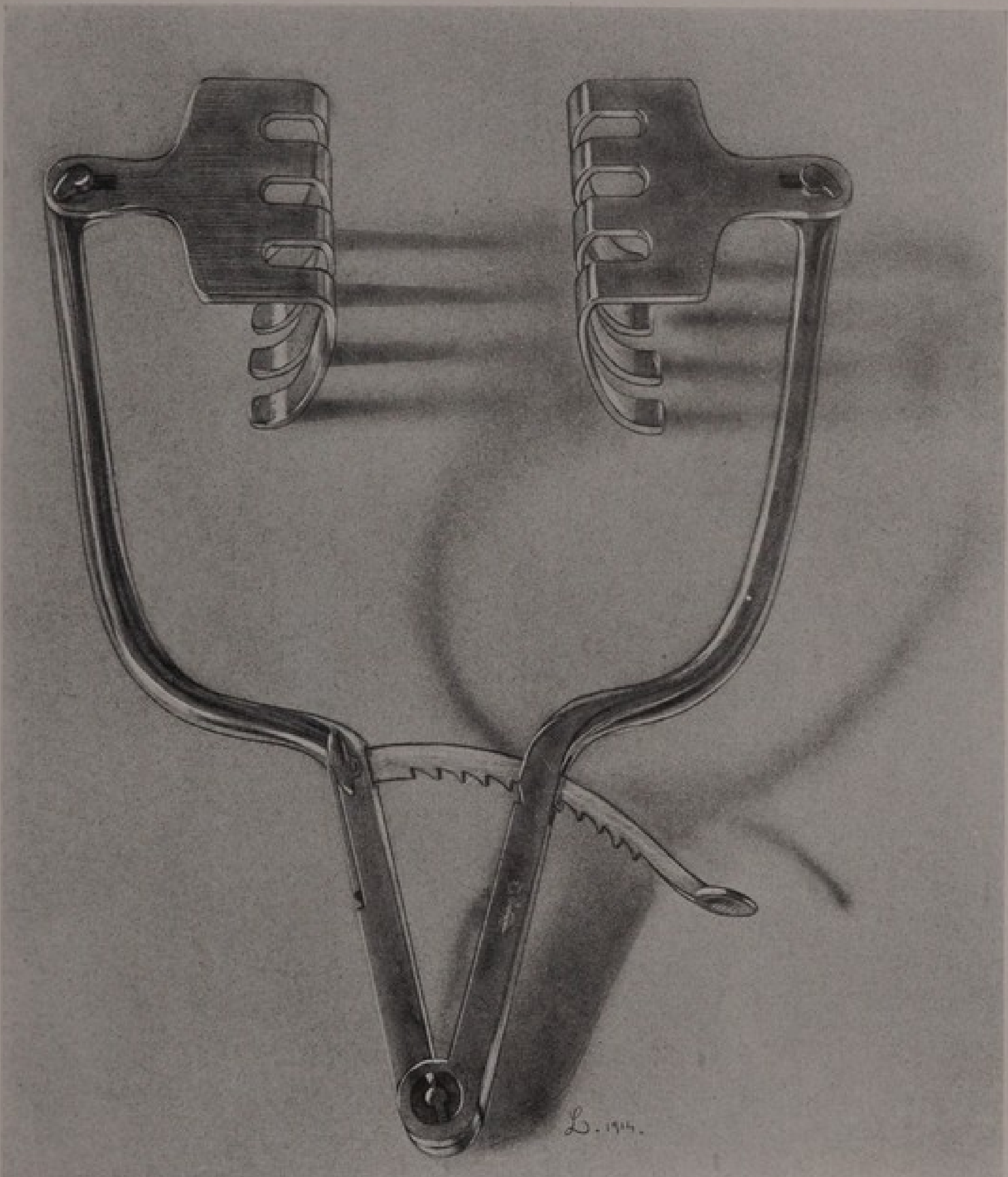


Fig. 66.—Automatic retractor for laminectomy. $\times \frac{2}{3}$.

oozing from the muscles, but it gives an excellent exposure of the field of operation.

The interspinous ligaments are now divided by rapid cuts with the scalpel. With a large rongeur forceps (Fig. 68) or a Horsley spine forceps (Fig. 69) the spinous processes are bitten off at their bases. In the cervical and upper dorsal regions the spinal canal will be opened at once, but in the lower dorsal and lumbar, considerable rongeuring will be necessary before the canal is opened. Then with quick bites of smaller rongeur forceps (Figs. 71–75) the laminæ are removed well out to their

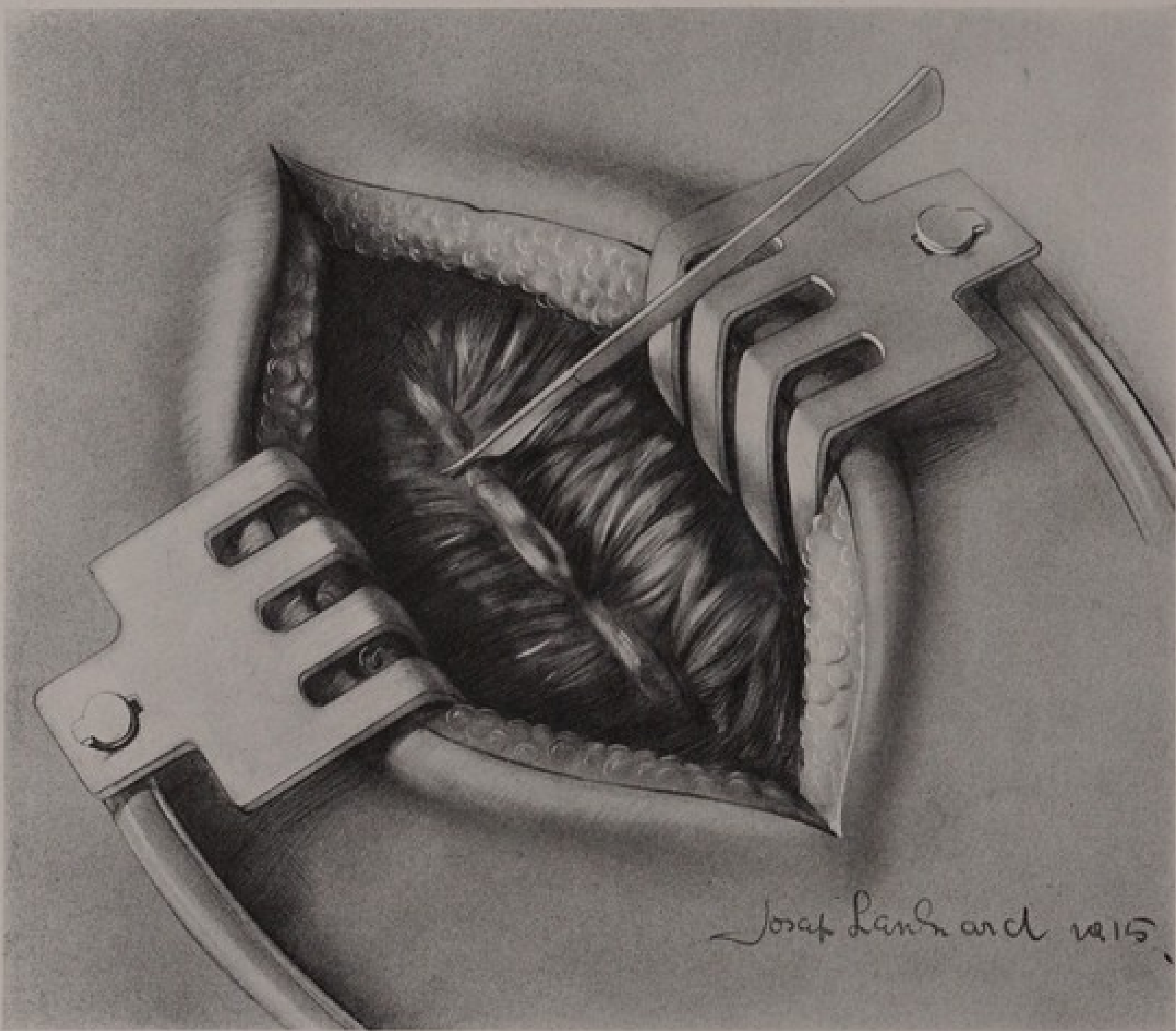


Fig. 67.—Laminectomy. II. The division of the interspinous ligaments.

articulating processes, beginning with the lowermost one exposed and working upward. During this part of the procedure, great care must be taken that no pressure is made upon the dura and spinal cord underneath.

As soon as the bone has been removed, the cavity is packed with gauze wrung out in hot solution, and by this means all bleeding is controlled. A little oozing from around the divided laminæ may persist. This can usually be controlled by traction on the flaps of the dura after this membrane has been incised.

The further procedure will depend upon the nature of the affection

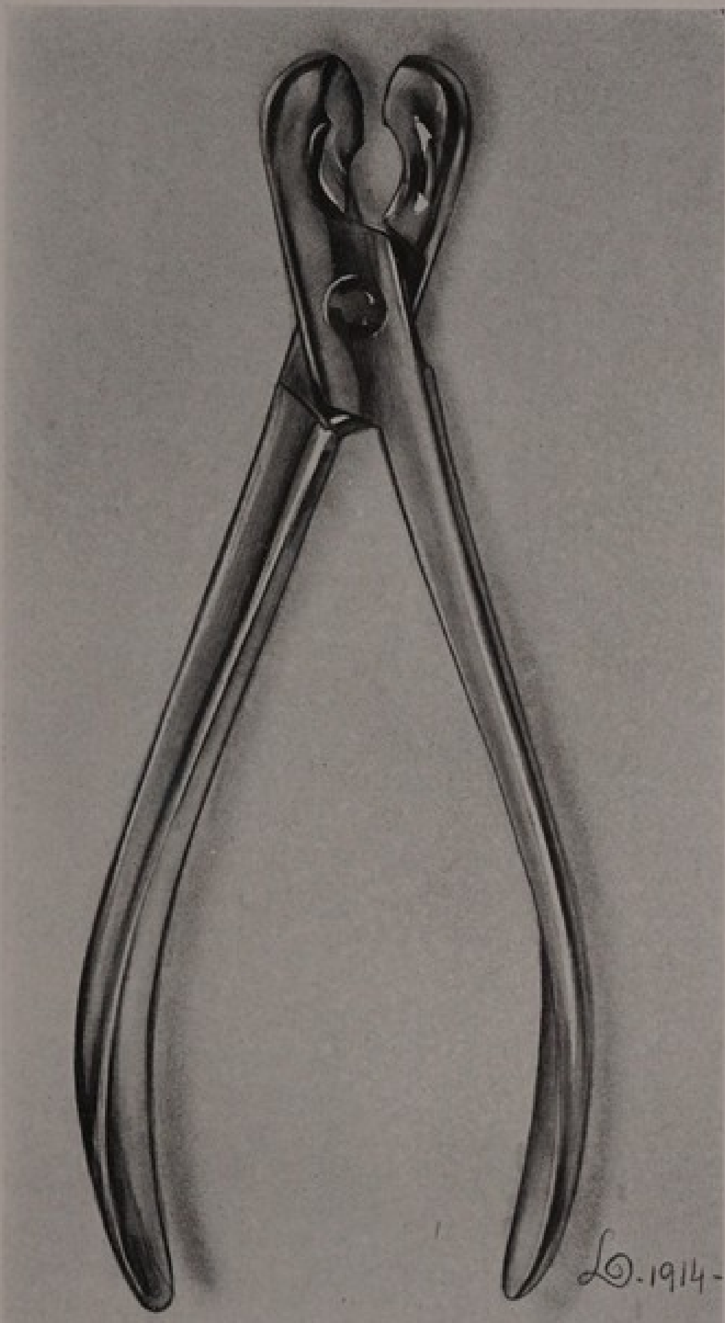


FIG. 68.—Large rongeur forceps for the removal of the spinous processes. $\times \frac{2}{3}$.

for which the laminectomy has been performed. As soon as the dura has been exposed, it must be gently palpated and the operator must note the presence or absence of cardiac and respiratory pulsations.

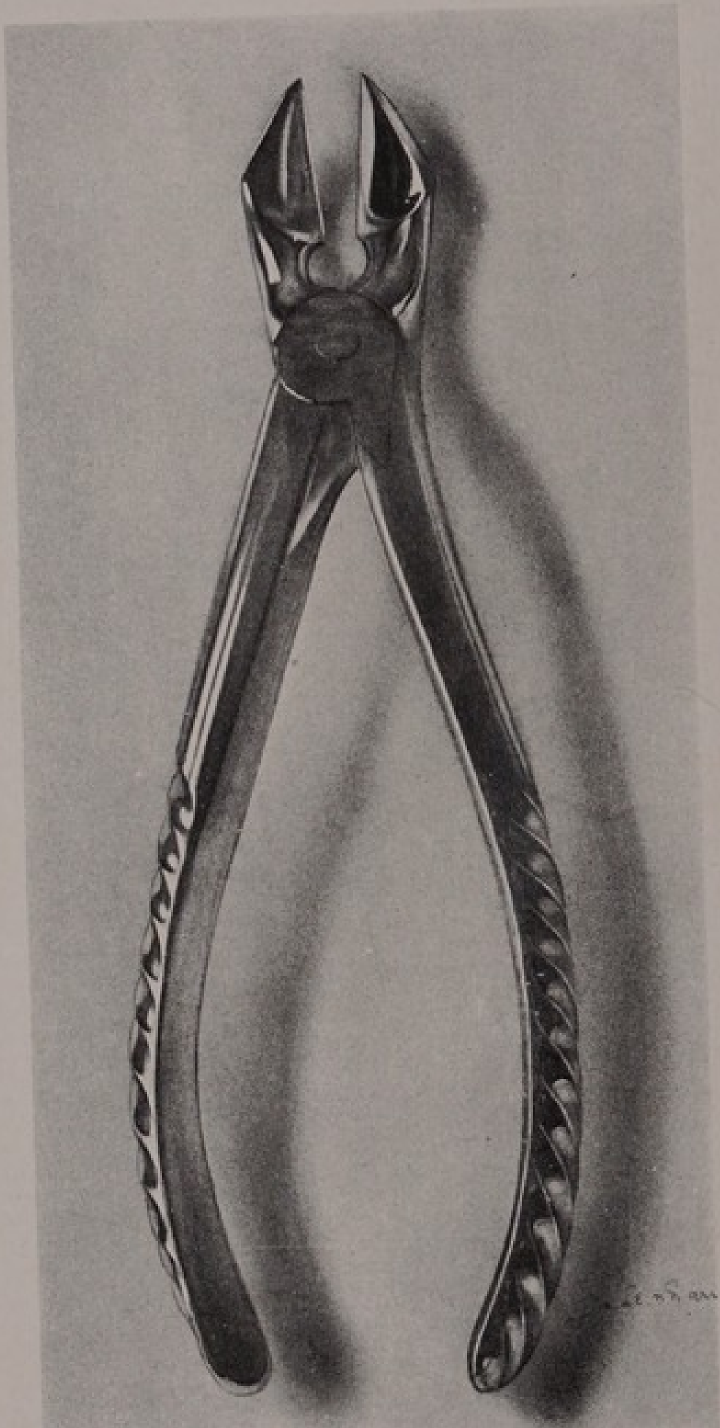


FIG. 69.—Horsley spine forceps. × ⅔.

When the dura is to be incised, the procedure is the following: The dura in the median line is grasped with fine forceps and a traction suture of fine silk is passed on each side of the forceps, care being taken that the needle does not injure the arachnoid or the cord. The two traction sutures are held tense and the dura is incised with a fine scalpel. If this

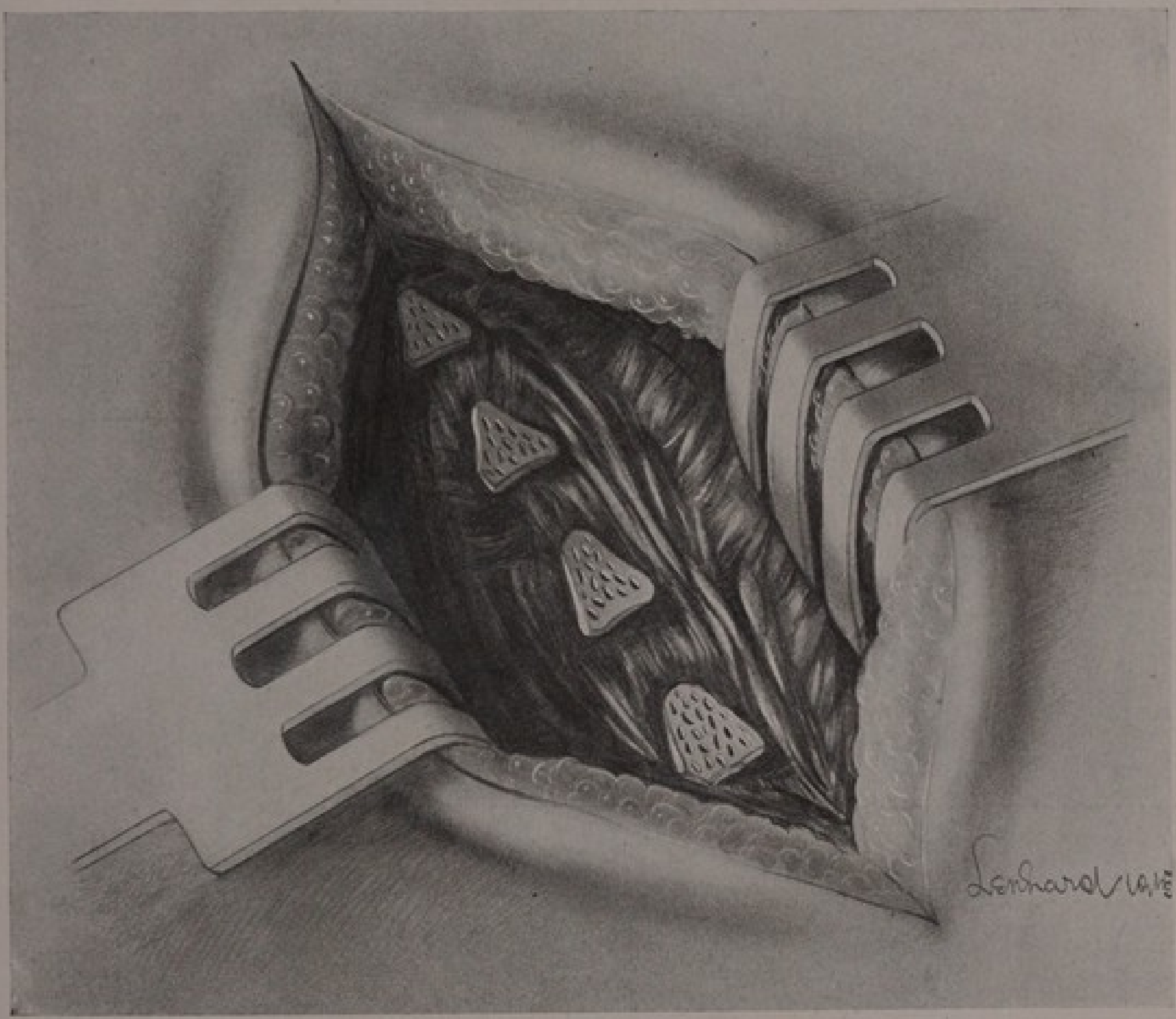


FIG. 70.—Laminectomy. III. The removal of the spinous processes.

is skilfully done, the arachnoid sac will not be injured; within it (through the fluid) the cord is to be seen.

The incision is then enlarged upwards and downwards with a grooved director, the dura tearing easily in the longitudinal direction. The cut edges of the dura are retracted with small two-pronged retractors or with mosquito forceps.

The arachnoid is then separately incised with fine scissors, the size and course of the vessels on the posterior surface of the cord, the appearance of the cord itself and of the inner surface of the dura being carefully noted.

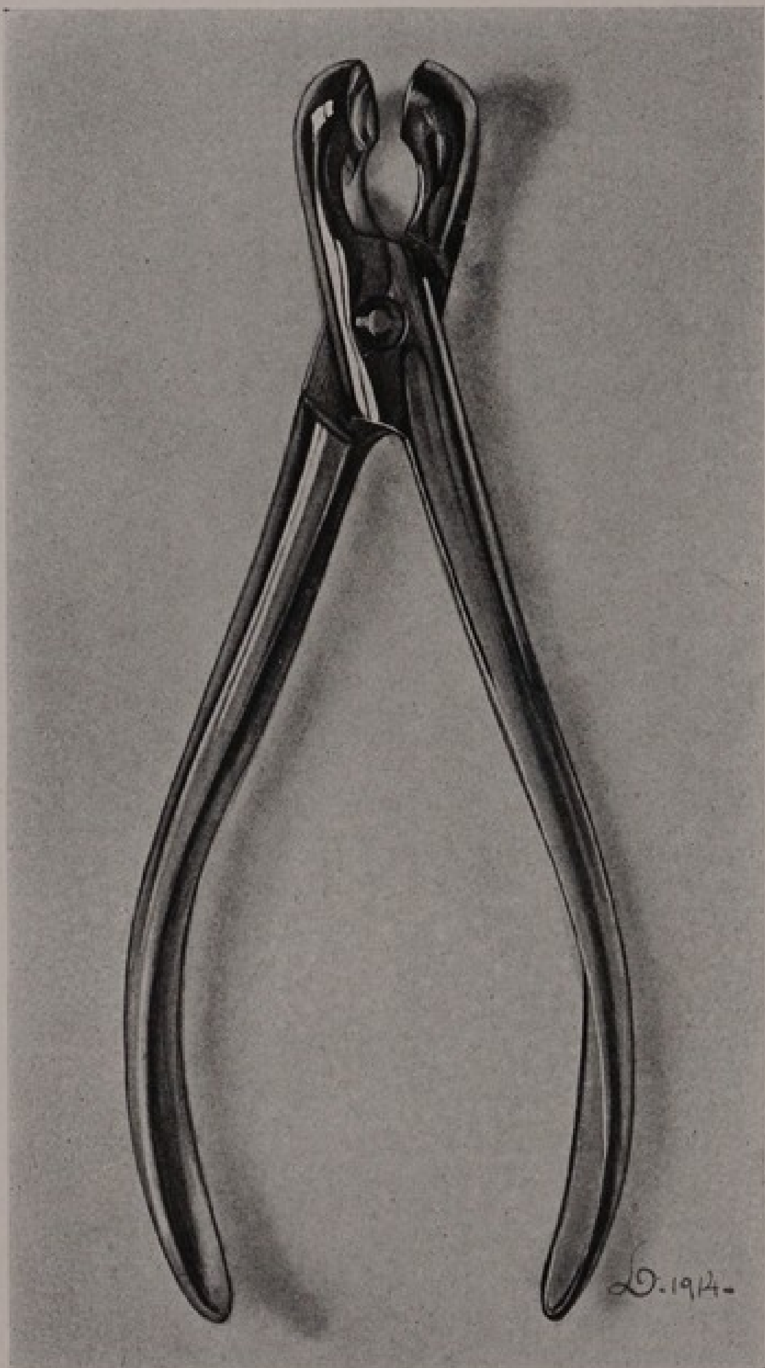


FIG. 71.—Rongeur for the removal of the bases of the spinous processes (natural size).

The further procedures will depend upon the nature of the operation to be performed and the conditions found. The cord itself may be carefully palpated in order to determine whether it is smooth or irregular in consistency, but the less the cord is touched or handled, the better.

**Exploration of the Spinal Canal.**—Those experienced in spinal surgery sometimes find it difficult to recognize the nature of the abnormal condi-

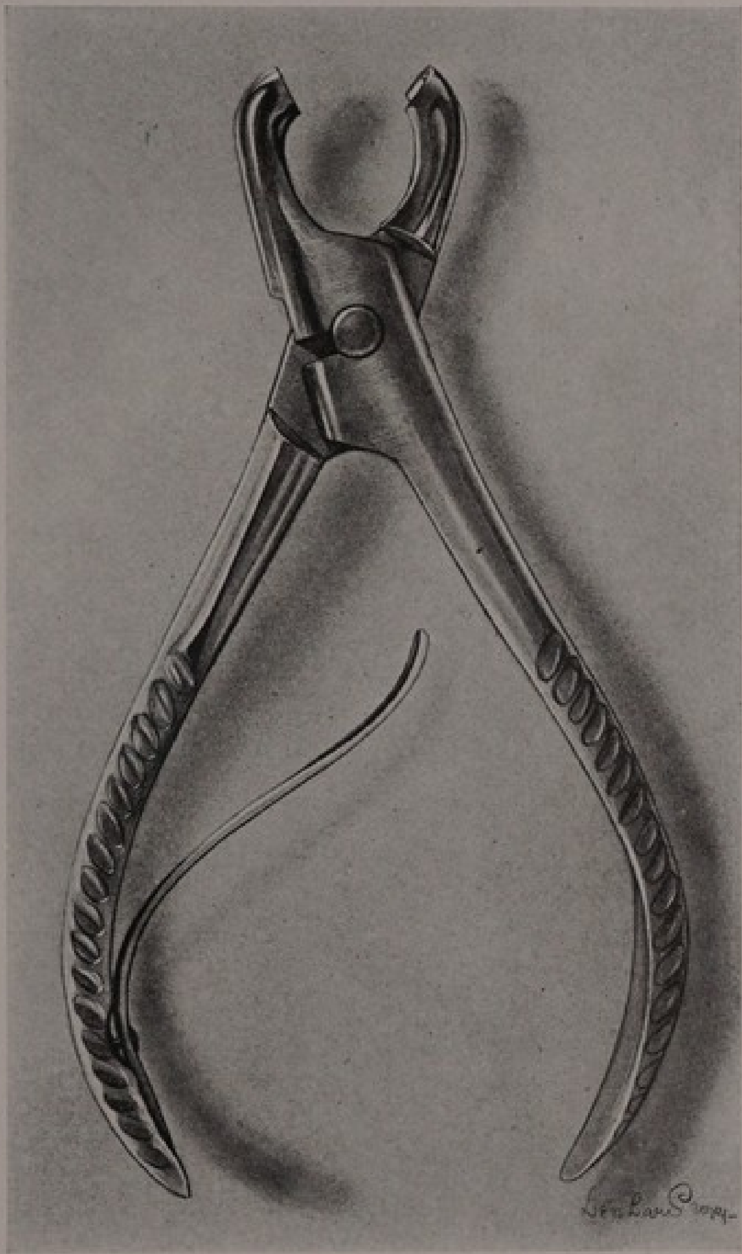


FIG. 72.—Rongeur for the removal of the laminæ. × ¾.

tions which are found. A few words upon the normal and pathological appearances of the cord and membranes is therefore permissible.

Normally the outer surface of the dura is of a bluish-white color and is smooth and glistening. A reddish or brownish discoloration is due to adjacent bone disease or to an inflammatory process in the dura itself. To the examining finger the membrane feels soft and it is easy to recognize that it is thin and that there is fluid underneath it. If the finger is gently passed over its surface, one can feel if the membrane is thickened, and

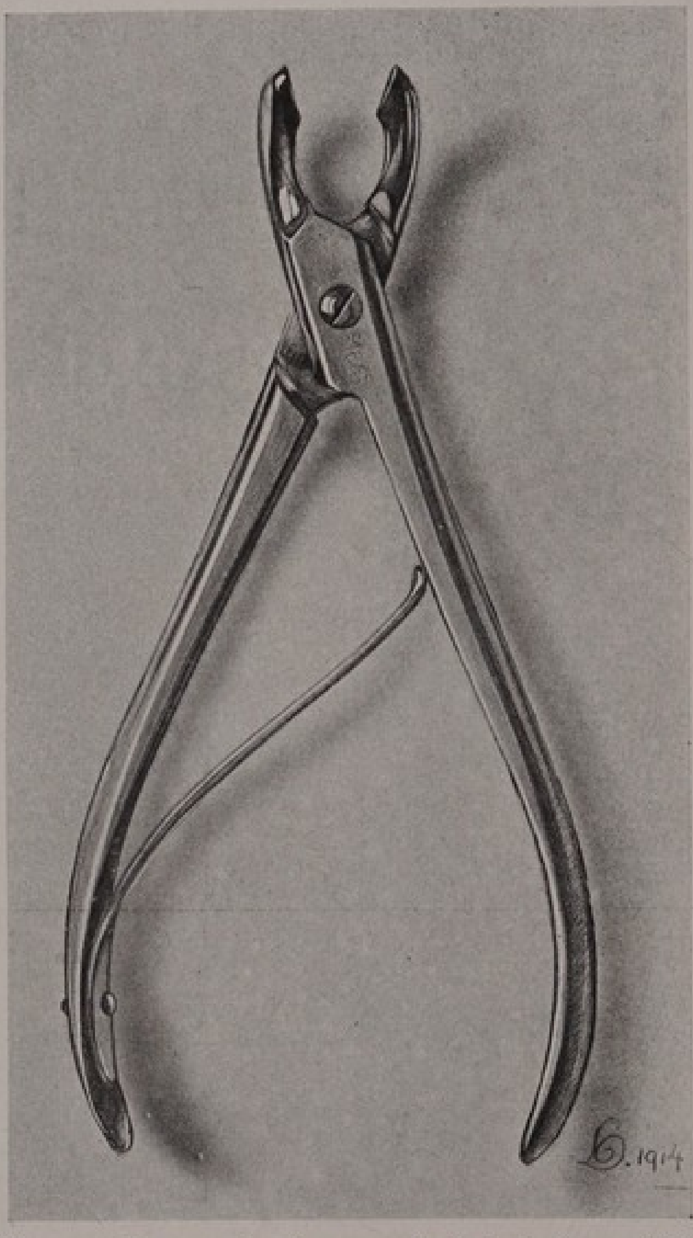


FIG. 73.—Rongeur for the removal of the laminæ. $\times \frac{3}{4}$.

sometimes (but by no means always) feel a tumor underneath it. A similar bulging and resistance may be due to the cord itself, if it is pushed backward by disease or newgrowth in front of it. In such a case the surgeon must be especially careful not to injure the cord when the dura is incised.

In rare instances the dura is the seat of a localized pachymeningitis. Before the dural sac is opened, if there is a suspicion of bone disease, the extradural space must be explored. After the dura has been incised, the

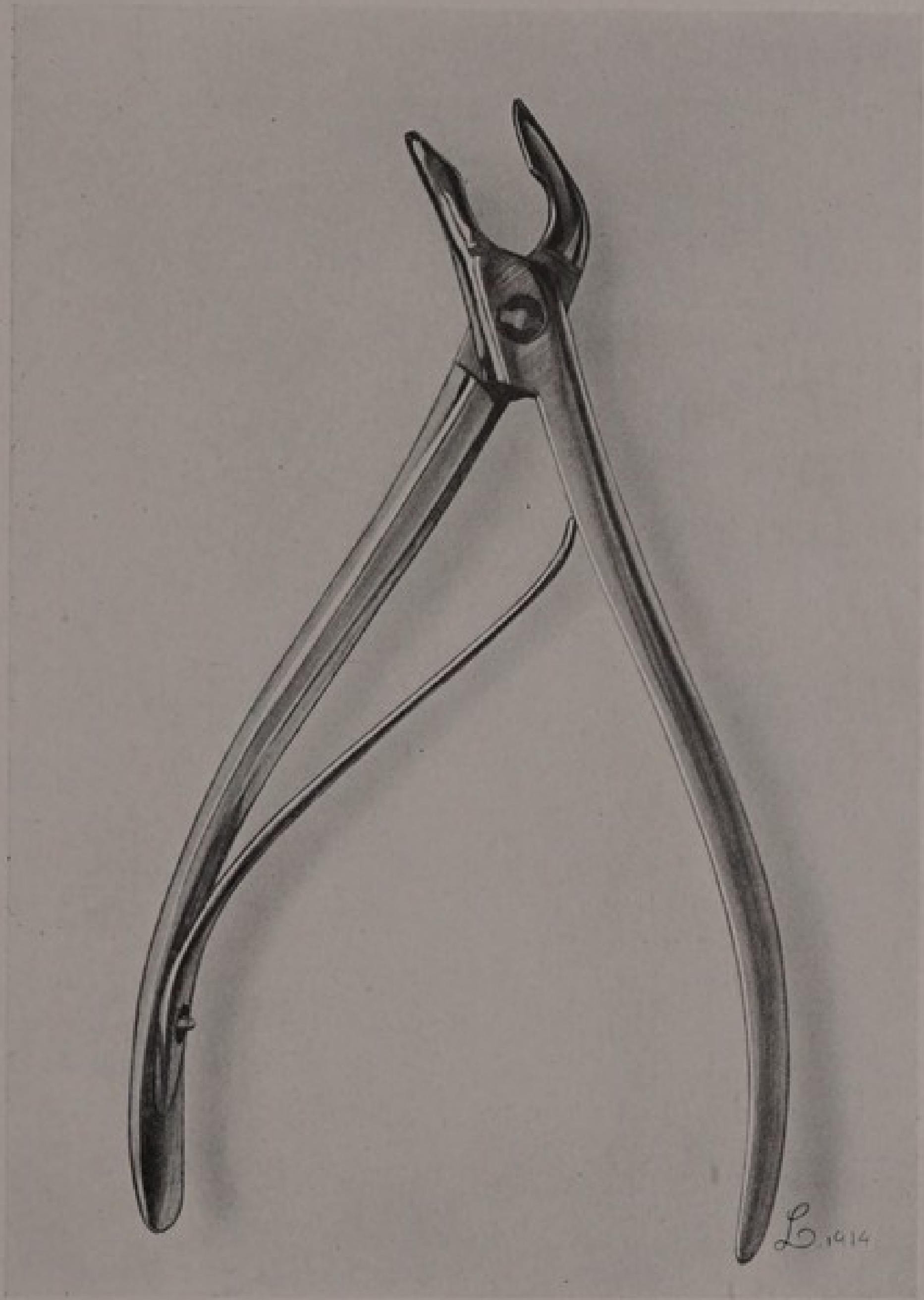


FIG. 74.—Rongeur for widening the spinal opening. × ¾.

arachnoid will be seen as a clear transparent membrane, which is not adherent to the smooth shining inner surface of the dura. Adhesions between the inner surface of the dura and the arachnoid are pathological, and any cloudiness or thickening of the arachnoid is an evidence of disease.

Frequently small calcareous plaques occur in the arachnoid; these have no pathological significance and can be peeled off without difficulty. The surface of the cord is of a creamy white color and is covered by a fine network of blood vessels. If the vessels are very large and tortuous, it means that there is either an inflammatory process within the cord substance or in the pia arachnoid, or that there is a pressure upon the vessels

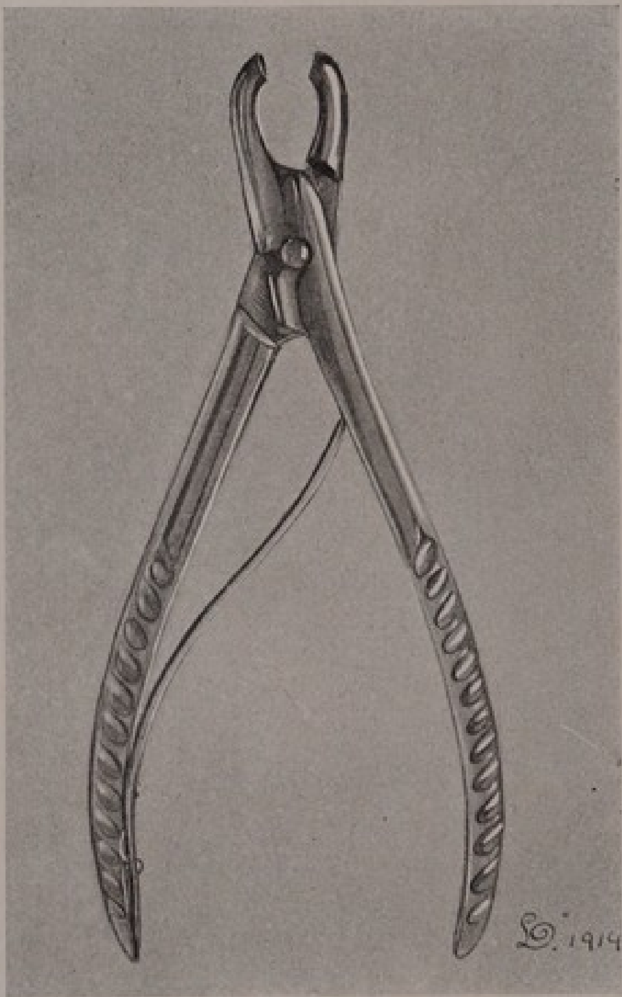
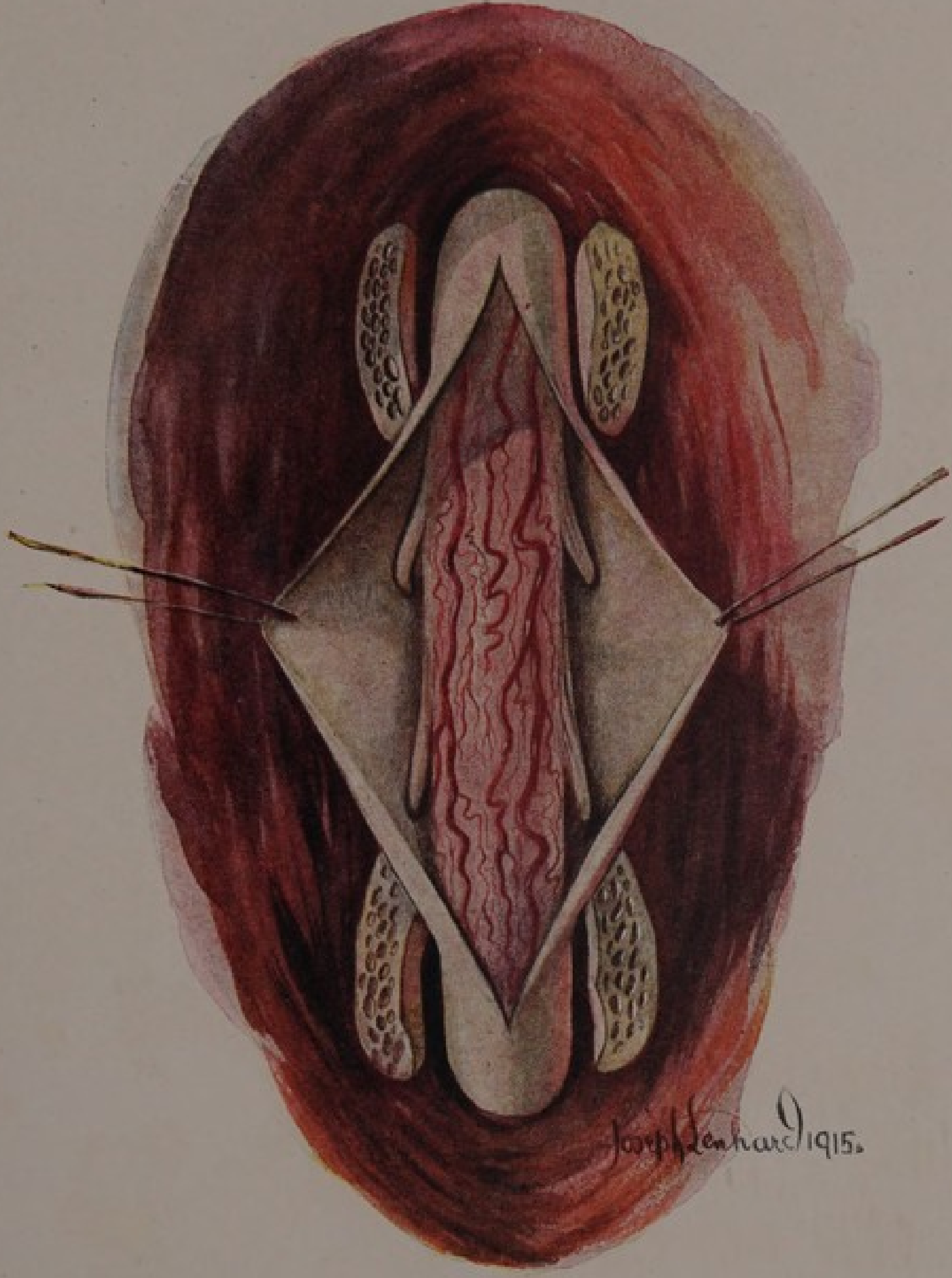


FIG. 75.—Rongeur for removing the overhanging edge of the laminæ in the dorsal region. × ¾.

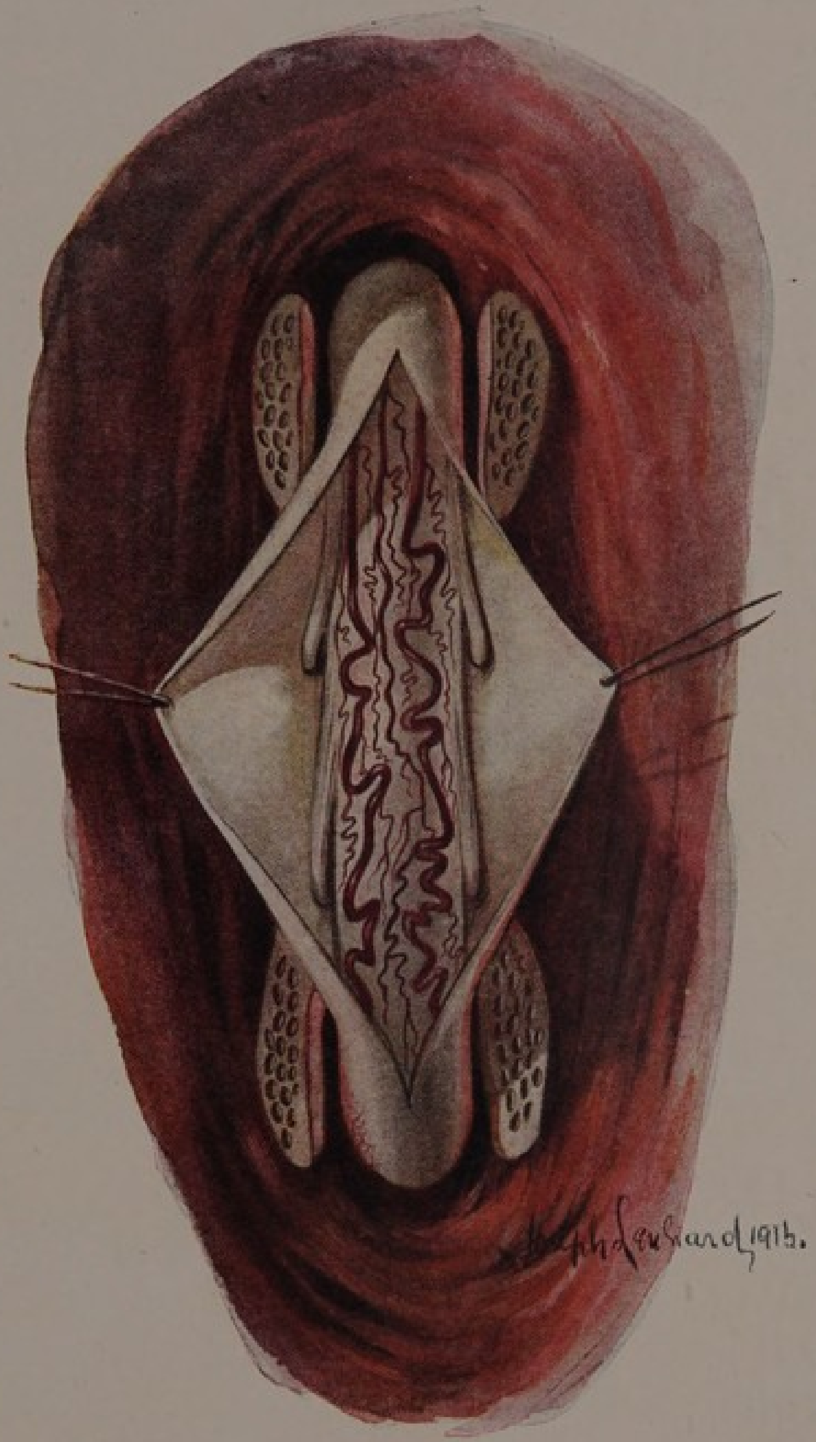
of the cord at a higher level than that exposed (Plates I and II). In myelitis and meningo-myelitis the cord is often of a reddish color and is covered by numerous dilated blood vessels (Plate I). When there is an obstruction to the return flow of the blood in the posterior spinal veins, as in newgrowths which lie on the posterior surface of the cord, the appearance of the cord below the level of the compression is altered. The normal creamy white color is preserved, but the veins are dilated and tortuous,

PLATE I



The spinal veins in meningomyelitis.

PLATE II



The spinal veins in spinal compression.

so that the swollen vessels stand out very prominently (Plate II). After some experience, the surgeon should be able to differentiate between a hyperemia of the cord due to inflammatory disease, and a venous congestion from compression of the spinal veins. After the appearance of the cord and membranes has been noted, a probe bent at the appropriate angle is carefully passed upward on the posterior surface of the cord. Under normal conditions the probe should pass upward in the mid-line

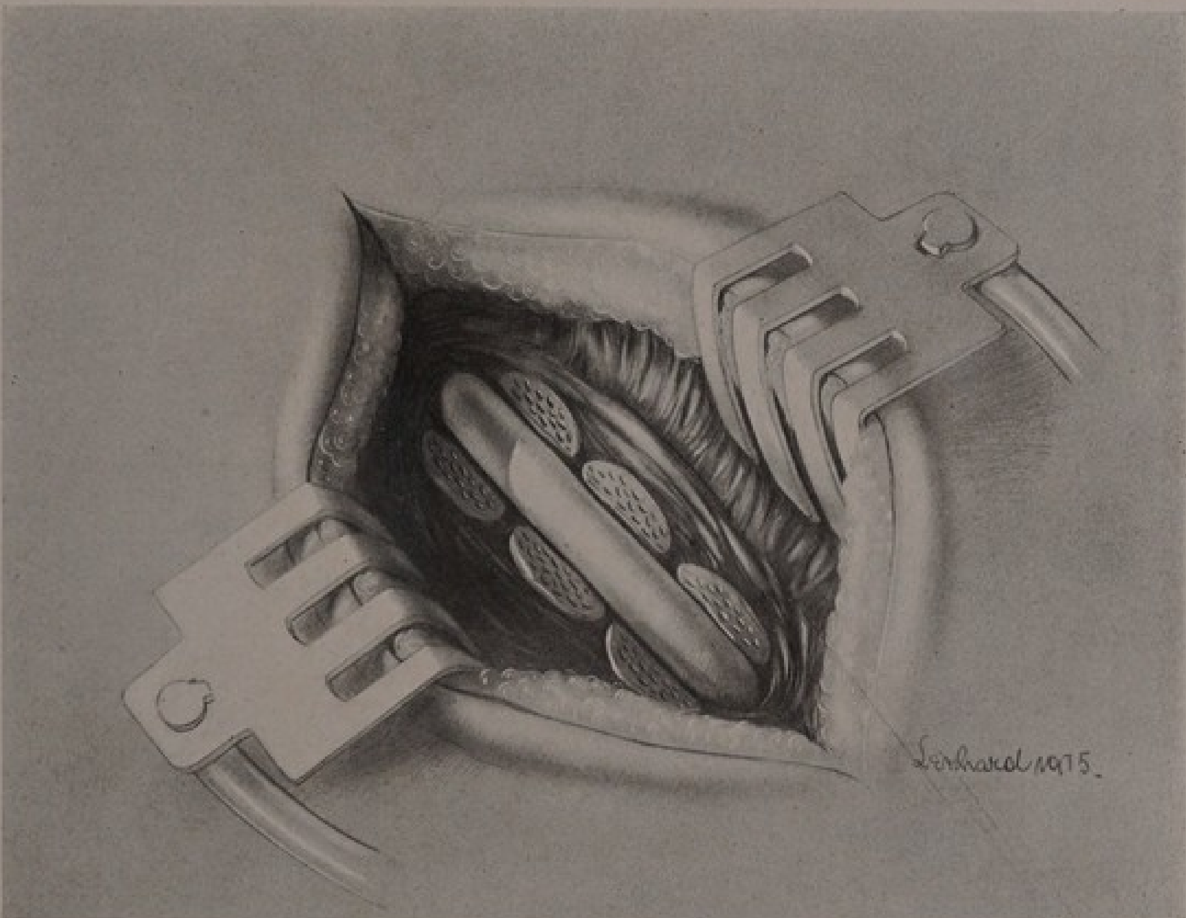


FIG. 76.—Laminectomy. IV. The dura exposed.

without meeting any obstruction. If it deviates from the median line it may meet with an obstruction due to posterior nerve roots or slips of the dentate ligament.

Slight manipulation, however, will allow the probe to be pushed forward. The same exploration should follow in a downward direction. If there are adhesions between the meninges, the passage of the probe will be obstructed so that it can not be pushed beyond the obstruction.

In order to explore the anterior surface of the cord the probe can be passed under a nerve root and then upward and downward on the anterior surface of the cord. It is preferable to grasp a slip of the dentate ligament with mosquito forceps, to cut the slip at the dura, and then to raise the cord by traction on the ligament. Traction on a slip of the dentate ligament is the best method for rotating the cord in order to expose its anterior surface (Fig. 79).

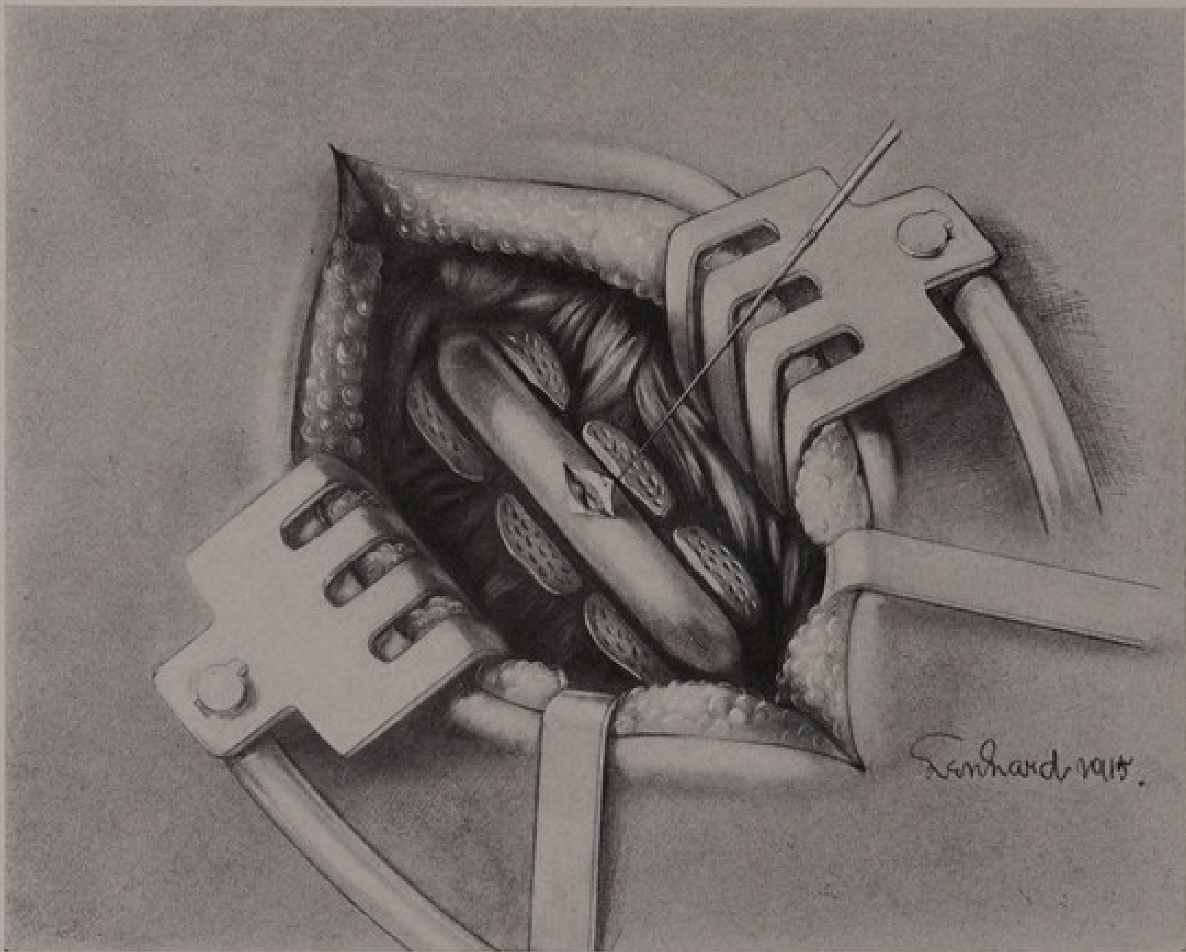


FIG. 77.—Laminectomy. V. The incision of the dura.

An obstruction to the probe in its upward passage may be due to an extramedullary neoplasm. After some experience the surgeon should be able to recognize the elastic feel of such an extramedullary tumor, even if it is several inches away from the upper end of the opening in the dura. When such an elastic obstruction to the passage of the probe is met with and a tumor is suspected, slight pressure on the probe will push the obstruction upward and there will be a sudden flow of cerebrospinal fluid. When this is observed, a tumor may be diagnosticated with certainty.

The detailed account of the procedure to be followed in the removal of an extramedullary or intramedullary tumor, in the incision of the cord for drainage of hydromyelia cavities and for internal decompression, and in the section of the posterior roots, etc., will be given in the chapters devoted to the subjects in Part III.

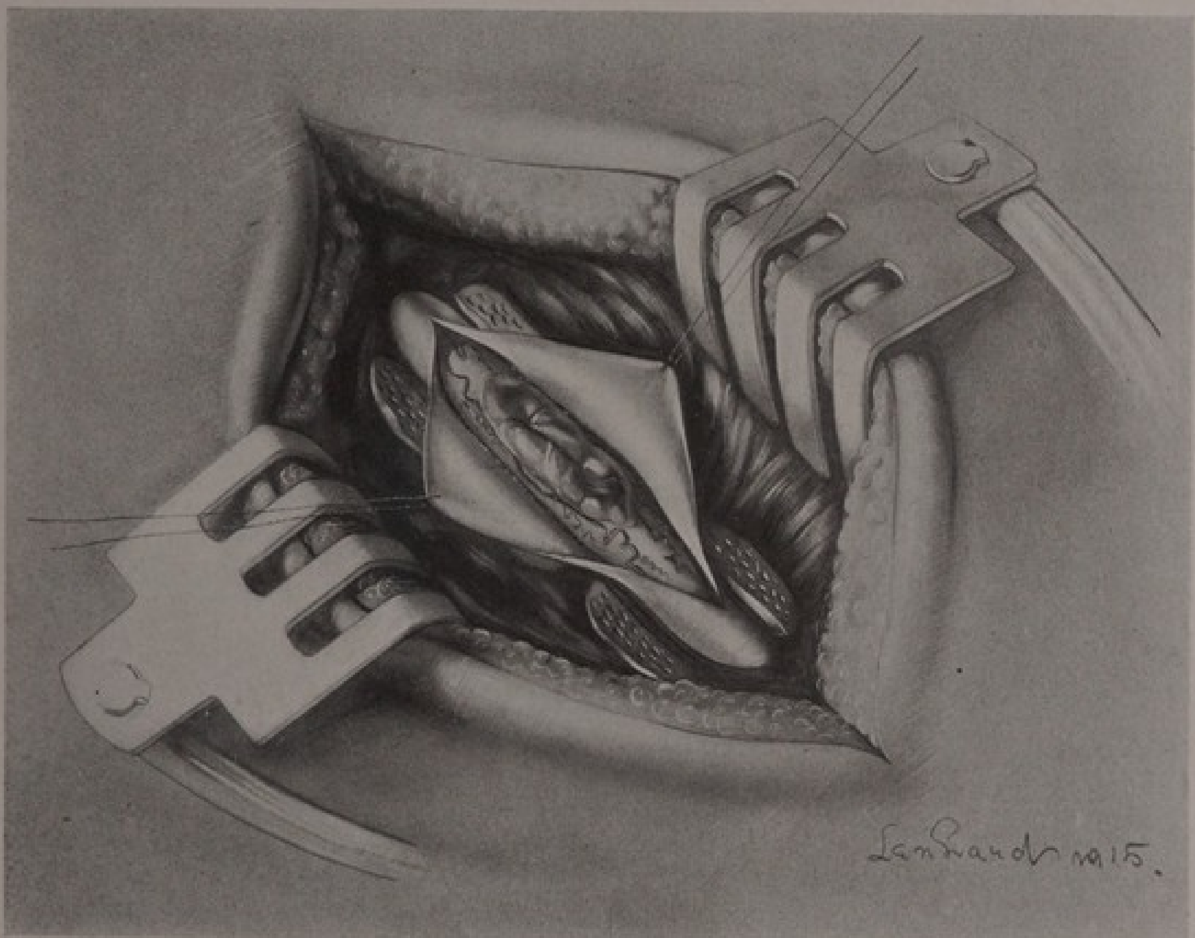


FIG. 78.—Laminectomy. VI. The tumor exposed.

After all oozing within the arachnoid sac has been controlled, the dura should (except where a decompressive operation is done or a growth within the substance of the cord is to be removed in two stages) be closed by means of a running suture of fine silk. The automatic retractor is then removed, the wound washed out with warm saline solution and the muscles united by interrupted sutures of strong catgut. In the cervical and dorsal regions two layers of muscles must be sutured, in the lumbar region three layers of sutures must often be inserted. Care must be taken that the upper and lower ends of the wound are well closed. The edges of the fascia are then united with chromic catgut and the skin closed by interrupted silk sutures. With few exceptions, a laminectomy wound should never be drained; it should always be tightly closed. Finally, a large firmly fitting dressing with adhesive plaster straps and bandage is applied.

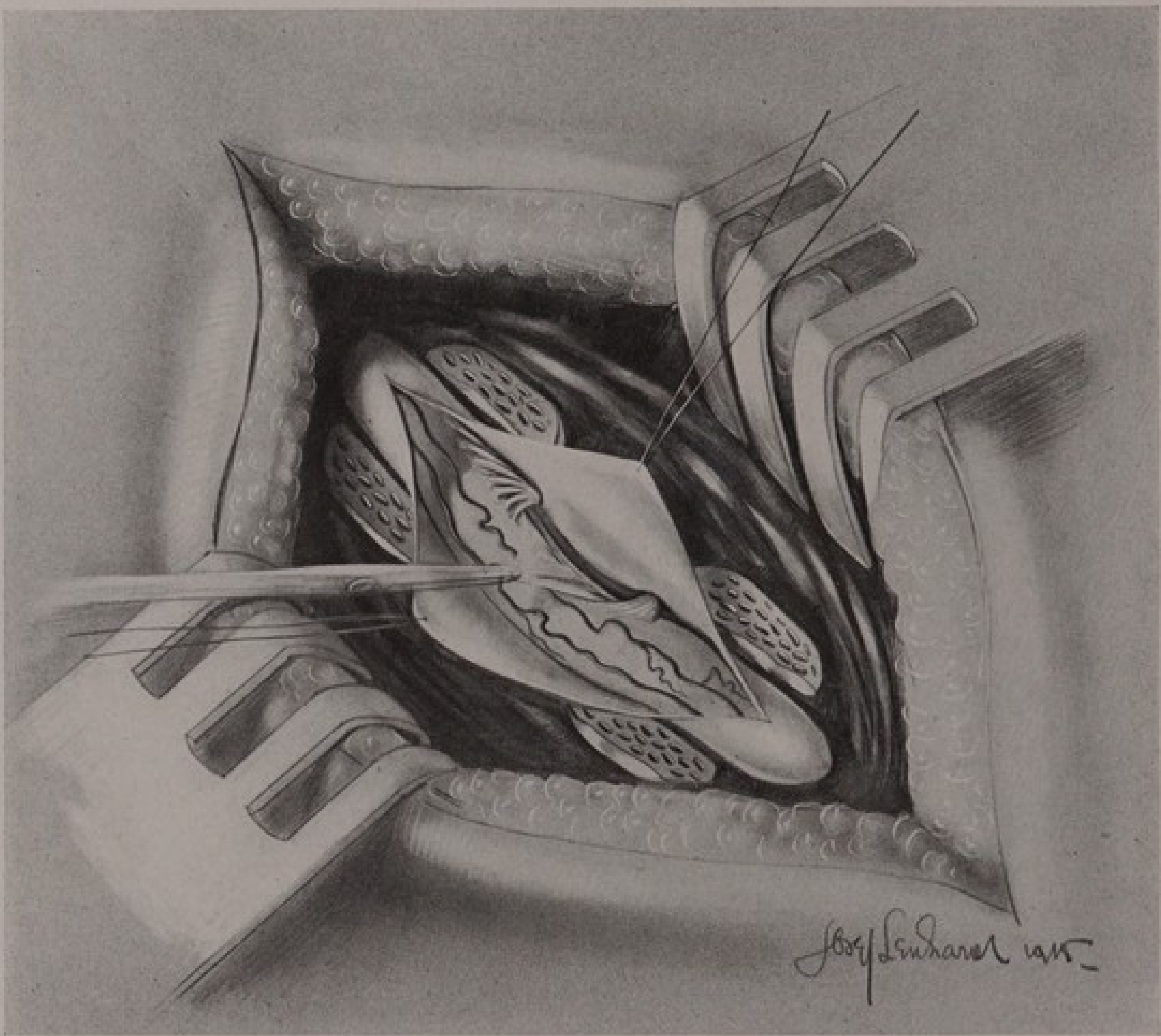


FIG. 79.—The method to be followed in exposing the anterior surface of the cord.

**After Treatment.**—It is unnecessary to fix the spine on a posterior splint unless the laminectomy has been done in the cervical region; in this case a broad well-padded wooden splint is incorporated in the dressings. The patient should, whenever possible, be kept flat on the back for several days, and should be placed on a water or air mattress as soon as he is returned to his bed. Unless there are special indications for it, the dressings should not be disturbed for eight to ten days.

Many of the patients are more or less paralyzed; they can not help themselves, and have to depend upon the care of the nurse.

When the patient is returned to the bed, he should be placed on the back with the head slightly raised on a pillow. If the laminectomy has

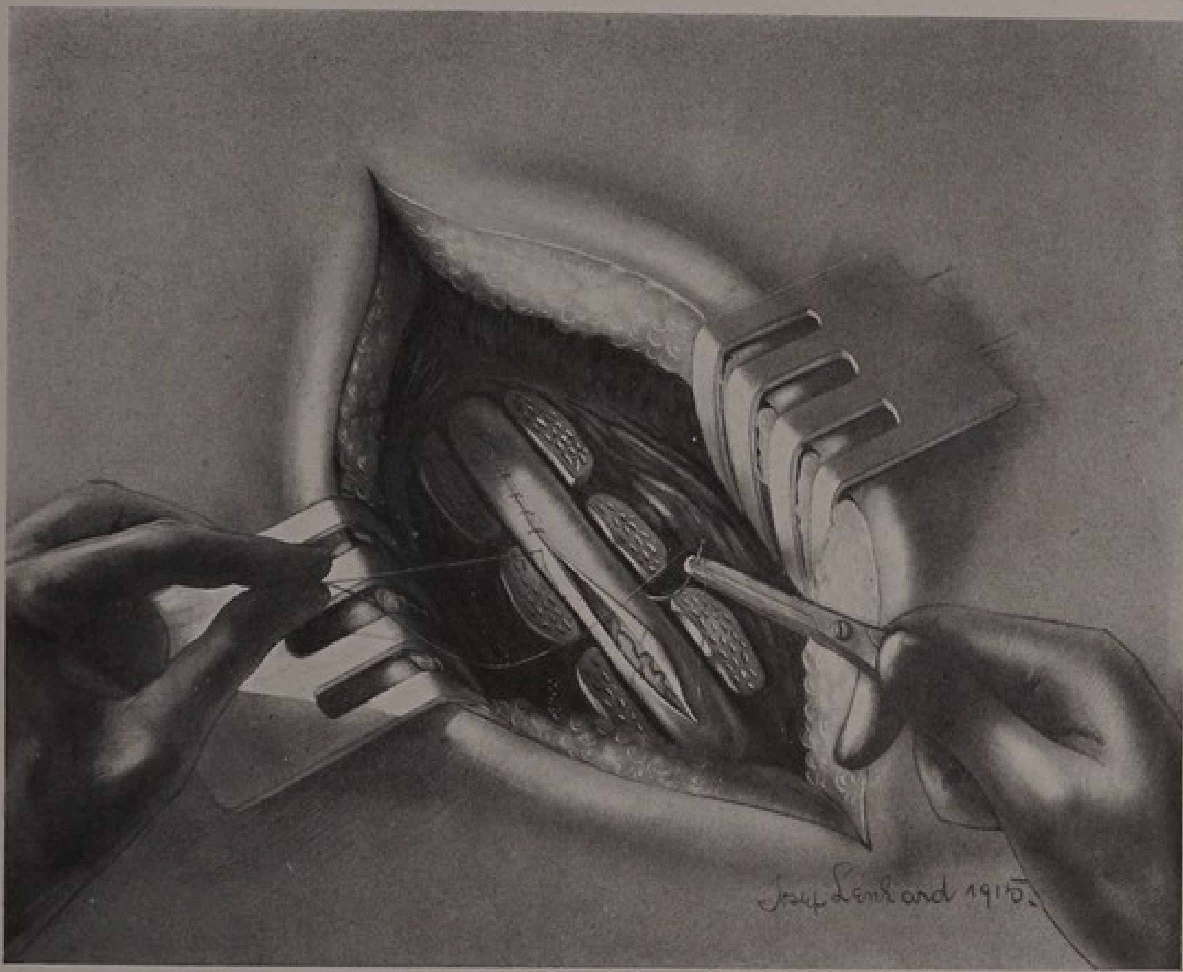


FIG. 80.—Laminectomy. VII. The suture of the dura.

been done in the cervical region, the patient will be more comfortable if his head is supported on each side by a large sand bag. Hot water bags should *not* be used. If hypodermic medication is necessary it should, if possible, be given in a part of the body that is not affected by the disease.

Great care must be taken of the bladder and rectum. Many of the patients have to be catheterized for long periods of time, and even under the most rigid surgical cleanliness a cystitis may develop. The inflammation may remain localized to the bladder, but the danger of secondary involvement of the kidneys is a very great one. Patients who have to be catheterized for many months seldom escape an infection of one or both kidneys. The bladder should never be permitted to become overdistended, but should be emptied by catheter every eight hours or oftener, if necessary. If cystitis develops, the bladder should be frequently washed out with boric acid solution or 1–10,000 solution of nitrate of

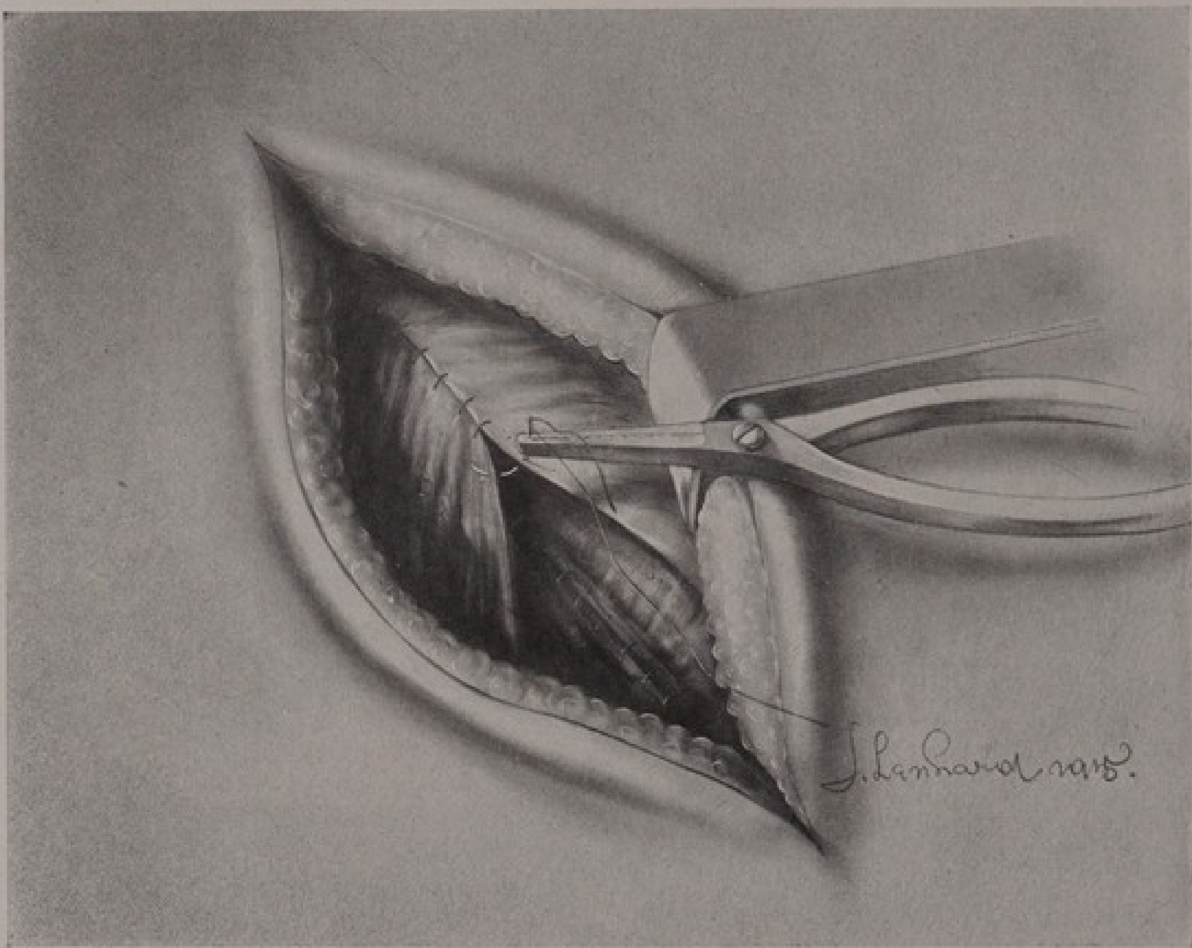


FIG. 81.—Laminectomy. VIII. The suture of the muscles and fascia.

silver. The cystitis will sometimes improve rapidly after a permanent catheter has been introduced.

Two or three days after the operation the patient may be turned on his side, and his position should be frequently changed so as to prevent decubitus.

Constipation is frequent and the bowels are best emptied daily by enemata.

The lower limbs must be supported on pillows. If sensation and power have not been completely lost in the lower extremities, the least movement of the limbs will cause the patient much pain in the back. This is due to contraction of the paravertebral muscles when the patient attempts to move the lower limbs. The pain usually disappears within a few days.

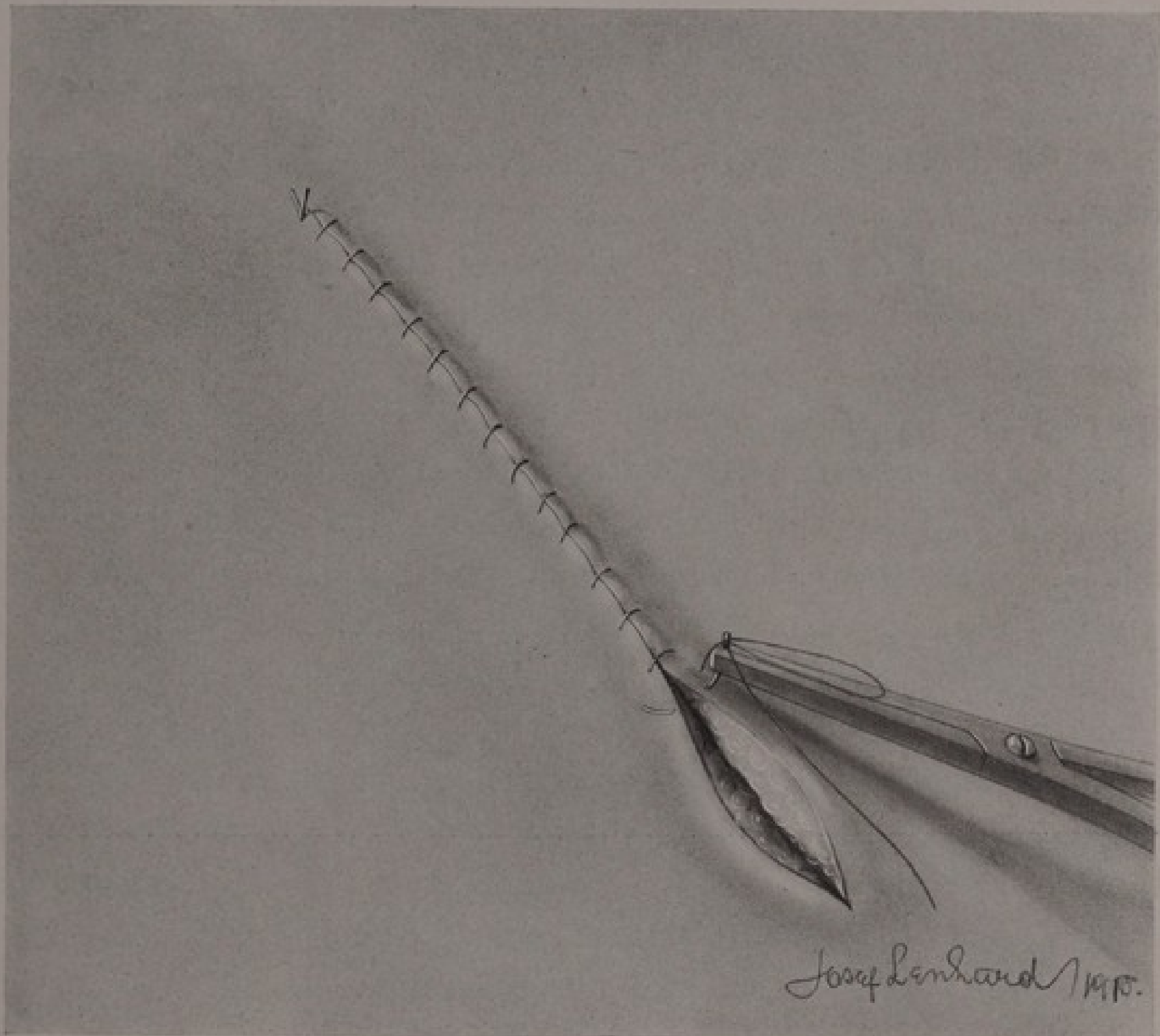


FIG. 82.—Laminectomy. IX. The suture of the skin.

Some of the patients have a rapid pulse (120 to 140) for a few days after the operation. This is especially apt to be the case when the laminectomy has been performed in the cervical region.

A rise of temperature to 102° or 103°F. is very frequent after a spinal operation in the cervical and upper dorsal regions, and occurs most often in the patients in whom the dura has been opened. The temperature usually falls to normal within two or three days. After cervical laminectomy, the temperature may remain several degrees above the normal for a week or more.

The knee jerks are often lost for twelve or twenty-four hours after the operation, and the ankle jerks are often much depressed for several days. These changes are probably connected with changes in the intraspinal pressure due to the loss of cerebrospinal fluid and the entrance of air into the subarachnoid space. They do not occur in those operations in which the dural sac is left unopened.

The patients are usually able to sit up in ten to twelve days after the operation and may be out of bed a few days later. Massage and exercises should be begun early, should be given daily, and should be continued for a long period of time.

**Difficulties and Dangers of the Operation.**—In the cervical and upper dorsal regions the operation of laminectomy is never difficult, and the manipulations necessary for the exposure of the dura should seldom require more than ten to twenty minutes. In the lower dorsal and lumbar regions where the vertebral arches are much thicker and more deeply placed, considerable rongeuring may be necessary before a good exposure of the spinal canal and its contents has been obtained.

*Two-stage operations* are necessary only for the removal of intramedullary growths by the method of extrusion and of growths which are very intimately adherent to the pia mater or to the roots of the cauda equina. In some operations for high cervical tumor, it is advisable to delay the actual removal of the growth so as to allow pressure conditions in the upper cervical cord and in the adjacent medulla oblongata to readjust themselves.

*The So-called Danger from the Sudden Escape of Cerebrospinal Fluid.*—Much has been written regarding the dangers when the dural sac is opened from the sudden escape of cerebrospinal fluid. These dangers are, I think, much overestimated, for I have never observed symptoms when the dura was incised and a large amount of cerebrospinal fluid escaped. When the dural sac is opened high up in the cervical region, however, it is advisable, on account of the proximity of the medulla, to lower the head end of the operating table.

*Hemorrhage in spinal operations* should never be excessive if the precautions of which we have spoken are remembered. If the anterior surface of the dura is to be exposed (as in the removal of a spur of bone due to a vertebral fracture), there may be considerable oozing from the venous plexuses on the posterior surface of the bodies of the vertebræ. This oozing can, however, be controlled by temporary compression with gauze wrung out in hot saline solution.

The surgeon must always be careful to avoid injury to the posterior spinal vessels, as troublesome oozing within the arachnoid sac might otherwise occur.

*Laminectomy in the upper cervical region* is attended with more danger than operations in other parts ofthe spine, on account of the proximity of the medulla and because of the origin of the phrenic nerve from the fourth cervical segment. In these high operations the surgeon and especially the anesthetist should be on the lookout for respiratory disturbances. If they occur, some method of artificial respiration, preferably the intra-tracheal insufflation of air, or air and oxygen, should be at once instituted. The removal of the spines and laminæ is, however, much more easy, because the spaces between the arches of the cervical vertebræ are greater than in any other part of the vertebral column. As the bodies of the cervical vertebræ are small in comparison with the other parts of the spine, the arches have a more important relation to the support of the vertebral column. For this reason, and this is especially the case in young children, as little of each lamina as possible should be removed.

*General Considerations Relative to the After Course of Patients upon Whom a Laminectomy has been Performed.*—If there are no complications from the anesthesia and if wound healing is aseptic, the convalescence of a patient who has undergone a spinal operation should be a very uncomplicated one. For several days the patients complain of much pain in the back, which is made worse by movements of the limbs or head, and anodynes and hypnotics are usually required.

*Bladder Disturbances.*—Even if no bladder disturbances exist before the operation, they are very likely to occur afterward. Usually there is retention of urine for a few days; rarely this persists for several weeks.

When the laminectomy has been done in the lumbosacral region, the retention may be accompanied by a lack of feeling of bladder distention; after an operation in the cervical or dorsal region, the patient will often know when his bladder is distended. When the patient regains control of his bladder, he is at first able to only partly empty the bladder. Unless incontinence existed before the operation, it should rarely occur afterward. If such incontinence does occur, it usually means that some injury has been done to the cord, or that there has been considerable bleeding within the sac of the arachnoid. If the incontinence is due to the latter cause, it will disappear within a few days or weeks; if due to the former, it may persist for months; and if the injury to the cord has caused a more or less complete transverse lesion, it may be permanent.

After the removal of a tumor or other disease of the cauda equina which has caused retention of urine as one of the symptoms, the retention of urine may persist for a number of months. In these patients one can often stimulate the bladder to empty itself by suddenly removing the catheter during catheterization, the patient being told at the same time to attempt to void his urine with the catheter in place.

*Abdominal Distension.*—Abdominal distension may occur after a laminectomy as after any other operation. But it occurs very frequently after a laminectomy in the lower dorsal region. After a spinal operation at this level, a very marked and, to the patient, very distressing abdominal distension often occurs, which can be only partly relieved by cathartics or enemata, and which usually persists for several days. The patients are unable to pass any gas, the abdomen becomes enormously distended, and vomiting occurs, so that, to one who has not seen the condition, the patient seems to present the clinical picture of acute intestinal obstruction. The symptoms, however, usually subside within a few days.

*Leakage of Cerebrospinal Fluid.*—If the dura has been carefully sutured and there have been no wound complications, leakage of cerebrospinal fluid should be of rare occurrence. Even if a two-stage operation has been done and the dura left open at the first sitting, the careful suture of the muscles, fascia and skin should prevent any leakage. If, nevertheless, leakage should occur, the dressings should be changed as often as they are wet, the skin being painted with tincture of iodine each time as soon as the dressings are removed.

**Decompressive Laminectomy.**—That the free opening of the spinal canal and the dura has a very striking influence upon some spinal diseases is now well recognized. What the main effect of the wide opening is we do not know. Bailey and I have shown that surgical exposure of the spinal cord, even in the absence of increased intradural pressure, may and often does affect some change which temporarily or permanently benefits or checks the symptoms of local spinal disease. In the paper referred to we stated tha twe were not in a position to offer a physiologic explanation of the phenomenon, although it was probably connected with the circulation in the cord itself, or a result of the admission into the subarachnoid space of light and air. The term "spinal decompression" was made use of as a convenient means of expression, although Bailey and I realized that in many cases there was no increase of pressure, and that the results reported from the operation were not entirely analogous to the results of cerebral decompression. Since the paper from which the above is quoted was published, we have had occasion to study a number of cases of this kind upon which I have performed laminectomy and, with increasing experience, have seen a large number of very beneficial results from the laminectomy in a great variety of spinal symptoms. We believe, therefore, that the opening of the spinal canal has a profound effect upon the spinal cord, and that it acts beneficially upon some spinal diseases whose nature is as yet not clearly understood and whose pathology is unknown.

We have seen these results in patients who presented the symptoms of a spinal tumor but in whom no tumor and no localized collection of fluid or affection of the meninges was found; in patients with the symptoms and signs of multiple sclerosis with indefinite sensory symptoms; in patients with abnormalities of the spinal vessels, and in syphilitic meningomyelitis in which the usual antisyphilitic treatment had been given for

10

a long time without benefit. In all of these patients there was no increase of intraspinal pressure nor other lesion of an expanding character. In still other patients with chronic inflammatory lesions of the meninges and nerve roots, and in neuritis of the cauda equina, we have observed this same result. Not by any means have all the patients derived benefit from the operation, but the number in which the symptoms were markedly improved or in which the patients were entirely relieved has been relatively large. In many, the relief has lasted for a number of years, so that we may hope that it is permanent.

We have never seen any benefit from operative interference in true myelitic softening of the cord.

When a decompressive laminectomy is performed, the laminæ should always be removed well out to the articular processes, the dura widely incised, and the cerebrospinal fluid allowed to escape freely. The meninges are carefully explored, adhesions, if present, being separated. Then the dura, muscles, fascia and skin should be closed as after any laminectomy.

The beneficial results from decompressive laminectomy where there is an increase of intraspinal pressure (inoperable expanding lesions, irremovable compression of the cord, swelling of the cord due to trauma, etc.) are so well known that they need only be mentioned for the sake of completeness.

**Functions of the Spinal Column after Complete Laminectomy** (Fig. 83).—From the esthetic standpoint, the appearance of the back of a patient who has had a laminectomy performed upon him is very satisfactory. In most cases, excepting for the linear cicatrix, the contour of the back appears almost normal. The mass of the paravertebral muscles and the scar tissue that is formed between the divided laminæ and the skin form a good support for the skin and an excellent protection for the spinal cord beneath.

The free mobility of the spinal column is usually fully recovered. For a number of days after the operation the spine is held very rigid, because of the pain which follows movements of the head, trunk, or extremities. As soon as the pain disappears the patients are able to turn

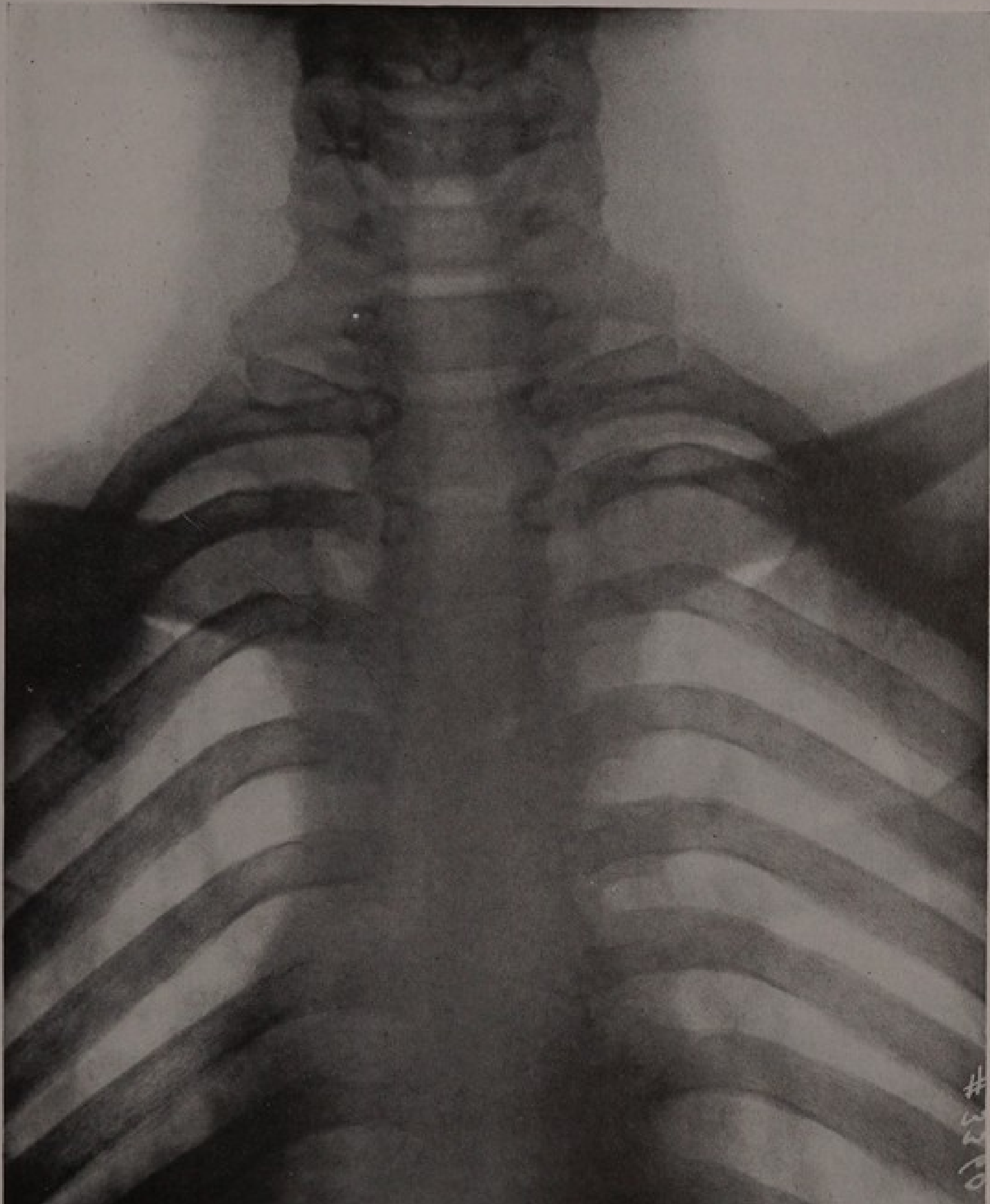


FIG. 83.—X-ray of the spine to show the amount of bone removed in a laminectomy from the sixth cervical to the third dorsal vertebræ.

freely, and within ten to fourteen days they are able to sit up and begin to walk. Considerable stiffness and rigidity of the spine may persist for several months, and this occurs especially after lumbar laminectomy. In most patients, after an operation upon the cervical vertebræ, the mobility of the spine is fully regained within two to three weeks. Some of the patients have a tendency to carry the head somewhat forward, as if there had remained some weakness of the cervical spinal muscles. Massage and exercises may be necessary before the vertebral column regains its normal mobility. Three to six months after a laminectomy has been done the vertebral column will be found as freely movable as the normal, or as it would have been in the individual case if no operation had been performed.

**Mortality of the Operation.**—It is difficult to obtain a satisfactory idea of the mortality of the operation of laminectomy, because the results vary with the affections for which the operations are done. The statistics of different operators vary within wide limits. Spinal surgery can only be successfully performed by those who have a large experience in this special branch of surgery. Oppenheim has reported twenty-five operations performed for him by several surgeons with eight fatalities from the operation. Krause had twenty-eight operations with eight deaths; in a later publication he stated that, exclusive of laminectomy for spinal fracture and cases of myelitis, he had performed forty-five operations with nine deaths. Hildebrand had thirty-five laminectomies with nine deaths; Nonne had thirteen operations with seven deaths; Sick had twenty-one cases and eight deaths.

On the other hand, Horsley reported twenty-four successive cases without fatality, and Oppenheim justly states that the dangers of a laminectomy are small when the operation is done by a surgeon of the experience of Sir Victor Horsley.

The above statistics refer to all the spinal operations performed by the authors quoted, excepting laminectomies for fracture of the spine and the cases in which myelitic softening was found at operation. Including operations for the conditions just mentioned, I have, up to April 1, 1915, performed 120 laminectomies with ten fatalities, and have had no deaths from the operation in eighty-seven successive cases. The following table gives my results:

TABLE OF RESULTS IN 120 LAMINECTOMIES[1]

Total Operative Mortality 8.3 Per Cent.; Excluding Acute Softening and Recent Fractures with Complete Crush of the Cord,[2] 4.2 Per Cent.

| Laminectomy for: | No. of cases | Recovered from operation | Cured or almost cured | Markedly improved[3] | Little or no improvement | Died | Died within one year | Total |
|---|---|---|---|---|---|---|---|---|
| Spina bifida occulta | 2 | 2 | | 2 | | | | 2 |
| Abnormal spinal vessels | 5 | 5 | 2 | 3 | | | | 5 |
| Recent fracture of spine | 3 | 1 | | 1 | | 2 | | 3 |
| Old fracture of spine | 5 | 5 | 2 | 3 | | | | 5 |
| Tumor, extradural, removed | 3 | 3 | 2 | 1 | | | | 3 |
| Tumor, extramedullary, removed | 13 | 13 | 9 | 4 | | | | 13 |
| Tumor, intramedullary, removed | 9 | 8 | 2 | 4 | 2 | 1 | | 9 |
| Tumor, intramedullary, not removed | 7 | 6 | | 2 | 4 | 1 | 3 | 7 |
| Tumor of conus and cauda | 4 | 4 | | 2 | 2 | | 2 | 4 |
| Tumor, multiple sarcoma | 1 | 1 | | | 1 | | 1 | 1 |
| Tumor, sarcoma of vertebræ | 6 | 4 | | 2 | 2 | 2 | 2 | 6 |
| Tumor, metastatic | 2 | 2 | | | 2 | | 2 | 2 |
| Aneurism of spinal vessels | 1 | 1 | | | 1 | | | 1 |
| Exploration | 10 | 10 | | 3 | 7 | | 3 | 10 |
| Exploration, acute softening | 3 | | | | | 3 | | 3 |
| Syringomyelia, hematomyelia | 4 | 4 | | 2 | 2 | | | 4 |
| Neuritis of cauda equina | 5 | 5 | 2 | 3 | | | | 5 |
| Pachymeningitis | 3 | 3 | 1 | 2 | | | | 3 |
| Acute osteomyelitis | 2 | 1 | 1 | | | 1 | | 2 |
| Osteoarthritis | 1 | 1 | 1 | | | | | 1 |
| Spinal decompression | 11 | 11 | 1 | 7 | 3 | | | 11 |
| Spinal decompression, meningo-myelitis | 2 | 2 | | 2 | | | | 2 |
| Division of posterior roots | 17 | 17 | | 13 | 4 | | 3 | 17 |
| Division of anterolateral tracts | 1 | 1 | | 1 | | | 1 | 1 |
| Totals | 120 | 110 | 23 | 57 | 30 | 10 | 17 | 120 |

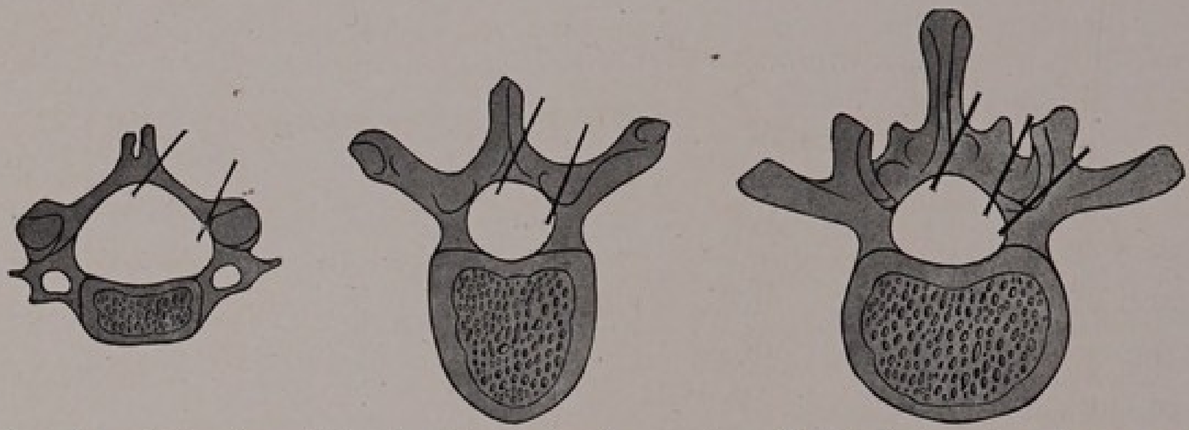
**Hemilaminectomy.**—In this operation the laminæ on one side only are removed, and by this means the spinal canal is opened and the dura exposed. The operation was first proposed by Bonome (1902) and was done by Alessandri in order to extract a bullet from the vertebral column. Hemilaminectomy has been very highly recommended by A. S. Taylor,

[1] There were, in addition, ten secondary laminectomies.

[2] These cases can fairly be excluded in a statement of operative mortality, as the patients died from their disease and not from the operation.

[3] Many of these patients have recovered entirely.

of New York, and it is due to him that the technic of the operation has been most developed. The operation is performed in a similar manner to the complete laminectomy, excepting that the paravertebral muscles



Figs. 84 and 85.—A cervical, a dorsal and a lumbar vertebra. The black lines show the amount of bone removed in a hemilaminectomy.

are separated only on one side and the laminæ removed on that side. The laminæ are removed from their articulating processes to the bases of the spinous processes (Figs. 84 and 85).

The advantages of and objections to hemilaminectomy have been mentioned in another part of this chapter (see page 115).

## CHAPTER XI

### DIVISION OF THE POSTERIOR SPINAL NERVE ROOTS

It is the custom to speak of division of the posterior roots, although in most instances parts of the roots are resected. Regeneration of roots and union of divided roots rarely occur inside of the dura (excepting in the cauda equina), but, whenever possible, it is advisable to resect pieces of the roots.

The operation of rhizotomy or division of the posterior spinal roots was proposed by Dana for the relief of severe neuritic pain, and was first performed by Bennett in 1886 and by Robert Abbe in 1888. Theoretically, Dana's suggestion was a correct one. There should be no more certain method for the relief of pain than the division of the sensory spinal roots. Many operations were soon performed with this purpose in view, and in a comparatively short time a large experience had been collected. Then it was found that very many of the patients who had been operated upon were not relieved of their pain. In spite of extensive root divisions which left no doubt that all sensory impulses from the periphery had been cut off, the pain persisted in many instances.

I have had under my care a patient with severe neuralgia of an amputation stump, in whom I divided intradurally all of the sensory and motor roots to the extremity, but the pain in the stump persisted. Frazier has reported a case of brachial plexus injury in which the sense of pain was not altogether removed from the affected limb even after the division of all of the roots from which the brachial plexus receives its sensory supply.

It is difficult to give an explanation for cases of this kind. In some of the patients an insufficient number of roots were divided; others had acquired the morphine habit, and it was difficult to say whether the persisting symptoms were or were not due to the drug habit. In some instances the pain was supposed to be of central origin. No matter what the explanation for the failures, the fact remains that many patients failed to obtain relief. This made the surgeons cautious in recommending posterior root section for pain, and the procedure has never become popular.

Division of the posterior roots in the treatment of spasticity was first brought practically before the profession by Ottfried Foerster, of Breslau, and it has thereafter been known as "Foerster's operation." The procedure is founded on the following theoretical considerations: Muscle tone is heightened by stimuli from the periphery through the posterior spinal roots to the motor cells of the gray matter of the spinal cord, and is controlled and regulated by inhibitory influences from higher centers through the pyramidal tracts. An increase of muscle tone will, therefore, occur whenever the inhibitory impulses from the brain are cut off by disease or lesion in some part of the pyramidal tract. Theoretically, this increase of tone or spasticity should be diminished if the stimuli from the periphery were excluded by division of the appropriate sensory spinal roots. The observation had been made by others that if a patient with multiple sclerosis developed a disease of the posterior columns and posterior roots (tabes), the spasticity due to the sclerosis would often decrease markedly as the posterior column disease progressed. Foerster correctly concluded that the ensuing relaxation was due to the interference with the centripetal fibers to the reflex centers in the spinal cord.

Posterior root section has been tried for a large number of spastic conditions, mainly, however, for congenital spastic diplegia (Little's disease).

Foerster also suggested that the posterior roots should be divided to control the gastric and intestinal crises of tabes. These visceral crises are produced by the irritation of the sensory sympathetic fibers from the abdominal organs which run in the posterior spinal roots. Some of the crises, however, are due to vagus irritation, and will not be influenced by posterior root division.

## THE INDICATIONS FOR DIVISION OF THE POSTERIOR ROOTS

1. *For Pain.*—As I have already stated, the surgeon should be conservative in his views on root division for painful conditions of the trunk or extremities. I have never seen a good result when the operation was performed for the pain of metastatic malignant disease or arthritis of the vertebræ, no matter how large the number of roots divided. In amputation stump neuralgias and other painful affections of the extremities, in which general treatment and local operations have been unavailing, division of the posterior roots may be tried as a last resort. It is impossible to state beforehand what patients or in what proportion of the cases the operation will be successful, and whether the relief will be temporary or permanent. In traumatic nerve root lesions, where the nerve is compressed by bone or inflammatory products, and in which the pain is localized to the distribution of one or several posterior spinal roots, the intradural or extradural division of the affected root may completely abolish the pain.

It is difficult to understand why nerve root neuralgias can be cured with almost complete certainty by the division of the affected root or roots, while painful conditions due to peripheral disease are so often uninfluenced by the root resection. It may be that the anastomoses of the peripheral nerves have something to do with the failures in so many of the second class of cases.

2. *For Spasticity.*—Posterior root division is indicated in those cases of Little's disease in which the contractures and atrophy of the muscles are not too far advanced. It should be done only after massage, active and passive exercises, and gymnastics have been thoroughly tried out for a year or more. In the very advanced cases of Little's disease, with marked contractures of muscles and ligaments, more can be accomplished by judicious tenotomies and plastic operations upon the muscles and tendons, and by Stoffel's operation (intramuscular division of nerves), than by Foerster's operation.

Some patients have been referred to me for operation in whom very little orthopedic treatment had been tried. In some of these patients

I have seen very great improvement follow regulated massage and exercises. In one man the improvement in the course of six months was so marked that a root division was no longer to be thought of.

On account of the fact that a large amount of post-operative treatment is necessary, for which an intelligent coöperation of the patient is required, the operation should not be done in idiotic or imbecile children.

In spastic conditions of the lower extremities due to an old injury of the cord, a residual lesion after syphilitic or tubercular disease or spinal tumor, in stationary disseminated sclerosis, the operation of posterior root division may be tried. Progressive disease should, however, never be operated upon, for the spasticity is certain to recur. If a patient with disseminated sclerosis is subjected to operation, it should only be done after the disease has remained stationary for one or more years.

3. *For Gastric Crises.*—If the gastric crises are very severe and continuous or frequently recurring, and if the general condition of the patient is good enough for an extensive laminectomy, the division of the sixth to twelfth posterior roots on both sides may be tried. The patient and his friends must, however, always be informed that relief is not certain, and that the laminectomy is always a severe operation for the already exhausted patient. I have been asked, more than once, to operate upon a patient in whom the crises were well controlled by small doses of codein or morphine, and in such a case I have always advised against surgical interference.

**Roots to be Divided.**—In many of the patients in whom posterior root section was performed for the relief of pain, spasticity or the visceral crises of tabes, too few roots were divided, and the failure to relieve could be justly blamed upon the fear of the surgeon that he would cause an anesthesia or an ataxia by the division of a larger number of posterior roots. It is important for the surgeon to understand when he is justified in disregarding Sherrington's law in order to insure the success of the operation, and in which patients he must preserve a sufficient number of posterior roots to avoid marked loss of sensation or ataxia.

1. For the relief of pain, one should always divide a larger number of roots than the number which is known to supply the painful area. Thus Foerster has shown that the sensory supply of the arm is derived not only from the fifth to eighth cervical and first and second dorsal, but also from the third and fourth cervical and the third dorsal. The sensory supply of the lower limbs is derived from the tenth, eleventh and twelfth dorsal as well as the lumbar and sacral roots. Therefore for the relief of inveterate neuralgias of an upper extremity, one must divide at least the fifth, sixth and eighth cervical and first and third dorsal, or the fifth, seventh and eighth cervical and second and third dorsal roots, or some other combination of these roots. One of the reasons why root division for pain in the upper extremities often failed was that all of the roots could not be divided on account of danger of a loss of sensation and an ataxia in the arm and hand. Some sensory disturbances of the fingers may result, even where fewer posterior roots than those I have mentioned above have been divided.

In the lower extremities the division of the eleventh and twelfth dorsal, second, third and fifth lumbar and second sacral may be done.

If the pain is due to an otherwise irremediable lesion of a single posterior nerve root, that root alone should be divided. As I shall mention in connection with the subject of spinal cord tumors, it is often advisable to divide a posterior root which has been long pressed upon by a new-growth, whether or not the tumor is removed at the operation. If this is not done, root pains may persist for months after the removal of the tumor.

2. When posterior roots are to be divided for the relief of a spastic condition of the lower extremities, the physician should make a careful examination of the affected limb or limbs and, before the operation is performed, must determine which are the spastic muscles. The posterior roots should never be cut schematically, but a clear idea of the amount of relaxation that is desired should be obtained. If this is carefully done, the limbs will not be made too ataxic. According to Foerster, the following is the root supply of the muscle groups of the lower extremities.

| | | |
|---|---|---|
| Thigh: | Flexors | L1, L2, L-3, L-4, L-5, S-1 |
| | Iliopsoas | L-1 to L-3 |
| | Sartorius | L-1 to L-3 |
| | Gracilis | L-2 to L-4 |
| | Tensor fasciæ | L-4 to L-5, S-1 |
| | Extensors | L-5 to S-2 |
| | Adductors | L-2 to L-4 |
| | Abductors | L-5 to S-2 |
| | External rotators | L-5 to S-2 |
| | Internal rotators | L-3 to S-2 |
| Leg: | Extensors | L-2 to L-4 |
| | Flexors | L-5 to S-2 |
| Foot: | Dorsal flexors | L-4 to S-1 |
| | Plantar flexors | L-5 to S-2 |

Foerster states that in the severe grades of Little's disease, the division of the second, third and fifth lumbar and second sacral posterior roots has given the best results, but I have made other combinations with satisfaction. As the fourth lumbar has to do with extension of the leg, a movement which is very important for walking, this nerve root should not be divided. In some patients, however, the third lumbar has to do with this extension at the knee, and I always test the third and fourth lumbar roots with the faradic current when they have been exposed, in order to make certain which of the two nerve roots should be preserved.

In the upper extremity it is usually necessary to divide or resect at least the fourth, fifth and eighth, or fifth, sixth and eighth posterior roots. The results in the upper limbs are rarely very satisfactory. Thus I have twice seen incomplete results after division of the fourth, fifth, seventh and eighth cervical and first dorsal roots. The best time to perform the operation in children with Little's disease is between the fourth and the seventh years of life. Before the fourth year the children are poor operative risks, and after the seventh year the connective tissue changes and the atrophies in the muscles and ligaments are so great that the results are seldom very good ones.

3. For the relief of the visceral crises of tabes, the sixth to twelfth dorsal roots must be resected on both sides in spite of the fact that an extensive cutaneous anesthesia will result. The loss of sensation in the thorax and abdomen is not of serious importance, as would be a marked sensory loss in the upper or lower limbs.

**Identification of the Roots.**—There may be some difficulty in identifying the roots that are to be cut, especially after the spines and laminæ have been removed. The relations of the nerve roots to the spinous processes have been shown in the figure on page 34. It is advisable to mark one spinous process at the upper end of the wound with a needle or ligature, and reference to the figure will show what nerve root leaves the dura at that level. In the lumbosacral region the identification of the roots can be made either from the fact that the first sacral root leaves the canal at the level of the fifth lumbar spine or that the first lumbar root lies on the lower "fork" of the dentate ligament (Fig. 14, page 32). Electrical stimulation of the anterior roots is sometimes necessary before the roots can be identified.

**Operative Methods.**—When posterior roots are to be divided for painful affections in the distribution of one or more nerve roots, the surgeon must remove the spines and laminæ required for the exposure of the roots at the level where they leave the dural sac. In the cervical and dorsal regions there is never any difficulty in distinguishing between the anterior and posterior roots. The posterior root lies dorsal to the dentate ligament and is only joined by the anterior root near the dural opening. As soon as the dura has been incised, the edges are retracted by means of ligatures or mosquito forceps until the nerves are exposed near the dural openings. By traction on the dura, the cord is raised up and the dura rolls out exposing the openings in it. In the cervical region the operator must make sure that he divides all of the root bundles which lie posterior to the dentate ligament. After the root has been raised up on a strabismus hook, it is grasped with mosquito forceps, divided near the dural opening and then 1 to 2 cm. of the root itself is excised.

When the operation is done for Little's disease or other spastic condition of the lower extremities, the twelfth dorsal and all of the lumbar spines and laminæ must be removed on both sides. If the nerve roots have to be divided only on one side of the cord, a hemilaminectomy may be done, but it is simpler and easier to perform a bilateral laminectomy. The incision extends from the eleventh dorsal spine to the upper part of the sacrum. After the spines and laminæ have been removed and the

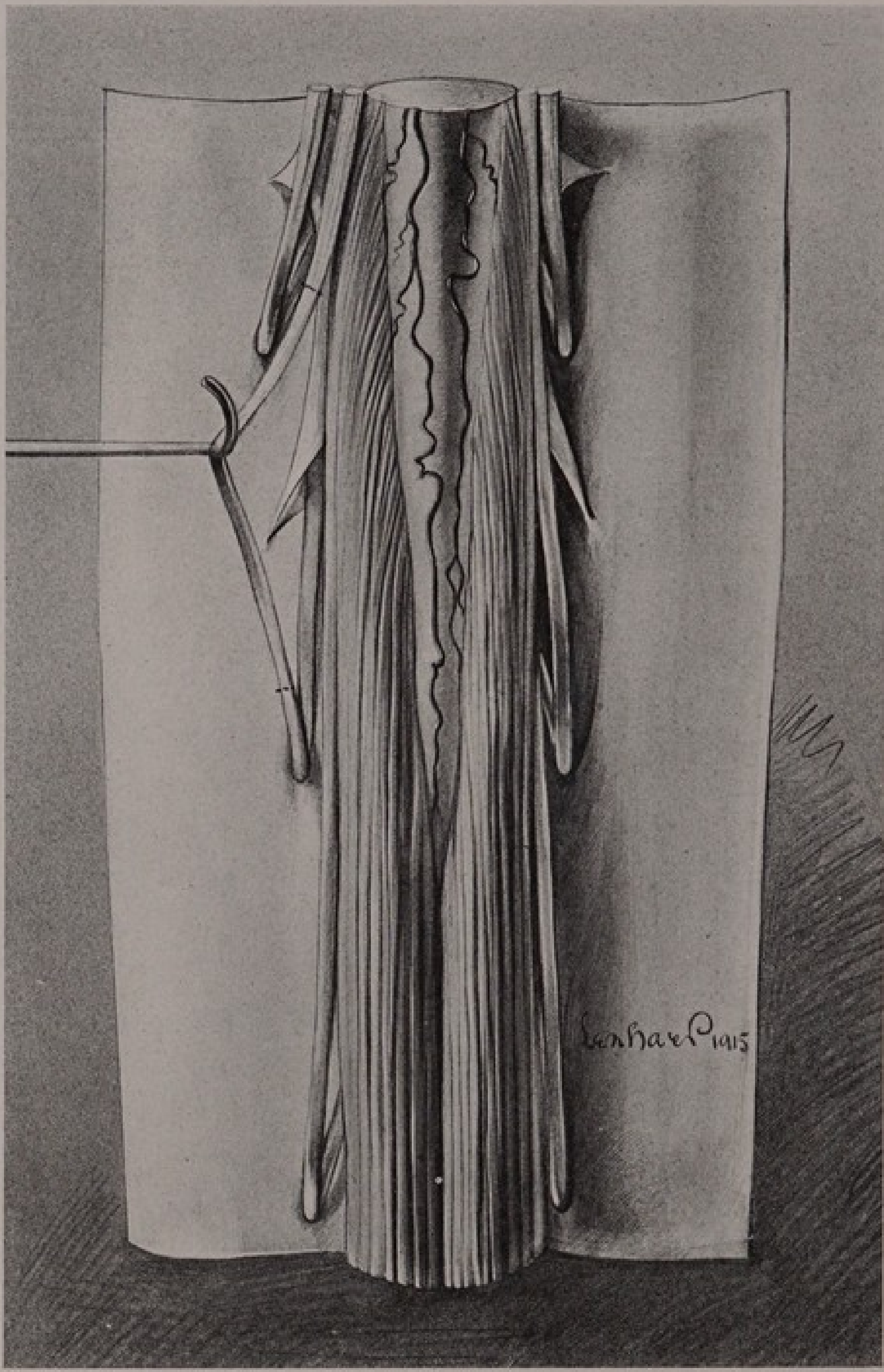


FIG. 86.—Resection of the posterior spinal roots, to show the method used in raising the sensory from the motor root, and the amount of nerve to be excised. ×2.

thick ligamenta subflava have been excised, the dura is incised and the dural edges are retracted in the usual manner. The conus and cauda equina (Fig. 12) are exposed and the first lumbar root identified in the manner above described. The fourth and fifth lumbar and the first sacral roots are much larger than the second sacral or the upper lumbar roots.

The posterior is usually larger than the anterior root and lies behind and to the outer side of it. In order to free the posterior root, the entire nerve is first raised up on a strabismus hook. The line of separation between the motor and the sensory roots is usually found without difficulty. The sensory root is now isolated upon a second strabismus hook, is grasped near the dural opening with small mosquito forceps (Fig. 86) and divided as near to the dural opening as possible. The stump is then raised up and 1 to 2 cm. resected. After the posterior roots of one side have been divided in this manner, the same procedure is carried out on the other side.

Sometimes a large vein accompanies one or other posterior root (most often the third lumbar), and the division of the vessel with the nerve root may cause troublesome bleeding. The vein should either be isolated and retracted, or it should be ligated with fine silk before the root is resected.

After the intradural manipulations have been concluded, the dura, muscles, fascia and skin are sutured in the usual manner.

At their origin from the conus the lumbar and sacral roots lie close together, and if the roots could be identified in this situation, only two or three vertebral arches (twelfth dorsal, first and second lumbar) would have to be removed. Attempts have been made to identify the nerve roots at the conus instead of at their foramina of exit from the dural sac (Wilms and Kolb, Elsberg). These efforts have not given very satisfactory results, because in most instances the nerve roots can not be distinguished from each other with certainty. Therefore the operator can not be absolutely sure that he is dividing the roots desired. Occasionally, however, if all of the posterior roots are raised up on a probe, the nerves can be distinguished from each other.

In performing a posterior root section for spasticity of the lower extremities I generally expose the conus first by removal of the arches of the twelfth dorsal and first lumbar vertebræ. The first lumbar posterior root is then identified by its anatomical relation to the "fork" of the dentate ligament upon which it lies (Fig. 14, page 32). A small slightly bent probe is then passed under the roots of the cauda equina on one side and the roots are raised up on the probe. If the roots can be distinguished from each other it will be easy to identify and divide the roots desired by counting from the first lumbar root. If the roots can not be identified, then the arches of the lower four lumbar vertebræ and part of the sacrum are removed, and the nerves cut at their foramina of exit.

Guleke has recommended that the roots be cut extradurally, the dural sac being drawn to one side and the posterior sensory root being freed from the motor root and divided or resected. There is rarely an advantage in Guleke's operation and, especially in stout and muscular individuals, there are a number of disadvantages in the method. Guleke speaks of the dangers incident upon the opening of the dural sac, but I think he much exaggerates the dangers. If the dura is carefully sutured, cerebrospinal leakage should practically never occur. The exposure of the nerves outside of the dura sometimes causes much troublesome oozing of blood. It may be almost impossible to separate the sensory from the motor part of the nerve root, so that some authors have advised that both sensory and motor roots should be divided. Intradural root resection or division is, I think, always preferable, excepting in the rare cases in which only one root has to be exposed and divided.

The division of the sixth to twelfth posterior nerve roots for the gastric crises of tabes requires an extensive laminectomy—six to eight vertebral arches have to be removed. The isolation and division of the roots is easily accomplished.

**After Treatment.**—The after treatment of patients who have had a laminectomy and division of posterior roots for a painful affection or for the visceral crises of tabes does not differ from that after a laminectomy for any other disease. When the root section is performed for a spastic condition, the limb or limbs, if they are sufficiently relaxed, should be bandaged upon a straight well-padded splint. A prolonged and carefully managed after treatment is necessary after posterior root division for Little's disease or other spastic condition. Massage and active and passive exercises must be continued for one or for several years, and tenotomies and plastic operations on the tendons are often required. Foerster has described most ingenious devices for stretching the muscles and for training the children. In addition to massage and passive movements, he has described chairs, to which are attached movable parts for stretching the limbs and for holding them in the desired positions. In his publications he enumerates a number of methods for teaching the patients to walk. The surgeon who desires to obtain as good results as possible must not fail to read Foerster's papers and to make use of the ingenious devices which he describes. The importance of the after treatment is very great, and but little permanent result can be expected unless the orthopedic treatment is persistently and conscientiously carried out. This has led some critics to declare that it was their belief that with the same amount of after treatment, many patients would show the same amount of improvement without the posterior root section. This, I believe, to be incorrect.

**Results.**—The following tables from Foerster (Surgery, Gynecology and Obstetrics, 1913, XVI, 463) give the results of the operation of division of the posterior roots in a large number of cases which he collected from the literature.

I. Root Section for the Relief of Pain:

44 cases—6 deaths; successful 12, unsuccessful 23, results unknown 3.

| | |
|---|---|
| Cervical roots | 22 |
| Thoracic roots | 11 |
| Lumbar and sacral roots | 11 |

II. Root Section for the Relief of Gastric Crises:

64 cases—6 deaths; successful 56, unsuccessful 2, no relapse 29, considerable improvement 18, small improvement 9.

III. Root Resection for the Relief of Spasticity:

159 cases—14 deaths.

88 cases of congenital spastic paraplegia, 6 deaths.

3 cases of hydrocephalus, 2 deaths.

8 cases of infantile spastic paraplegia.

4 cases of traumatic spinal spastic paraplegia.

1 case of spinal tumor.

1 case of Pott's disease.

6 cases of syphilitic spinal spastic paraplegia.

11 cases of disseminated sclerosis, 4 deaths.

23 cases of spastic arm paralysis, 2 deaths.

The operative results in the hands of single surgeons have been better than those cited in the above tables. Kuttner lost only two patients of thirty-two operated upon; Eiselsberg had no deaths among twelve cases; I have performed root section twenty-two times without any fatality.

Aside from the immediate operative mortality, the question that interests us regards the final results in the patients. It is difficult to cite statistics on this subject. There is no doubt that suitable cases of spastic paraplegia can be much improved by division of the posterior roots. Patients that were hopelessly bedridden can, by means of root section and thorough orthopedic treatment, be put on their feet again. The results in the upper extremities are not good, only few patients are much improved, and the operation should be tried only in the most favorable cases.

In the lower extremities the results are often very satisfactory, and I have seen a number of patients who had been bedridden for long periods regain control over their lower limbs so that they were able to walk without assistance. In every patient in whom a root resection for Little's disease has been performed, a certain amount of ataxia will follow. This ataxia will improve with the development of the muscles. I have gained the impression that one can never obtain the desired amount of relaxation without some ataxia, and therefore slight ataxia is an evidence that a sufficient number of roots have been divided or resected.

# CHAPTER XII

## DIVISION OF THE ANTEROLATERAL TRACTS FOR PAIN. THE TECHNIC OF ASPIRATION AND INCISION OF THE CORD

### DIVISION OF THE ANTEROLATERAL TRACTS OF THE CORD FOR PAIN

In 1912 Spiller and Martin published a paper on "The Treatment of Persistent Pain of Organic Origin in the Lower Parts of the Body by Division of the Anterolateral Columns of the Cord," and proposed a new and most ingenious method of treatment. As we have seen in the preceding chapter, division of the posterior spinal roots in metastatic spinal disease or in irremovable growths in the lower extremities associated with severe pain rarely gives relief. The patients may remain alive for

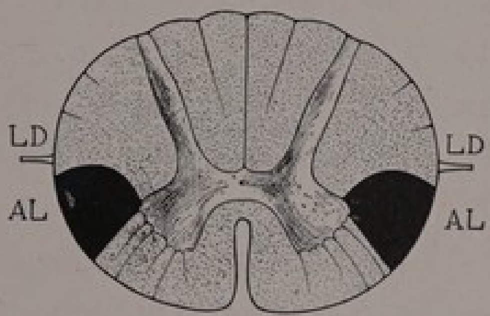



FIG. 87.—Cross section of the cord to show the anterolateral tracts. AL, anterolateral tracts; LD, dentate ligament.

several years. Drugs soon lose their effect, and the suffering is so great that the serious proposition has been more than once made to divide the spinal cord entirely across, above the level of the disease.

Spiller and Martin proposed to divide the anterolateral tracts (Fig. 87) (in which run the fibers for pain and temperature sensation) in the dorsal region. Their patient had a non-removable malignant tumor which involved the lower part of the spinal cord on the left side and which caused the patient great suffering. After two years, Martin performed a laminectomy, removing the sixth, seventh and eighth dorsal arches. The spinal cord was exposed and the anterolateral tracts on both sides were divided. The patient was entirely relieved of his pain. Since that time the operation has been performed a number of times among others by Beer, by Foerster and by myself, and it must be considered as a valuable method in this desperate class of cases.

**Technic of the Operation.**—The surgeon must inform himself of the exact location and size of the anterolateral tracts. In general, they lie between the attachment of the dentate ligament and the origin of the anterior nerve roots, and are about 2 to 3 mm. in width. It is advisable to divide the tracts in the middorsal region unless the disease extends to a higher level of the cord. If the pain is only on one side of the body, the anterolateral column of the opposite side of the cord must be divided, but in most instances it will be necessary to cut the tracts of both sides.

The cord is exposed in the usual manner by removing the spines and laminæ of two vertebræ and opening the dura. A slip of the dentate ligament is then grasped with forceps, cut free from the dura, and the cord raised and rotated by means of traction. A small von Graefe knife, with its cutting edge pointed outward, is carefully introduced into the cord just in front of the dentate ligament to a depth of about 2 or 2½ mm. and brought out just behind the line of origin of the anterior roots. The cord tissue is then cut outward (Fig. 88). Great care must be taken that the knife is never deeper than about 2 mm. from the surface, so that the pyramidal tract is not invaded. After the anterolateral tract on one side has been cut, a similar procedure is carried out on the other side of the cord. It is advisable to make the incision of the cord at the level of the divided slip of the dentate ligament so as to avoid injury to the adjacent nerve roots. The dura, muscles, fascia and skin are then sutured in the usual manner.

If the operation has been correctly done, the pain should be entirely relieved, and if both columns have been divided, there should be a complete loss of pain and temperature sense below the level of the lesion. If one anterolateral column has been cut, the loss of pain and temperature sense should occur on the opposite (the affected) side of the body. If the operation is correctly done, without injury to other fiber tracts, the patients present no symptoms aside from the sensory loss described above. After the patient has recovered from the operation he must be warned

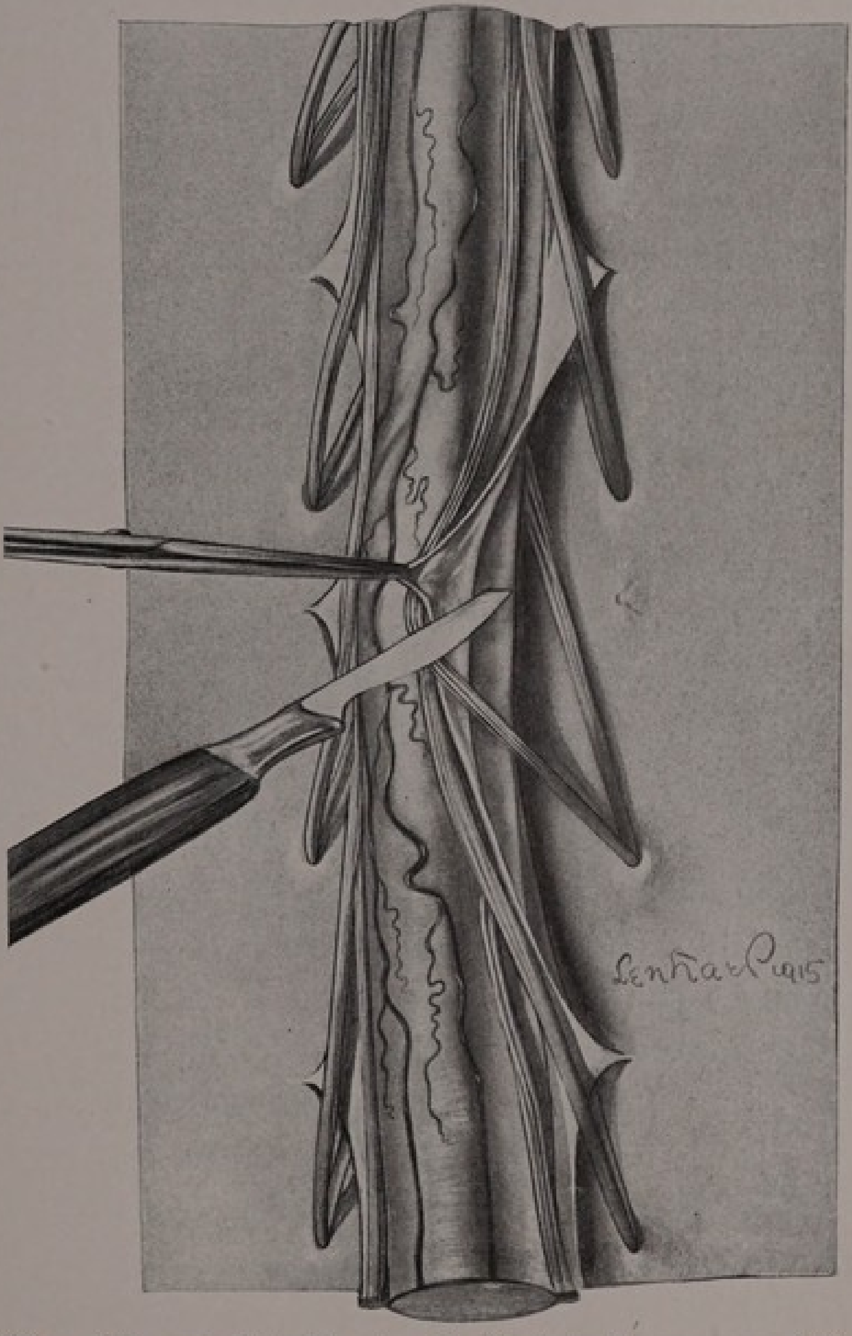


FIG. 88.—Division of the anterolateral tracts. To illustrate the exposure of the anterolateral tract and the direction in which the knife is introduced. × 2

that the feeling for pain and for temperature has been lost, and that great care must be taken not to burn himself.

The operation is a new one and further experience will have to demonstrate its usefulness and its limitations.

## THE TECHNIC OF ASPIRATION AND INCISION OF THE CORD

The cord can be punctured with a needle with entire safety, provided that only the finest aspirating needle is used and care is taken not to injure even the smallest vessels which enter the cord through the posterior median septum or which run in the pia mater. In doing the aspiration, it is advisable to make the puncture near but not through the posterior median septum. The cord must be carefully steadied, as the pia offers some resistance to the entering needle. A slip of the dentate ligament is grasped on each side with fine mosquito forceps and held in place. Extreme care must be taken that the direction of the needle is held constant. Needless to add, the cord must never be grasped with an instrument or with the fingers.

If clear fluid is obtained by aspiration, a small incision a few millimeters in length is made in one posterior column into the cavity. In the chapter on the removal of intramedullary growths (see page 271) I have described the instruments that must be used and the method to be followed. The edges of the incision usually separate somewhat, so that the opening in the cord will remain patent, and the fluid will drain into the subarachnoid space. If necessary, several incisions at different levels may be made. If the cavity is found to contain fluid blood, it must be emptied by careful aspiration after the incision in the cord has been made. If the cavity is connected with the central canal of the cord, the surgeon may be able to see the openings of the central canal in the wall of the cyst cavity. Clotted blood must be very carefully removed with fine forceps, the clot being grasped with the forceps and gently withdrawn from its bed in the cord.

In the case of spinal gliosis, the incision may have to be extended until it is several centimeters in length. The edges of the cord generally become everted, so that an internal decompression of the cord is obtained.

It is hardly necessary to emphasize the fact that an incision in the cord in any of the diseases I am speaking of should only be made after the most careful consideration of its advisability, and should only be performed by a surgeon who is experienced in this line of work. The utmost care is necessary in order to cause no serious lesion, and the very delicate procedure must be accomplished without the minutest bleeding.

It is true that an incision of the cord must be considered a serious surgical interference; injury to nerve tissue should be avoided whenever possible. The spinal cord is more delicate than most parts of the brain, because many important fibers are crowded together in a small space.

In Chapter XVII I have described the part of the cord into which an incision can be made which will injure the minimum amount of nerve fibers and cause very few, if any, symptoms. In that chapter I have also shown that the incision of the cord for the removal of localized intramedullary tumors is now placed on a firm foundation. Further, Allen has demonstrated by his experiments that an incision can be made in the spinal cord without causing any but temporary symptoms, and he has recommended that in fractures and dislocations of the vertebræ with contusion of the cord the swollen and edematous cord should be incised.

What surgeon would hesitate to incise the brain tissue in order to drain a cyst or abscess, or to remove a subcortical tumor?

Under the proper precautions, therefore, and with the correct indications, there is every justification for the incision of the spinal cord in some pathological conditions such as hematomyelia, syringomyelia (see Chapter XVIII), in some intramedullary growths of the cord, etc.

# CHAPTER XIII

## THE INDICATIONS FOR AND CONTRAINDICATIONS TO LAMINECTOMY

The indications for the opening of the spinal canal will depend upon the diagnosis that has been made. The small amount of danger from the operation and the beneficial results observed in a large number of spinal operations where nothing removable was found, and finally the uncertainty of diagnosis in some patients, have led us more and more often to recommend exploratory laminectomy.

Notwithstanding this viewpoint, however, a laminectomy should never be advised or performed until after the questions of diagnosis, of dangers, and of results to be hoped for or expected have been carefully weighed.

The operation of laminectomy should be performed only by the surgeon who, by anatomical studies of the vertebral column and spinal cord, and by dissections on the cadaver, has gained special experience for this line of work. When performed by the experienced surgeon, the dangers of the operation should be very small.

On account of the prolonged course of many spinal diseases, operative interference should rarely be attempted in the very old or very feeble, although it is sometimes surprising how well these patients will stand the operation. In renal and cardiac disease and in diabetes, the contraindications to an operation upon the spine are the same as in surgical interventions in other parts of the body. As I have mentioned in another chapter, the laminectomy can be done under local or under spinal anesthesia.

If the spinal disease is in the cervical region and there are marked symptoms of interference with respiration or with the heart's action, it is better to delay the operation until the pulse and the breathing have improved, or to operate under local anesthesia. If a patient with cervical disease has high temperatures and no other than the local cause can be found to explain the fever, it is often advisable to delay the operative interference, because the fever may be due to a rapid ascending softening of the cord.

In recent fractures of the vertebræ with injury to the cord, laminectomy should be performed only when the patient's general condition is sufficiently good and when the symptoms make it clear that the spinal cord has not been entirely crushed at the level of the injury. To operate upon a patient with a spinal fracture who has the symptoms of a complete crushing of the cord (excepting in the region of the cauda equina) is not only useless, but is sure to throw discredit upon a surgical procedure which is most valuable in the proper cases. If the injury has occurred in the region of the cauda equina, the spinal canal should be opened as soon as the patient's general condition permits. There seems to be little doubt that the nerves of the cauda are capable of regeneration; if they are pressed upon by dislocated bone, this pressure should be relieved; if the nerves have been divided by the trauma, the ends should be united by suture.

If the symptoms indicate that all of the cord functions have not been lost, if some sensation and motor power persist, if some of the reflexes, knee jerks or ankle jerks, etc., are still present, a laminectomy should be performed as soon as possible. Root pains may follow a spinal fracture with the symptoms of a transverse lesion of the cord; they may be so severe that a laminectomy for their relief may be required. Root pains are, however, unusual with transverse crushing of the cord.

In old fractures of the spine with persistent symptoms the results of X-ray examination may indicate that there is pressure of bone on the cord which should be removed. In some cases the patients suffer for years from root pains due to meningeal adhesions or to pressure by bone, and these patients can be entirely relieved of their pain by separation of adhesions and division of the affected nerve roots, together with a free removal of spines and laminæ so that the beneficial effects of the decompression are also obtained.

When the symptoms and signs presented by a patient are those of an extramedullary disease which is gradually advancing, unless the diagnosis of metastatic disease in the vertebral column or advanced Pott's disease is certain, a laminectomy is always indicated. Even if the symptoms are irregular and indefinite, and the sensory level symptoms poorly defined, the operation is justified.

If the diagnosis of extramedullary tumor has once been made, the operation should not be delayed. It is just as incorrect to allow a patient with a suspected spinal tumor to become paraplegic, as to permit an individual with a brain tumor to become almost blind before surgical interference is instituted. If a patient has once become paralyzed, the recovery from the symptoms will require a much longer time and, in spite of the successful removal of the newgrowth, some loss of function may be permanent.

On the other hand, a long-standing paraplegia is no contraindication to the operation, for after the removal of an extramedullary tumor which had caused a complete paraplegia for four years, I have seen considerable recovery of motor and sensory power. Even though the damage to the cord is an irreparable one so that the loss of function will persist, the removal of the compressing newgrowth may be followed by the healing of trophic ulcers and the improvement of bladder and rectal symptoms.

I believe that every intramedullary tumor with level symptoms should be subjected to an exploratory operation; in not a few of the cases the tumor can be removed, and in others great improvement may follow the operation, both from the decompression and from the effect of partial extrusion of an intramedullary infiltrating tumor. Tubercular disease in the cord substance may form well-localized and encapsulated masses which can be removed from the substance of the cord with most satisfactory results.

In some cases of syringomyelia with very marked focal symptoms, laminectomy and decompressive incision of the cord are justified, and the same is true of cases of localized cavity formation in the cord.

In these patients, however, there must be definite level signs, as an evidence of a localized process which is causing an increase of intramedullary pressure.

Localized diseases of the meninges, pachymeningitis, leptomeningitis, even of syphilitic origin, should be treated by laminectomy if the anti-syphilitic treatment has been thoroughly tried and the disease is nevertheless steadily advancing. Here, again, the surgeon must find his indications from the signs and symptoms of localized cord pressure.

That Pott's disease with compression of the cord by bone or by collections of pus may demand opening of the spinal canal is a subject upon which there is general agreement.

The majority of cases of tubercular spondylitis require orthopedic treatment (rest, immobilization, extension), and surgical interference to relieve spinal cord symptoms should only be tried after all other therapeutic methods have been exhausted. The patients with marked spastic symptoms as evidence of cord compression are more favorable cases for laminectomy than those in whom paralytic phenomena predominate. There are cases of tuberculosis of the spine, however, in which the paralysis occurs very rapidly and in which an intravertebral abscess or a sudden pressure upon the cord by a sequestrum or by dislocated vertebræ is more probable. If the general condition of the patient is not too poor, a decompressive laminectomy is indicated without delay.

Laminectomy is also frequently required for resection of the posterior nerve roots in spastic affections of the extremities (Foerster's operation), or for the division of the anterolateral tracts (Spiller and Martin's operation) for the relief of painful conditions of the trunk and extremities.

The subject of posterior root section for pain and for the gastric crises of tabes dorsalis has been considered in detail in the chapter devoted to this subject. The surgeon must be very conservative in making his indication for operative interference in these patients, and the possibility of a psychic factor or of the influence of morphine, to which so many of these patients have become addicted, must be carefully considered.

True softening of the cord of infectious origin should never be operated upon. In the cases in which the operation has been performed under a wrong diagnosis, the progress of the disease was often accelerated after the surgical interference. These patients are usually made worse by the operation and will succumb more quickly to their disease.

If a softening of the cord is met with, the cord should be palpated as little as possible, and the operation should be rapidly concluded. In cervical myelitis the exposure of the cord seems to favor an advance of the disease in an upward direction, and symptoms of an involvement of the medulla are very apt to appear within twenty-four to forty-eight hours of the operation. At lower levels, laminectomy and opening of the dura seem likewise to exert an unfavorable influence upon the cord disease. The improvements in our diagnostic acumen, however, should make mistakes in diagnosis very rare.

A spinal operation may finally be required in some cases of arthritis or spondylitis on account of compression of the nerve roots or the cord by new-formed bone, in many cases of spina bifida, and in abnormalities of the spinal blood vessels.

With the uncertainties in diagnosis, with our still limited knowledge of the pathology of the spinal cord, any focal disease which has been slowly progressing at a constant level should be operated upon. Every local spinal disease of several years' duration, whose nature is not clear, demands an exploratory operation, unless the diagnosis of progressive degenerative disease of the cord itself can be made with certainty. Decompressive laminectomy is justifiable, and often indicated, in some cases of multiple sclerosis and in many cases of chronic meningo-myelitis and caudal neuritis.

# PART III

# THE SURGICAL DISEASES OF THE SPINAL CORD AND MEMBRANES, AND THEIR TREATMENT

## CHAPTER XIV

### SPINA BIFIDA. SPINA BIFIDA OCCULTA

Spina bifida is a congenital abnormality of development in which there is a defect or cleft in one of the neural arches with a protrusion through the opening of spinal membranes without or with nerve roots and cord tissue. In very rare cases the cleft is in the body of one or of several vertebræ and the protrusion occurs anteriorly. This anterior spina bifida has little or no practical surgical interest.

The arrest of development usually affects all of the tissues of the back, and extends over one or two or a large number of vertebræ. In rare instances there has been no bony defect, but a prolapse of the membranes has occurred through an opening or defect in the ligamentous structures. Usually, however, part of the arches of several vertebræ are wanting, together with part of the dura. If the cord, in its development, has formed a central canal, the pial and arachnoid sacs are usually complete and form part of the wall of the protrusion.

To understand the varieties of spina bifida, a good knowledge of the development of the spinal cord and vertebral column is necessary. As we are mainly interested in this condition on account of the spinal cord lesions, only a general idea of the development of these parts can be given.

In the embryo the medullary groove is formed by two longitudinal ridges of epiblast. These ridges finally unite to form the spinal cord and central canal within, and the skin on the outside. Between these epiblastic ridges others, derived from the mesoblast, arise, which finally unite over the inner layer of the epiblast (spinal cord) to form the spinal membranes, vertebræ, muscles and ligamentous structures, and are covered in turn by the outer layer of the epiblast which forms the skin (Fig. 89). Spina bifida is due to an arrest of development in parts of these layers before complete fusion has occurred; it may be due to a lack of development of the mesoblast or of the epiblast, or more often of both of these layers. Fusion of the layers of the epiblast and mesoblast occurs latest in the lower part of the spine, and spina bifida is most common in this location. It occurs, however, in all parts of the spinal column, although it is relatively rare in the cervical and upper dorsal regions.

There is much confusion in the nomenclature of the different varieties

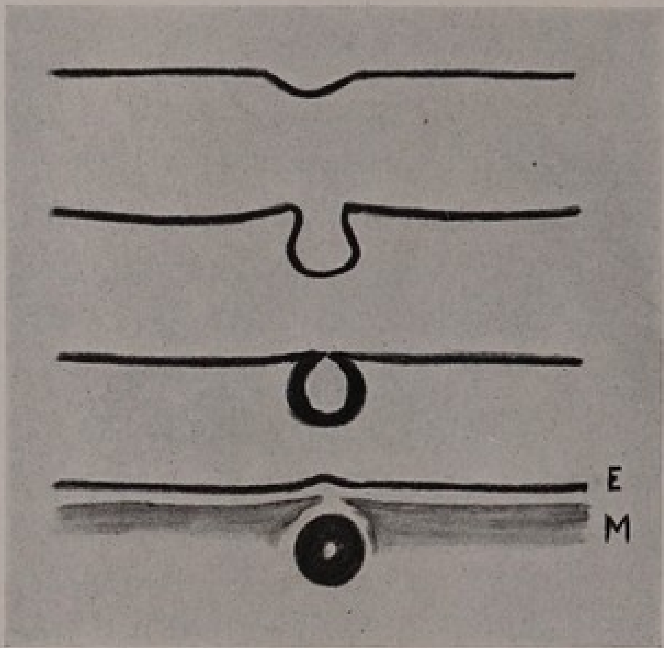



FIG. 89.—The development of the spinal cord, from the primary medullary groove to the formation of the spinal cord. E, epiblast; M, mesoblast.

of spina bifida, due to the fact that they gradually merge one into the other. For practical purposes it is best to divide the cases of spina bifida into two groups: (1) those due to arrest of development of the mesoblast, and (2) those due to a defect in both mesoblast and epiblast.

1. **Mesoblastic Spina Bifida, Meningocele.**—(*a*) The simplest form of spina bifida is the *extradural meningocele*. In this form the arrest of development has affected only the vertebral arches and the dura. The spinal cord and nerve roots lie within the normal arachnoid, and there is a collection of fluid between the skin and the arachnoid. At the summit of the spina bifida the wall of the sac consists only of the skin, while near

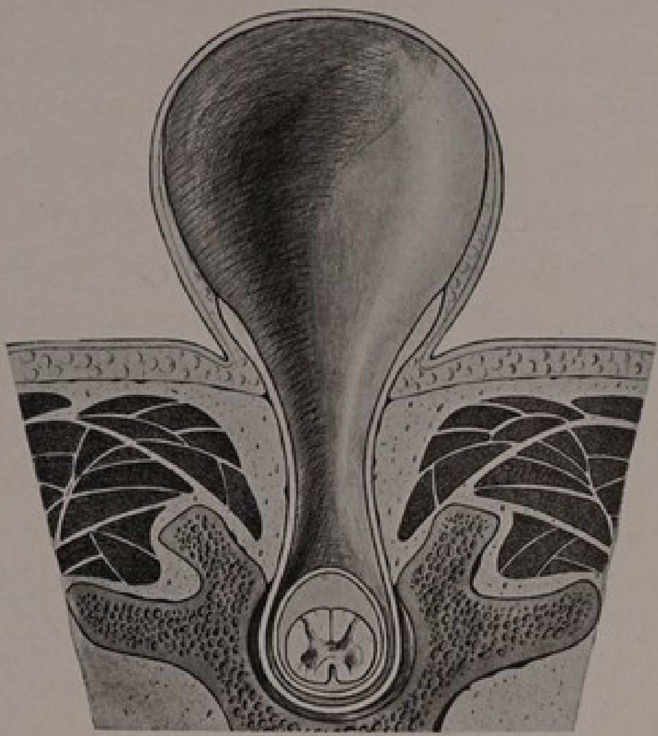


Fig. 90.—Subdural meningocele. The spinal cord and arachnoid membrane are normal. The sac is formed by the dura and skin.

Fig. 91.—Subarachnoid meningocele. The arachnoid layer forms part of the wall of the sac.

the base there is also dura mater. This is a rare form of meningocele, and one that is easily remedied by surgical interference (Fig. 90).

(*b*) The *subarachnoid meningocele* is more common (Fig. 91). Here the arachnoid forms one of the layers of the wall of the sac, and the hernial protrusion of the arachnoid is distended with fluid. It is very often impossible to determine that the arachnoid has been incised when the sac of the spina bifida is laid open. When a subarachnoid meningocele occurs in the lumbosacral region, loops of the roots of the cauda equina may be found in the sac, but they can usually be pushed back into the spinal canal without difficulty. If the cleft in the vertebral arches is very

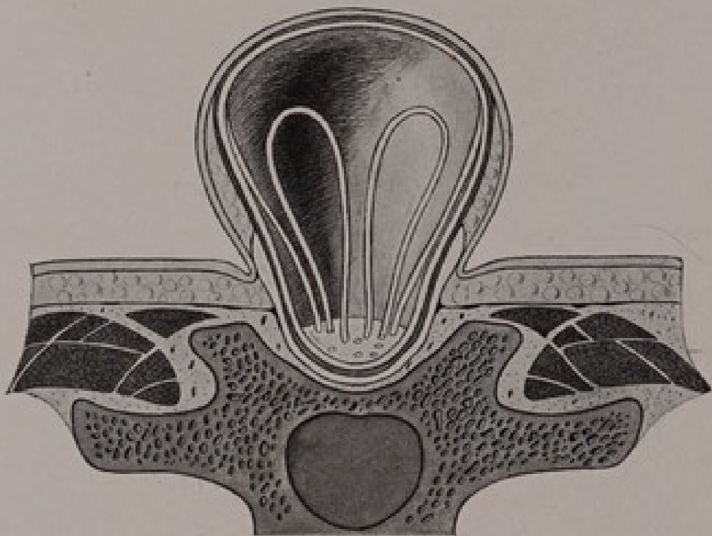


FIG. 92.—Subarachnoid meningocele with prolapse of nerve roots.

broad so that there is a shallow groove instead of a canal, a large number of the roots of the cauda may prolapse and some of them may run through the walls of the hernial sac (Fig. 92).

About 10 per cent. of the cases of spina bifida are meningoceles. The protrusion is often pedunculated and the sac covered by normal skin. This skin may be as thin as paper, however, and its summit may be of a rosy color and almost transparent. The neck of the sac of a meningocele is often secondarily obliterated so that a closed cavity remains. This occurs especially in cervical meningoceles.

**2. Spina Bifida Due to Defects of the Mesoblastic and Epiblastic Tissues, Myelocele, Meningo-myelocele, Myelo-cystocele, Rachischisis.** (*a*) *Myelocele, Myelo-meningocele.*—According to some authors, a subarachnoid meningocele which contains the roots of the cauda equina should be called a myelo-meningocele, but I think it preferable to limit this name to the variety in which the spinal cord or its nerve roots are abnormal in form or position, while those cases in which a normal cord or normal nerve roots have prolapsed with the arachnoid should be called simple meningoceles.

Myelocele or myelo-meningocele is a much more serious abnormality, in that the normal development of the spinal cord itself has been arrested. The original neural ridges have failed to unite in one part, and, as a

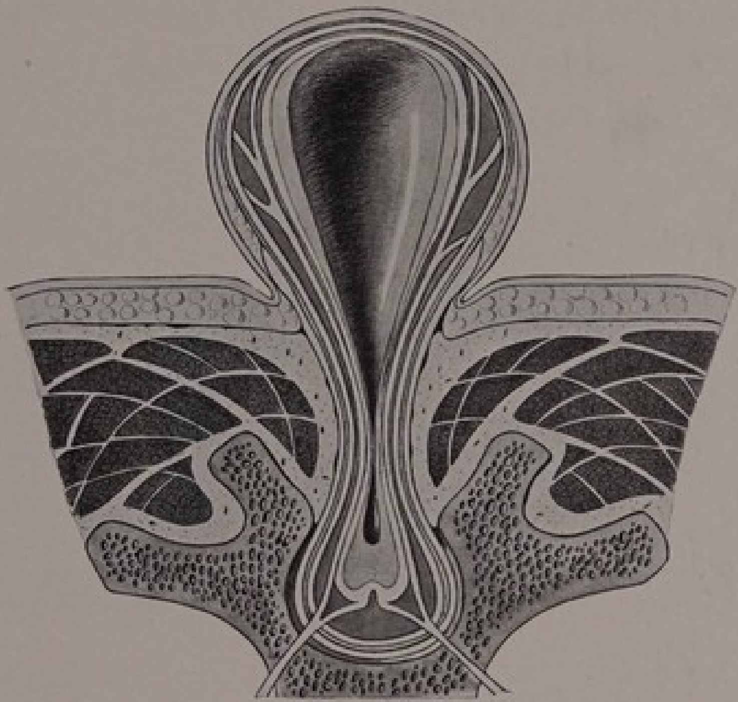


FIG. 93.—Myelo-meningocele. Changed cord tissue forms part of the wall of the sac.

result, the spinal cord is deformed, and the cord, nerve roots, or the roots of the cauda equina are attached to or spread out over the dorso-median aspect of the sac. This variety of spina bifida is very frequent, forming, in my experience, more than one-half of all of the cases (Fig. 93).

Sometimes the central canal of the cord is partly formed but much dilated, so that one may speak of a *myelo-cystocele* (*syringo-myelocele*), and in this variety the wall of the sac at the summit of the spina bifida consists of skin and subcutaneous tissue, arachnoid, pia and degenerated cord tissue. The posterior spinal nerve roots are usually found to originate from the wall of the sac, posteriorly or postero-laterally, and run forward in the wall of the sac to the dural openings. Occasionally, the entire tissue of the cord is protruded through the opening in the bone, either with or without the arachnoid on its anterior surface. In this variety the incision of the sac at its summit will expose the anterior nerve roots in the cavity of the sac. If they run free in the sac, the anterior layer of the arachnoid has not prolapsed with the flat open cord. If, however, the nerve roots are found inside the sac covered only by a thin layer of arachnoid, it means that the arachnoid membrane on the anterior surface has prolapsed and has been inverted with the cord tissue (Fig. 94).

In these forms the incision of the sac at its summit will pass through skin and subcutaneous tissue, arachnoid, thin degenerated cord tissue and

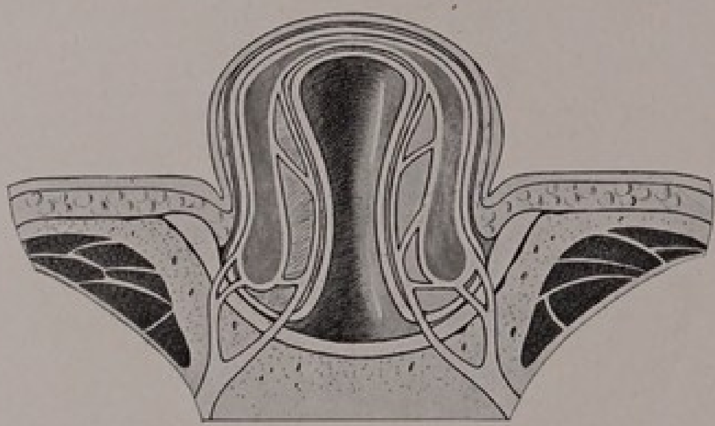


Fig. 94.—Syringo-myelocele. The changed spinal cord and all the membranes both behind and in front of the cord, with the exception of the dura on the anterior surface, have prolapsed.

possibly another layer of arachnoid. The cord tissue is sometimes so much changed and so thin that it is impossible to recognize it when the sac of the spina bifida is being incised, and the true condition of affairs can only be recognized by the course and relations of the anterior and posterior nerve roots.

Myeloceles and their various forms usually occur in the lumbar region, and are associated with a defect in two or three vertebræ. The base of the protrusion is usually a broad one, and there is a thick circle of connective tissue at the base, just under the skin and subcutaneous fat. The summit of the protrusion is of an oval shape covered by very thin epidermis of a reddish color, which is often translucent. Around this area can be seen the attachment of the normal skin.

In all the forms we have mentioned there are usually marked motor and sensory disturbances in the lower extremities with loss of control of the bladder and rectum. In a large number of the little patients the outlook for improvement after an operation is very slight.

The worst form of spina bifida is that in which the spinal cord and nerves are without a covering of any kind, and in which the granulating cord tissue is exposed. In this form, called *rachischisis*, the defect in the skin, soft tissues, bony arches and membranes is a large one, and the rudimentary cord with its pial vessels forms the summit of the swelling. The appearance is a very characteristic one. At the summit of the swelling the open cord resembles a granulating mucous membrane surrounded by an area of translucent membrane, which blends all around with the skin. The openings of the spinal canal can often be seen in the upper and the lower part of the reddish velvety area, and cerebrospinal fluid can be observed to escape from the upper opening.

This extreme anomaly is usually accompanied by congenital defects in other parts of the body. There is usually complete motor and sensory paralysis of the lower limbs. The infants usually die within a few days after birth.

## THE DIAGNOSIS OF SPINA BIFIDA

With the exception of spina bifida occulta, of which I shall speak later, the diagnosis of spina bifida can usually be made without difficulty. The presence of a congenital round fluctuating tumor which becomes tense when the child cries, and with which are often associated motor and sensory symptoms in the lower limbs, is characteristic. Occasionally the swelling is very small and only slightly prominent, and has to be differentiated from a teratoma, lipoma, or nævus of the back. In the large majority of instances the diagnosis "spina bifida" is made on inspection.

It is often difficult and frequently impossible to recognize the variety of the spina bifida before operation. The diagnosis of pure meningocele may be made if the mass is pediculated, if there is little or no increase of size when the child cries, and if no sensory or motor disturbances can be discovered.

The diagnosis of myelocele or myelo-cystocele can seldom be made with certainty. Transillumination of the sac will often reveal shadows due to the spinal cord or nerve roots, unless the fluid in the sac is opalescent from admixture with blood. Sometimes, however, there are septa or strands of connective tissue in the sac which may throw shadows like nerve roots. Transillumination is best done in the dark with a small electric light bulb.

If the neck of the sac has become obliterated so that there is no communication between its interior and the general subarachnoid space, pressure upon the sac will not cause it to decrease in size or to become less tense. If, on the other hand, there is a distinct increase in the size of the protrusion when the child cries, and if pressure upon the protrusion causes it to diminish in size and the fontanelles to become more tense, there is no doubt of the communication of the sac with the spinal and cerebral subarachnoid space, and the examiner may be certain that he has to deal with a subarachnoid meningocele or with some form of myelocele.

Pressure upon the protrusion may markedly increase the bulging of the anterior fontanelle and, if there has been some hydrocephalus, nystagmus and convulsions may follow. In one instance by firm pressure upon a large lumbar myelocele I was able to cause a distinct engorgement of the retinal veins visible by the ophthalmoscope. The larger and the more extensive the defect in the vertebræ, the less the chance for relief by operative interference. If the defect is a large one, it can often be distinctly felt or it will show upon the X-ray plate. If the opening is very small, the chances of a meningocele are greater.

The worse the form of the spina bifida, the more apt there are to be other congenital defects. Of these the most frequent are hydrocephalus, umbilical hernia, recto-vesical communications, scoliosis, and club feet.

Motor and sensory disturbances in the lower extremities, with paralysis of the bladder and rectum, occur more often with the severer forms of spina bifida; it is therefore important to be able to recognize that there is or is not a marked loss of power or sensation in the lower extremities. The examination is often very unsatisfactory in infants. A paralysis of the lower limbs will prevent the infant from drawing up the limbs when they are pricked with a pin, and we must then depend upon the crying of the child for evidences of normal or diminished sensation. Some of the little patients are able to move the lower limbs although the limbs are entirely anesthetic, as I have noted in a number of instances. On the other hand, the infants may have very marked "réflexes de défense" (see Chapter IV), and I have more than once been uncertain whether a sudden drawing up of the lower limbs was due to a reflex or a voluntary movement. Voluntary movements of the lower limbs are the only certain evidence of good motor power.

Similar difficulties are met with in the attempt to determine whether there is an incontinence of urine and feces. The examiner must watch the infant and try to determine whether or not there is a continual dribbling of urine. In one patient I was able with the finger to recognize a marked relaxation of the anal sphincter, and thus to conclude that rectal control had been lost.

It is often difficult to obtain distinct knee jerks and ankle jerks in infants; therefore the absence of these reflexes may mean nothing.

## TREATMENT OF SPINA BIFIDA

If left to themselves, the majority of patients with spina bifida would succumb within the first year of life from infection of the sac and meningitis, from urinary sepsis, or from the complicating hydrocephalus. In a few instances in which the protrusion was very small the sac has shrunk, the fluid disappeared, and the infant has recovered completely. These were no doubt cases of subdural meningocele. Many patients have lived five or more years with meningoceles. It is very probable that many of the adult patients with spina bifida occulta are examples of cases of small protrusions which were not discovered until they gave definite symptoms in adult life.

Marked hydrocephalus always contraindicates surgical interference, but the operation may be performed in spite of the presence of a slight degree of ventricular distension. I have seen at least one child with hydrocephalus that recovered nicely after an operation for spina bifida. In another case repeated ventricular punctures had to be performed for a number of days after the operation.

Complete loss of power in the lower limbs makes the outlook for improvement after an operation poor, because the probability of marked changes in the cord is greater. Undoubted cases have been reported, however, in which a paralysis of the lower extremities improved and even

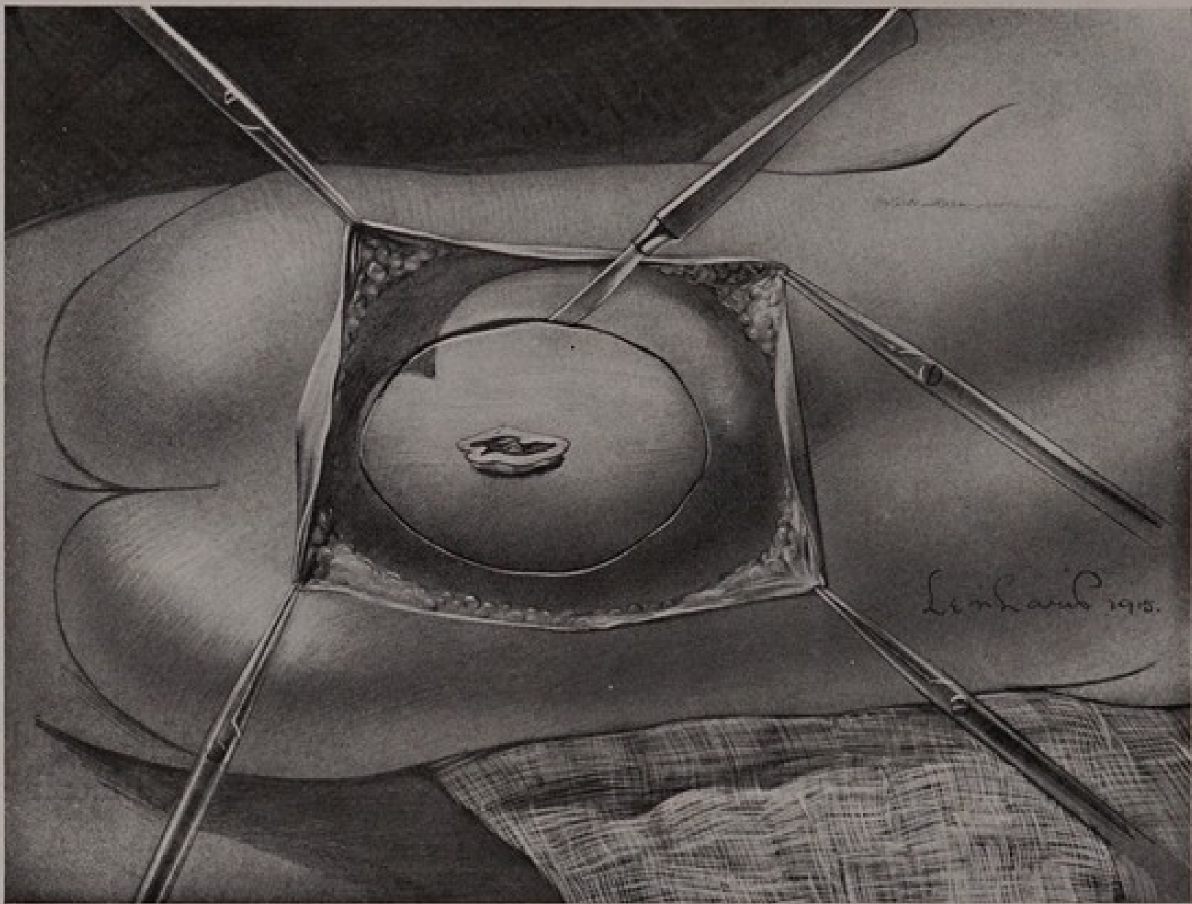


Fig. 95.—Plastic operation for spina bifida. I. After exposure and ligation, the sac of the meningocele has been cut off. The incision for fascia plastic.

disappeared entirely after the operation. In these cases the symptoms were probably due to pressure rather than to a real lesion of the cord. Incomplete or even complete paralysis of the lower limbs is not by itself an absolute contraindication to operative interference, but when it is combined with hydrocephalus, operative interference is useless.

Whenever possible, the operation should be delayed until the infant is a few months old, and during the interval every effort should be made to keep the child in good physical condition. The infant should be breast fed if possible, and everything done to prevent enteritis. The surface of the spina bifida should be carefully protected with cotton, and ulceration of the skin prevented by smearing it with vaseline or zinc oxide ointment. If there is danger of rupture of the sac, it is advisable to partly empty it by means of aspiration, a fine needle being introduced near the base of the sac.

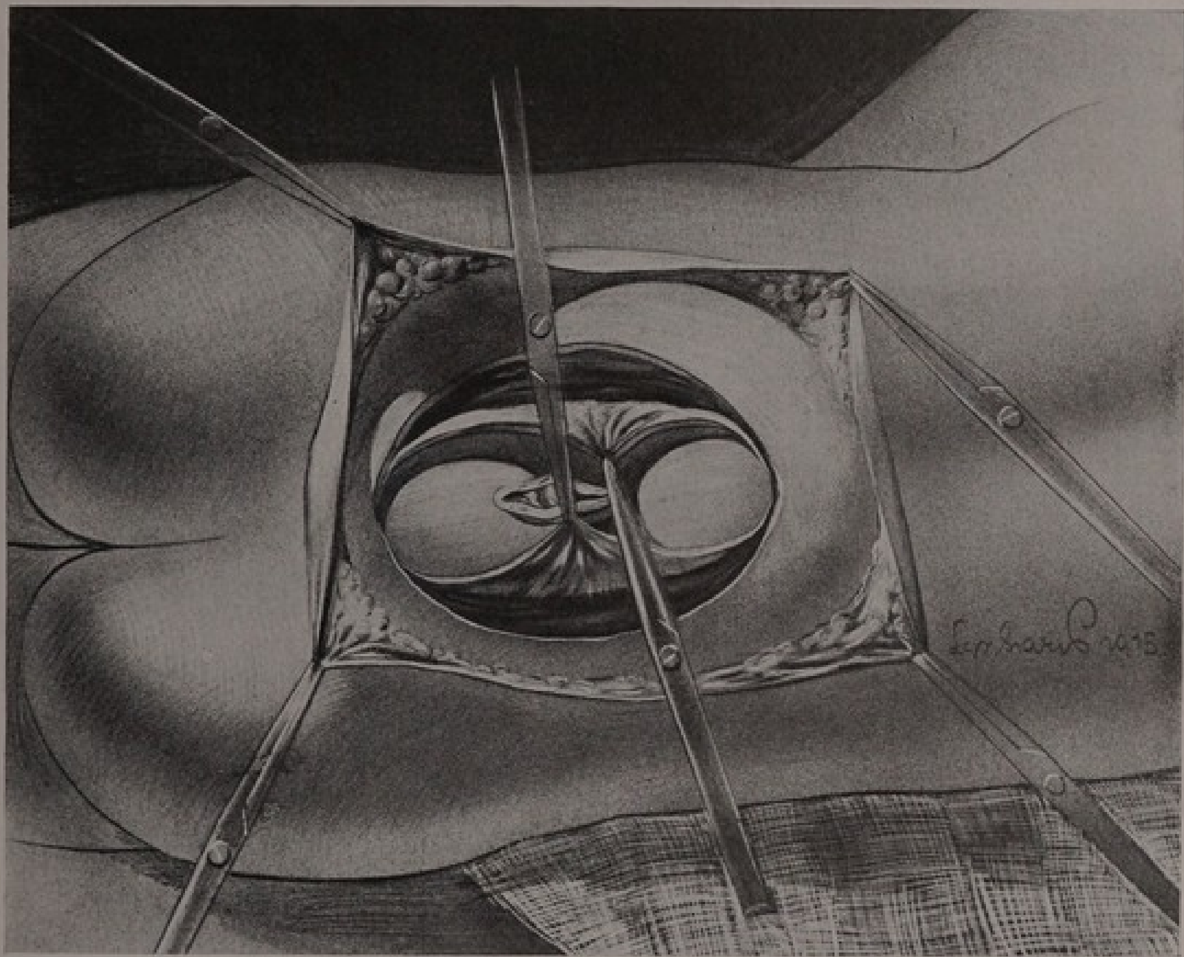


Fig. 96.—Plastic operation for spina bifida. II. Closure of the defect left after excision of the meningocele. The fascial flaps are approximated.

As a curative procedure, all non-operative methods, such as aspiration of the sac followed by injections of irritating fluids, have been abandoned as useless and dangerous. The only treatment for spina bifida is an operative one.

**Technic of the Operation** (Figs. 95, 96 and 97).—The child should be placed in the prone position or somewhat on the side, and the hips be elevated on a pillow or warm-water bag. Ether anesthesia by the open mask should be begun only when the skin has been sterilized and everything is ready for the operation.

If there is ulceration of the sac, this should be thoroughly rubbed with strong tincture of iodine. For the preparation of the general field of operation, ordinary tincture of iodine diluted with an equal part of alcohol should be used. It should be a general rule to save as much skin as possible, and to excise only the ulcerated area. In pediculated meningoceles a longitudinal or transverse incision is made near the base of the pedicle and a skin flap turned down. The incision is then carefully deepened around the pedicle until the edges of the thick fibrous ring (the edge of the dura) are exposed. This edge is carefully freed all around the pedicle, and an incision is made into the cavity of the pedicle. As soon as an opening has been made into the thin membrane (the arachnoid) which forms the inner lining, the operator must pass a probe into the cavity in order to determine whether a communication with the spinal canal is present. At the same time, the inner wall of the cavity is examined in order to find any nerve roots that may have prolapsed into the sac.

If there is no communication with the subarachnoid space of the spinal canal, the sac is tied off at its base with catgut and removed. If, on the other hand, there is a communication with the spinal canal, the arachnoid is divided all around, the edges of the membrane being grasped with mosquito forceps. After the sac has been removed, the opening in the pedicle is closed by a catgut ligature. The edges of the dura are then sutured over the pedicle. If the defect in the spinal canal has been a very small one, the skin is now closed by silk sutures. If the cleft is larger, however, some kind of plastic operation is necessary to cover the opening. A plan which is often successful is to dissect up the skin of the back sufficiently to expose the fascia for about 1 in. around the opening. A circular incision is made through the fascia and partly through the muscles of the back, and these dissected up all around to near the edges of the defect. The edges are then sutured together over the median line, and the outer edges of the fascia sutured together over this. If the tension is too great, relaxing incisions may be made or suture of the fascia may have to be abandoned.

Another useful plastic operation is to make a rectangular flap of fascia and muscle on each side, with its base near the opening of the spinal canal. One of the flaps is then sutured over the defect and the second flap sutured over the first. These rectangular flaps may also be made, one with its base nearest the median line, the other with its base away from the mid-line. The muscle fascia flap with its base nearest the median line is then reflected over the defect and fixed by sutures, the second flap being finally sutured over the first. The skin incision is then closed after the requisite amount of redundant skin has been excised.

If the spina bifida has a broad base, the procedure for the exposure of the sac must be a different one from that just described. A longitudinal incision is made over the sac with an elliptical excision of the ulcerated area, if that be present. The incision is carefully deepened until the sac is opened. The contents and the walls of the sac are then carefully examined. If there are loops of spinal nerves which lie free in the sac, they must be carefully replaced in the spinal canal. If small nerve filaments end in the wall of the sac, they may be divided. If larger nerves end in the wall of the sac or run in the walls, they must not be injured. The walls of the sac must be divided beyond the nerve roots, and the roots with the inner wall of the sac returned into the spinal canal, after the cut edges of the sac have been united by sutures, and the arachnoid cavity thus reformed. This dissection may be very difficult, and much care must be taken when the portions of the sac that do not carry nerve elements are trimmed off.

Sometimes considerable of the inner part of the walls of the spina bifida must be preserved in order to have sufficient tissue for the reconstruction of the spinal sac.

It is usually very difficult, and in most cases impossible, to distinguish between the various forms of myelocele at the operation, and, without microscopical examination, it is often impossible to recognize that the wall of the sac is partly formed by thin degenerated cord tissue. As soon as skin flaps have been turned down on each side of the sac with excision of the central ulcerated or rosy-red area, the sac is carefully opened by a small longitudinal incision. If the dilated spinal canal can be identified, the fluid should be emptied by careful aspiration with a fine needle, as much of the sac excised as possible, and the edges then united by sutures of fine silk. Occasionally it may be necessary to make an incision into the cavity of the syringo-myelocele before the fluid can be evacuated and the membranous spinal canal can be reconstructed.

The reconstruction of the membranous spinal canal in the presence of a large myelocele with extensive cleft in the vertebral arches is seldom satisfactorily accomplished. The reflection of the skin over the sac may be very difficult on account of its thinness, but the attempt must always be made to separate the skin from the other parts of the sac wall. Very often, little of the sac wall can be excised on account of the nerves running in it, so that the greater part must be returned into the spinal canal. This may be difficult because the spinal groove is either very shallow, so that there is no cavity into which the nerve tissue can be placed, or because so much tissue has to be replaced that there is no room for it. In these cases the newly constructed membranous canal will have to remain on the back unprotected by any tissue, except fascia and muscle flaps which are united over it.

In the worst cases there may be so little tissue that it is impossible to reconstruct any kind of a membranous tube or canal, and the operator has to be satisfied if he can cover over the exposed portions of the cord and nerve roots with fascia and muscle flaps derived from the tissue of the back. The outlook in such cases is always a hopeless one.

I do not believe that a defect in the vertebral arches in infants should ever be closed by transplanted bone or fascia. All bone plastic operations are too severe for the infants and have in most instances resulted in failure. In the rare cases in which spina bifida is seen in older children (five years or over) such bone transplantation may be tried, but never in infants of a few months of age. Transplantation of fascia is also seldom indicated, because it is seldom possible to obtain a sufficiently large piece of fascia from any part of the infant's body. Heteroplastic fascia transplants will seldom heal in; they usually necrose and have to be removed or are absorbed. The application of a layer of silver wire (Witzel) has given a good result in one case. Infants with rachischisis should never be subjected to operation, as the outlook is an absolutely hopeless one.

The skin wound should never be drained, but the edges of the skin should always be closed by suture. The after treatment is very important. The child should be kept upon the abdomen for at least one week, if possible. This can often be accomplished by having the child strapped to a previously prepared well-padded plaster-of-Paris mould. Many of the children can remain on the back, if the wound is carefully sealed with collodion and protected by an appropriate protective dressing. Careful nursing is necessary to prevent soiling of the dressings by urine and feces.

## RESULTS

As the mortality of the operation has been very high in the first months of life, varying between 35 and 50 per cent., it is advisable to defer operation as long as possible. Many of the infants operated upon within the first few months of life died from the shock of the operation; others from meningitis due to infection, from marasmus, or from the complicating hydrocephalus. The immediate operative mortality is at least 25 per cent. for the first year of life. Of course, the results will vary with the form of the spina bifida. Thus I have operated upon five meningoceles with five recoveries, upon seven meningo-myeloceles with only three recoveries. All of the patients over two years of age recovered nicely from the operation. I have seen one child with marked motor and sensory disturbances regain power in the paralyzed limbs.

## SPINA BIFIDA OCCULTA

Spina bifida occulta is a variety of spina bifida, most often met with in young adults, in which there is no true sac and in which there is a fibrous connection between the skin and the spinal cord, or its nerves or membranes, through a cleft in the arch of one of the vertebræ.

While the condition is congenital in its origin, it seldom causes any symptoms until adolescence. In the early months of fetal life the spinal cord ends opposite the coccyx, but the vertebral column grows in length more rapidly than the spinal cord, so that at birth the cord extends only to the third lumbar vertebra, and in adult life to the base of the first lumbar vertebra.

In spina bifida occulta the skin is adherent to the membranes, to the nerve roots, or to the cord itself; hence, with the growth of the bony canal

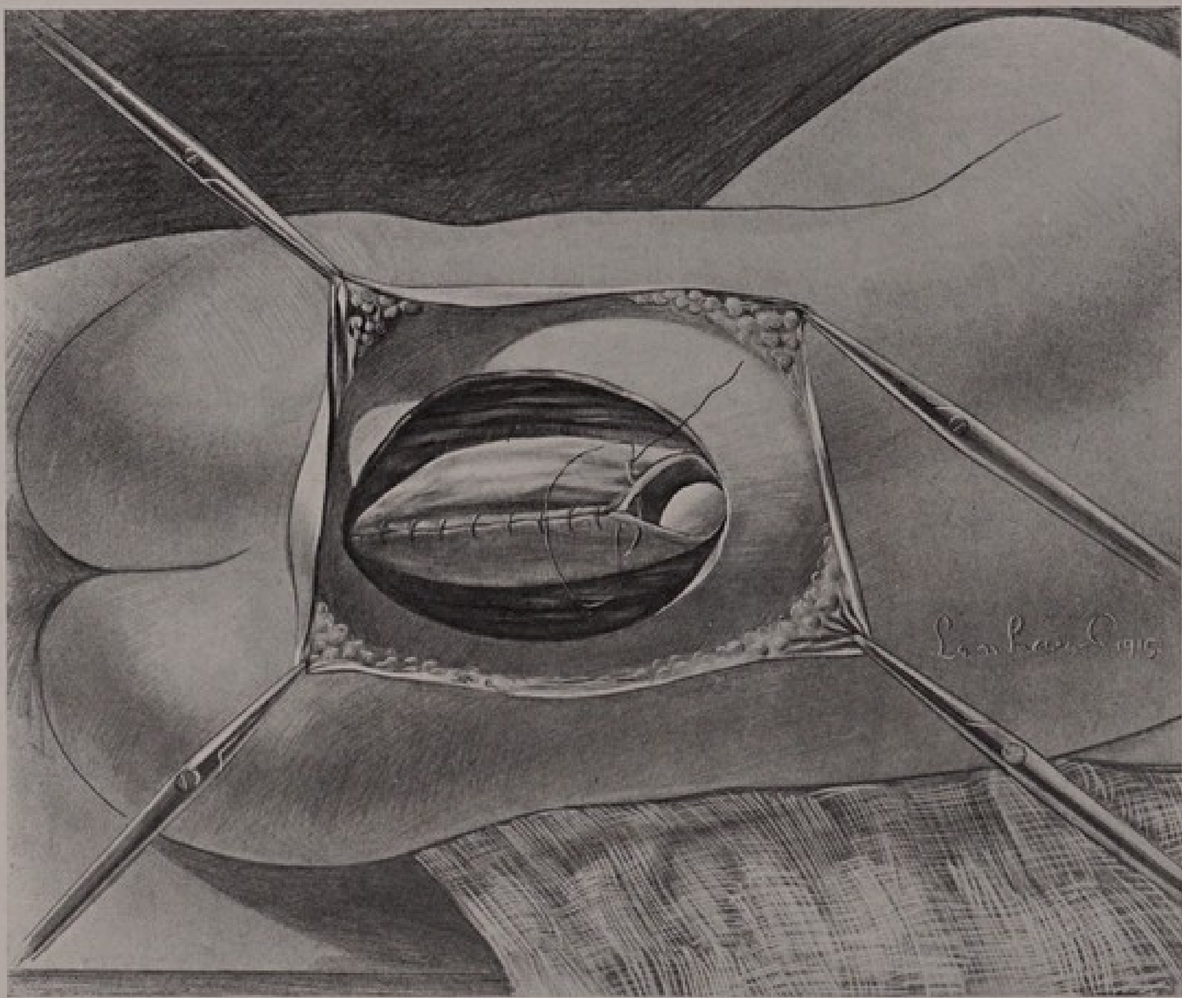


Fig. 97.—Plastic operation for spina bifida. III. The edges of the inverted fascial flaps are sewn together.

away from the end of the cord, traction upon the membranes or the nerve roots and cord must follow.

This condition occurs most often in the lumbar, lumbosacral or sacral regions. The cleft in the bone is generally closed by a thick fibrous membrane which is continued as a thick band to the under surface of the skin. As an evidence of the developmental anomaly, there is often a growth of fatty tissue or of muscle tissue into the spinal canal through the hiatus in the bone. This hiatus affects most often one vertebral arch, although not so rarely two or three vertebræ are affected. The skin over the cleft, shows in most instances, marked changes. There may be a depression or dimpling of the skin which may be coarse, wrinkled, pigmented

Fig. 98.—The lipoma on the back of a patient with spina bifida occulta.

and present numerous fine radiating scars through which the cleft in the bone can be distinctly felt. More often, however, there is a diffuse lipoma under the skin (Fig. 98), which may be connected by a fibrous band with another mass of fat within the spinal canal, or there may be a marked growth of hair on the skin (Fig. 99). This hypertrichosis has been found in more than one-half of the patients—it was present in two out of three cases that I observed, two of which have been studied and described by W. M. Brickner. With this anomaly other deformities—club-foot, scoliosis and lordosis, etc.—are often associated.

In some instances the condition is undoubtedly a result of a small spina bifida which had ruptured in intrauterine life, but in the majority of cases it is probably due to the lack of separation over a localized area

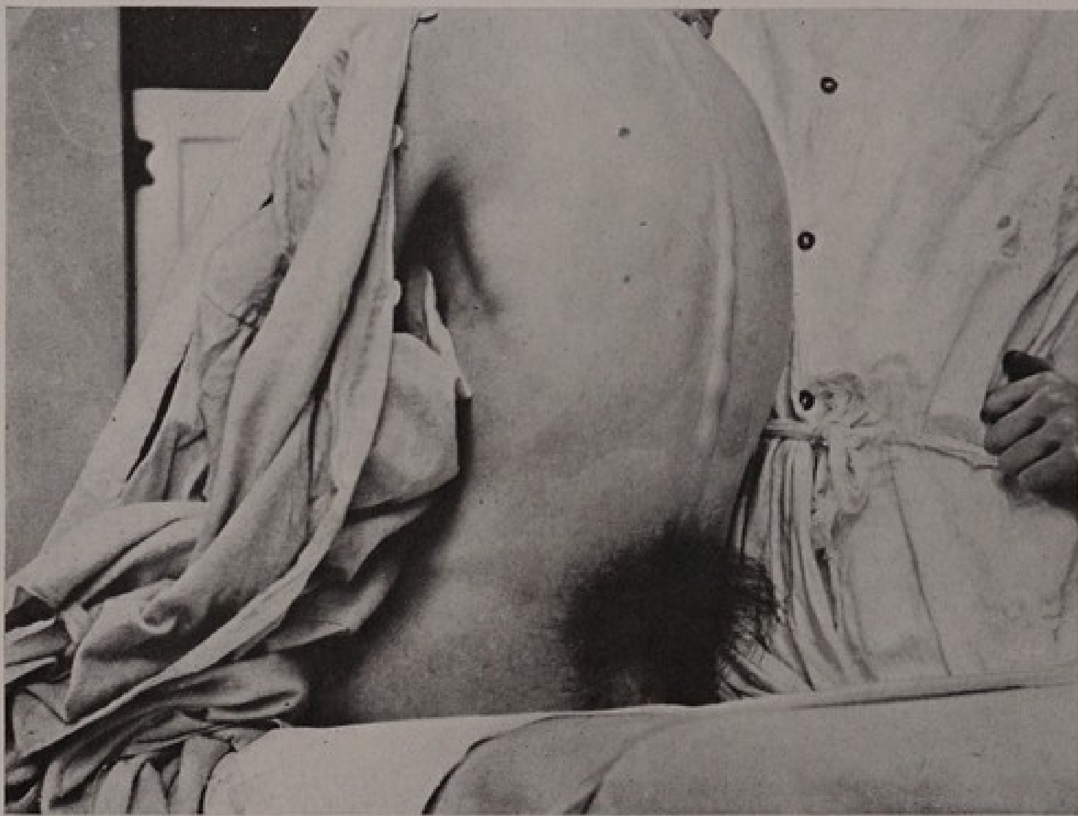


FIG. 99.—Growth of hair over the region of a spina bifida occulta.

of the two layers of the epiblast which form on the one hand the neural tube, and on the other hand the skin.

The frequency of spina bifida occulta is probably greater than generally supposed, because there are doubtless many cases which cause no symptoms, and therefore escape notice.

**Symptoms.**—While symptoms may occur at an early age, they usually are first observed between the ninth and the twenty-fourth year. The symptoms for which the patients seek relief may be progressive weakness or paralysis of the lower limbs, sensory disturbances in the legs, incomplete control over the bladder and rectum or incontinence, trophic changes in the lower extremities or the lower part of the back.

The motor weakness most often affects the extensors of the feet so that drop-foot on one or both sides is observed. Spastic paraplegia has been observed in one patient. There may be marked atrophy of the muscles of the thighs and legs with diminution or loss of one or both knee or ankle jerks. The motor and sensory disturbances will vary with the part of the cord or with the nerve roots affected. If the lesion is in the

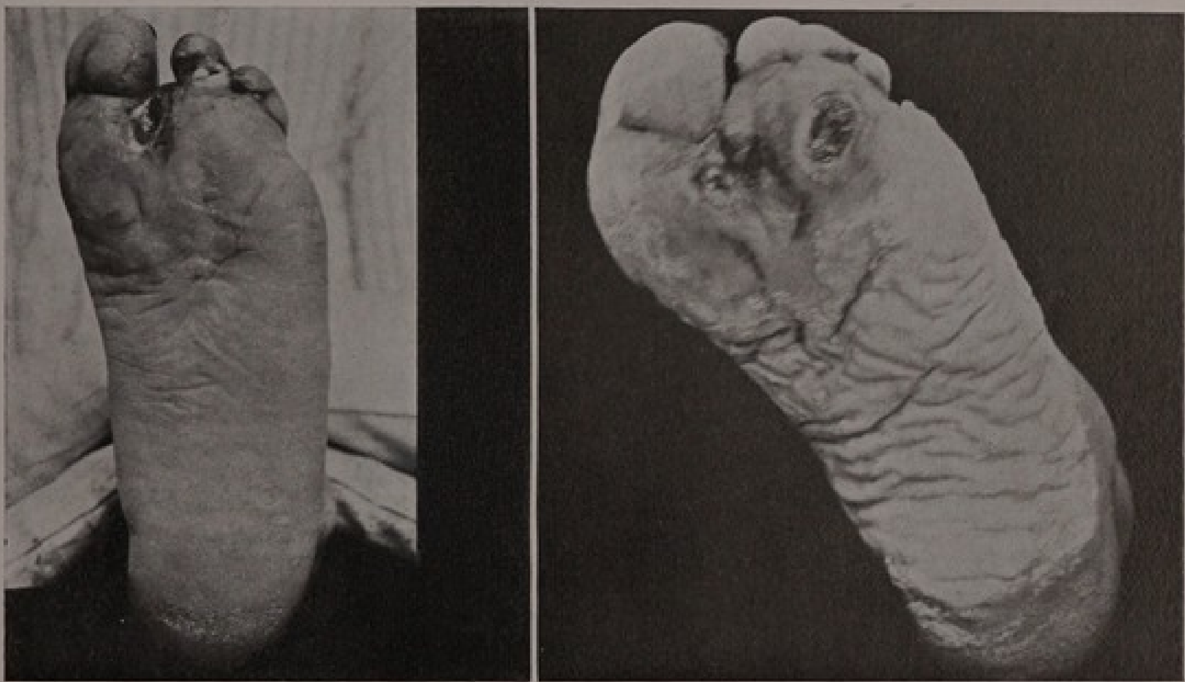


FIG. 100.—Trophic ulcers in a case of spina bifida occulta.

lower lumbar or sacral regions, there may be no motor and few ill-defined sensory symptoms.

Some patients seek medical aid on account of the vesical and rectal disturbances. These may be the only symptoms, as in a case I have recently operated upon.

The trophic changes most often observed have been perforating ulcers of the buttocks and feet, especially on the plantar surfaces of the feet and the toes (Fig. 100). The pain from these ulcers may be severe and persistent, and amputations of the toes or of the foot have been performed in a number of cases.

**Diagnosis.**—The presence of a lipoma or a hypertrichosis in the lower part of the back should always make one think of the possibility of a spina bifida occulta. The defect in the bone can rarely be felt, but in most cases the cleft in the bones can be recognized on the X-ray plate. In every patient who comes to the physician with bladder or rectal disturbances, or symptoms referable to the lower limbs, the vertebral region must be carefully examined. If there is a lipoma or a hypertrichosis in the lumbar or sacral regions, the possibility of a spina bifida occulta must be kept in mind. An X-ray examination of the spine should never be omitted, for the diagnosis can often be made from the X-ray alone.

**Treatment.**—Only those cases of spina bifida occulta which give rise to symptoms require surgical interference. A longitudinal incision is made through the skin, and the lipoma freed on all sides. At the middle of its under surface a tough fibrous band will usually be encountered. This band is carefully isolated down to the point where it enters the cleft in the vertebral arches. The fibrous band can usually be followed through the fibrous tissue that fills up the cleft in the posterior part of the vertebral canal. Part of the fibrous tissue in the cleft is carefully excised, until normal dura is exposed above or below. The fibrous band is either excised at the level of the dura or, better, an incision in the dural sac is made to one side of the attachment of the band and the condition of the cord and nerve roots determined. If there are no nerves adherent, that part of the dura which forms the base of the fibrous band is removed with the band, and the opening then closed by suture. If, as occurred in one of my patients, there is a small cavity in the deepest part of the fibrous band which is connected with the subdural space, this must be examined, as one of the nerve roots is often found in it. If there is a lipoma or muscle tissue within the canal which has caused pressure upon the cord or nerve roots, it must be excised. Abnormalities of the cord may be found in young children, which can not be remedied by the surgeon. In one of my patients a diffuse lipomatosis which surrounded a number of the roots of the cauda equina was exposed, but it could not be removed without undue trauma to the nerve roots.

In some cases the fibrous band does not extend to the skin but only to the fascia, so that the real condition of affairs is only recognized when the opening in the fascia is exposed. In these patients, especially if the cleft in the bone is a small one, the arches of one or two vertebræ may have to be removed before the thickened dura can be exposed.

The results of operation in children will depend upon the condition of the spinal cord. If this is incompletely developed, little can be gained by the operation. If, however, there are fibrous bands which bind together the cord or the nerve roots, great improvement in the symptoms may follow the operation.

Where symptoms appear only in adolescence, the outlook for relief by operation is a good one. The bladder and rectal disturbances may disappear entirely, and sensory and motor symptoms may be almost entirely relieved. The lack of control of bladder and rectum may persist in spite of the operation, as was the case in one of my patients. The trophic disturbances which appear in adult life are due to traction on the cord tissue or the spinal ganglia, degenerative processes in the ganglia, or secondary ascending degeneration in the spinal cord. If the trophic ulcers are due to traction, they will heal as soon as the relations of the tissues have returned to the normal; if they are due to actual lesions of the spinal cord or spinal ganglia, they may persist. In one of the patients reported by Brickner amputation of one foot finally had to be resorted to in order to give relief.

Some patients complain of severe pain along the course of one or of several nerve roots, and, on examination, a hypesthesia is found over the area of distribution of the affected roots. In one of my patients the pain was entirely relieved by the intradural division of the affected posterior roots.

# CHAPTER XV

## ABNORMALITIES AND DISEASES OF THE SPINAL VESSELS

Our knowledge concerning the effect of arterio-sclerosis, of thrombosis and embolism of the spinal vessels upon the spinal cord is still very limited. Complete obstruction of the blood supply to a part of the spinal cord is followed by signs of softening (myelomalacia) similar to that which occurs in the brain. Softening in small areas of the spinal tissue may occur from sudden obstruction of a terminal vessel, in syphilitic myelitis, and more often in caisson disease.

Obstruction of branches of the aorta is followed by a marked increase both in the size and the number of the anterior and posterior spinal vessels. Haberer (Zeitschrift für Heilkunde, 24 (N. F. 4), 26, 1903) has described the case of an apparently healthy woman who had borne seven children and who died with symptoms of acute myelitis. At the post-mortem examination there was found a congenital obliteration of the aorta with a collateral circulation formed by means of the spinal arteries.

Aside from the conditions I have mentioned, there are others that require a more extended consideration because the enlarged vessels may be the cause of the spinal symptoms. These are (1), arterio-venous aneurisms of the posterior spinal vessels and angiomata; and (2), varicosities and enlargements of the posterior spinal veins.

### ANGIOMA OF THE CORD; ANEURISM OF THE SPINAL VESSELS

Aneurism of the spinal vessels is very rare; only a few cases are known in the literature. The first case is one described by Brasch (Berliner klin. Wchnschr., 1900, Nos. 52 and 53), in which the anterior and posterior surfaces of the cord from the fifth dorsal segment to the filum terminale were covered by a mass of enlarged and convoluted arteries which compressed the spinal cord, causing softening of the spinal tissue and secondary ascending degenerations. Enlarged arteries were also found along the


FIG. 101.—Aneurism of posterior spinal vessels.

course of many of the spinal roots. As the patient had a marked hypertrophy of the heart and advanced renal disease, Brasch believed that the spinal vascular changes were entirely secondary to a long-continued high arterial pressure. Raymond and Cestan (Revue Neurol., 1902) described a case of spastic paraplegia due to an aneurism of the posterior spinal vessels, and Heboldt (Archiv f. Psych., XVI, 813) gives an account of a post-mortem examination on a young girl in whom multiple miliary aneurisms were found in the extramedullary and intramedullary vessels of the spinal cord. Gaupp (Beiträge z. path. Anat., 1888) recorded a case of angioma of the cauda equina, Berenbruch one of angioma of the cord secondary to an angio-lipoma of the back, and Lorenz a case of cavernous angioma of the cord.

In all of these cases there were marked spinal cord symptoms, and in most of the patients the condition was found at autopsy. In 1912 I published a case of arterio-venous aneurism of the posterior spinal vessels which caused all the symptoms of a spinal tumor, and which was found when a laminectomy for a suspected newgrowth was performed (Fig. 101).

William H., thirteen years of age, a patient at the New York Neurological Institute on the service of Dr. Pearce Bailey, was transferred to the Surgical Service for operation on January 20, 1911.

Two years before, the patient fell through a scaffolding and was kept in bed for two days on account of a "concussion of the spine." One year before, began to complain of pain in the left thigh, which was especially severe when he was lying down. Soon after the right thigh became affected and the lower limbs began to feel weak. The pain in the thighs soon disappeared, but the limbs became weak and stiff and at times he had no control over his bladder and rectum.

**Physical Examination.**—Cranial nerves and upper extremities normal. Abdominal and cremasteric reflexes can not be obtained. Both lower limbs very spastic, the left more than the right. Can move lower limbs very little on account of spasticity. Left foot can be slightly raised from the bed; slight flexion at knees is possible. Knee jerks much exaggerated, double patellar clonus, double ankle clonus and Babinski. There is a marked diminution of all three sensations over the L 2, L 3, L 4, L 5 and S 1 areas on both sides, but more marked in the left limb. No tenderness over lumbar spines. Wassermann and X-ray examinations negative. Large flat lipoma over sacral region.

Laminectomy, January 20, 1912 (Dr. Elsberg). Removal of spines and laminæ of eighth, ninth, tenth and eleventh dorsal vertebræ, and incision of dura, exposed a large mass of tortuous blood vessels about 4 cm. in length and fully 1 cm. in thickness. Above, an artery and a vein, each 5 to 6 mm. in width, entered the mass; below there were also two large vessels running down to the cauda equina. The walls of the vessels were very thin, and in the attempt to ligate the main source of the blood supply, considerable bleeding occurred. Only part of the mass could be excised. No vessels appeared to come out of the cord itself, but there were a number of branches from the anterior surface of the cord. The wound was closed in layers in the usual manner.

Recovery from the operation was uneventful, but there was no improvement and the patient returned to his home about six weeks after the operation. The condition was the same about six months later.

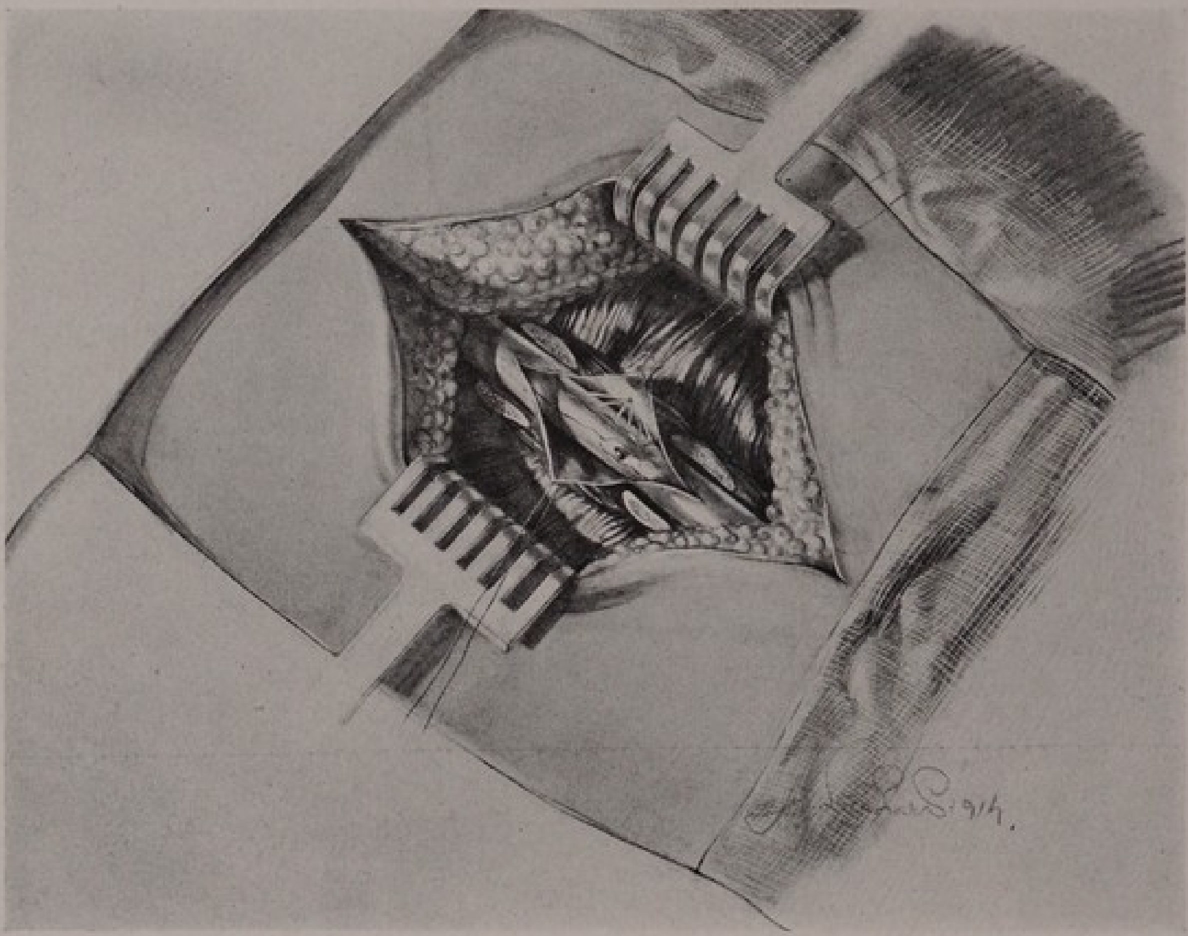


FIG. 102.—Dilatation of an intramedullary vein complicating an angio-lipoma of the back.

This was a true case of arterio-venous aneurism of the posterior spinal vessels, and was probably secondary to the trauma two years before. The cord was much flattened by the mass of blood vessels; they could not be excised on account of their close relations to the cord tissue.

In the case of angioma of the cord secondary to an angio-lipoma of the back, Berenbruch states that the angioma contained blood vessels which ran directly into the cord. I have operated upon a patient in whom a large mass of fat filled with dilated veins was found in the subcutaneous fat of the back. The patient had spinal symptoms at the fourth dorsal level and, at operation, a large dilated vein was found (Fig. 102), which arose from the cord at the exact level of the sensory and motor signs. The dilated vein was ligated at its entrance into the cord, but, as was to be expected, the patient did not improve after the surgical procedure.

## ABNORMALITIES OF THE SPINAL VEINS

As is well known, there are two main posterior spinal veins, which run on the posterior surface of the spinal cord from the conus medullaris to the medulla. These two veins are normally somewhat tortuous; they lie superficial to the origins of the posterior spinal roots, and communicate with each other by means of branches. The main trunks are joined by small veins from the posterior spinal roots.

**The Diagnosis of Spinal Compression from the Appearance of the Veins below the Point of Pressure.**—The posterior spinal veins are sometimes considerably enlarged below the level of a spinal compression. On account of interference, by the pressure of an extramedullary neoplasm, with the return venous flow, the veins are much enlarged and engorged with blood for a considerable distance below the tumor. When the cord of such a patient has been exposed, one or both posterior spinal veins appear very large and very prominent; they are often more tortuous than normal. In intradural inflammatory processes—meningitis and meningo-myelitis—the cord has a pink color due to the fine network of distended veins and arteries in the hyperemic area. The appearance is not the same as that below a spinal compression, in which distended veins stand out prominently on the creamy white background of the cord. In several patients upon whom I performed laminectomy for a spinal tumor, and did not find the growth at the suspected level, this venous engorgement led me to search for the growth higher up. In one instance I had to remove five additional vertebral arches before the tumor was exposed and removed. The appearance of these distended veins is so characteristic that, once recognized, their significance is a very definite one; it is important for the operator to understand what they mean.

After a little experience one can without difficulty differentiate this venous engorgement from an ordinary inflammatory hyperemia of the cord. (Plates I and II facing p. 134.)

**Localized Enlarged and Varicose Veins of the Cord** (Figs. 103–110).—Of far greater interest to the physician and the surgeon, not only because of their relative frequency, but also on account of the possibilities of

Fig. 103.—Enlarged posterior spinal vein which runs an abnormal course under two nerve roots.

relief by operation, are enlargements and varicose conditions of the posterior spinal veins.

Up to the year 1912 only four cases had been reported in the literature in which compression of the spinal cord through enlargement of the venous channels had occurred. Gaupp gave a description of a case, with the title "Hemorrhoids of the Spinal Pia Mater," in which the lumbar cord was compressed by the dilated and tortuous vessels. Krause (Chirurgie des

Gehirns und Rückenmarks, 1911) gives the history of a case with illustrations. He performed a laminectomy upon a patient who was supposed to have an intravertebral tumor which had caused a complete paraplegia, and found the lumbosacral cord covered by a mass of dilated and tortuous veins, some of which entered the substance of the spinal cord. Jumentie and Valensi (Revue Neurol., XIX, 1911, 81) describe the post-mortem appearances of the spinal cord in a patient with complete paraplegia. On the posterior surface of the cord, between the sixth cervical and the seventh dorsal segments, there were numerous dilated veins. Some of these veins accompanied the nerve roots to the dural openings. Finally, Lindemann (Zeitschr. f. d. gesammte Neur. u. Psych., 1912, XII, 522) describes a case of varices of the vessels of the spinal pia mater and the cord as the cause of a total transverse cord lesion. The patient had the signs of a slowly progressive transverse lesion of the cord of two years' duration, and succumbed to decubitus and sepsis. At the post-mortem examination the veins on the posterior surface of the cord, beginning about 7 cm. below the cervical enlargement, were much dilated and very tortuous. From the second lumbar segment to the conus, the veins were so much dilated that they caused a marked flattening of the cord. On the anterior surface the vessels were also enlarged, but not as markedly as on the posterior surface.

The case described by Krause is the only one in which the abnormality of the spinal vessels was found on the operating table. Krause's patient presented the symptoms of an intravertebral newgrowth of seven years' duration. At the operation he found a mass of dilated veins, some of which entered the cord at the level of the ninth to the twelfth dorsal vertebræ. The operator was able to ligate a number of the vessels, but the patient did not improve, and death occurred three months later. With the exception of these cases, abnormalities in the size and course of the veins on the posterior surface of the cord have not been described in the literature.

Among 120 laminectomies for spinal disease, I have six times found one or several much enlarged veins on the posterior surface of the spinal cord. In all but one of the patients the enlarged vein ran a straight course, and in several of the patients the enlarged portion of the vein accompanied one of the spinal roots. All of the patients had the signs and symptoms of a level lesion, and the greatest enlargement of the blood vessel was found at the level exposed. Two of the patients suffered from severe root pains, and in them a branch of the enlarged vein accompanied these posterior spinal roots.

As soon as the laminectomy had been performed and the dural sac incised, the picture presented by the enlarged vein was a very striking one. On the right side was a vein of normal size; on the left side was a vessel which was three to six times as large as, and whose course deviated more or less from, the normal. The enlarged vessel sometimes ran underneath or around one or more nerve roots. In one case the vein was very tortuous, so that it might fairly be called "varicose;" in another instance only the branch of the vein which accompanied the nerve root at the level was enlarged. In still another instance a branch of the large vessel —itself three or four times as large as normal—entered the substance of the spinal cord near or in the posterior median septum. In all of the patients the enlarged vein lay on the left side of the cord—in some part of the dorsal region in five, and in the lumbosacral region in one case.

In all of the patients the greatest (or only) enlargement of the vein was found at the exact level of the symptoms, and on the side on which there had been root pains. It is fair to presume, therefore, that there was some connection between the enlargement of the vein and the cord symptoms. Whether the venous enlargement was the primary condition (which I doubt) and the cord disease was secondary, whether the reverse was the case, or whether both played a part, it is impossible to state.

In two of the patients the symptoms were so similar to those of a spinal tumor that a diagnosis of tumor had been made. In one patient the enlarged vessel lay in the general region occupied by a tuberculoma which was successfully removed from the substance of the lower dorsal cord. In several cases no preoperative diagnosis could be made, but an exploratory operation was performed on account of symptoms of cord disease at a definite level.

The discovery of the enlarged or varicose vein was made at the operation in each instance. When the laminectomy had been done and the dural sac had been opened, the enlarged vein was at once noticeable. That the enlargement was not a temporary one, due perhaps to the exposure of the cord and the change in pressure conditions, was proven by the fact that the spinal vein of the other side appeared normal in size and position.

Up to the present time only one excised vein has been subjected to microscopical examination. Dr. Leo Buerger, to whom I am indebted for the examination of the specimen, reported that there was "a hyaline degeneration of the vessel walls."

Although the significance of these enlarged veins is not clear, I have generally excised the piece of vein at the operation. The enlarged vein can be raised from the cord by means of a strabismus hook, and ligatures of fine silk passed around the vessel by means of a small aneurism needle. As these veins are easily torn, great care must be taken. If the vein which accompanied the posterior root was larger than normal, the root vein was always excised down to the dural opening.

Of the six patients, two had a spastic paraplegia with level sensory symptoms of long standing, and these patients were not improved by the laminectomy and excision of the enlarged part of the vein.

The patient with a tuberculoma of the cord has steadily improved, but it is fair to presume that the improvement was due to the removal of the growth and not to the excision of the dilated vein. In one patient who suffered from severe root pain, and in whom a much enlarged vein ran with the affected root, the pain ceased entirely after laminectomy and excision of the enlarged vessel.

Two patients were thought to have a spinal cord tumor, but nothing excepting a localized enlargement of the left spinal vein was found. Both of the patients had well-marked motor and sensory symptoms, and the operation was followed by marked improvement. One patient, whose history is given below in some detail, completely recovered within three months of the operation.

Case I.—A Turk, twenty-three years of age, was admitted to the Neurological Service of Mount Sinai Hospital on the service of Dr. Sachs, in October, 1914. The patient complained of cramp-like pains in the left side of the abdomen, running down the left lower extremity, of three months' duration. With this there had occurred symptoms of increasing loss of power and spasticity in the lower extremities.

Physical examination showed that the abdominal reflexes were absent on the right side. The knee jerks were exaggerated, left greater than the right. There was no clonus or Babinski. The left leg was weaker than the right. There was a slight tenderness of the spinous process of the ninth dorsal vertebra. The Wassermann and X-ray were negative. The symptoms gradually grew worse, so that one week later

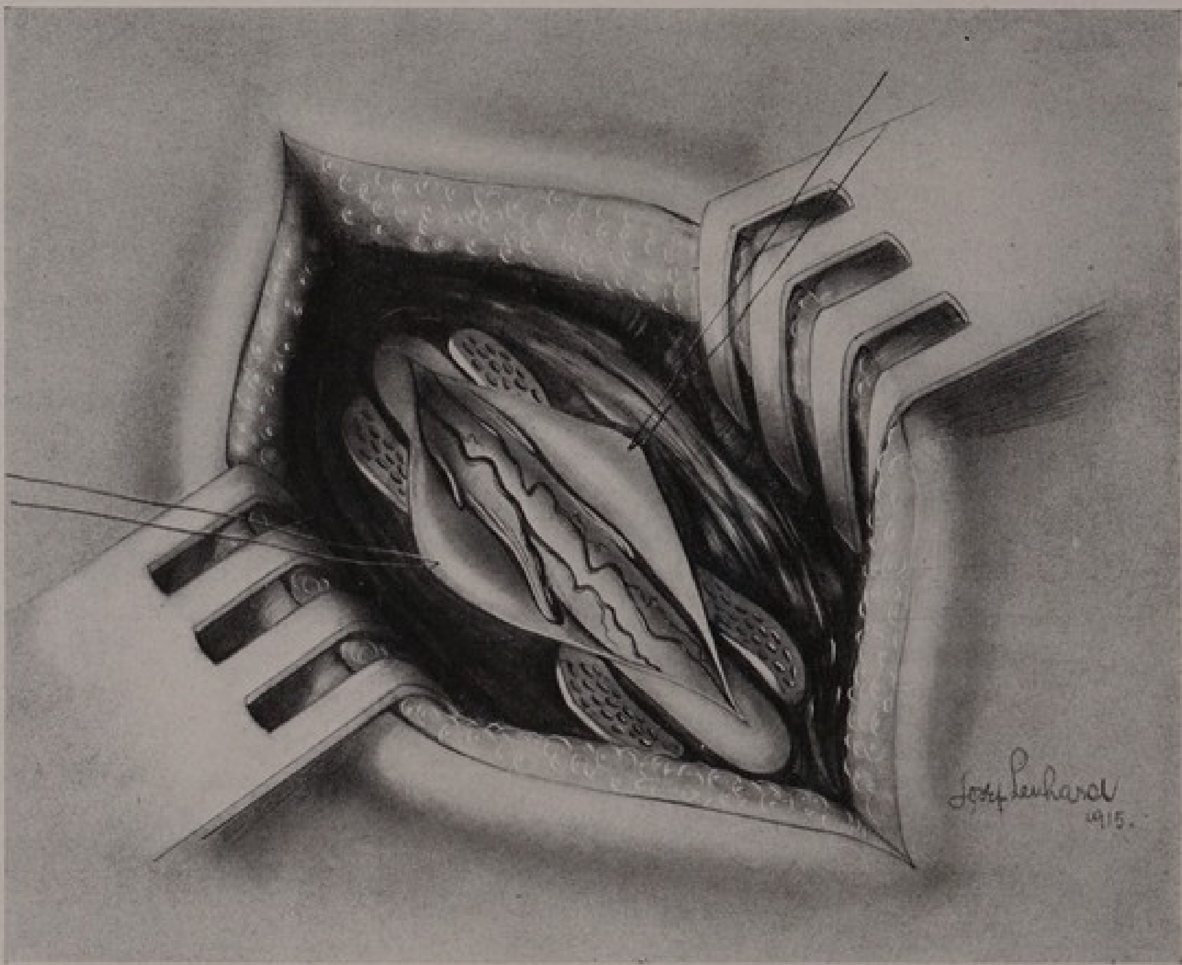


FIG. 104.—Enlarged branch of a posterior spinal vein which accompanied the eighth dorsal spinal root on the left side.

he had slight Babinski of the left side with exhaustible ankle clonus and spasticity of the left lower extremity. The sensory signs consisted of almost complete loss of pain, temperature and touch of the right lower extremity up to the level of the ninth dorsal segment. The symptoms therefore pointed to a focal lesion surely extramedullary, probably in the left anterolateral region between the eighth and tenth dorsal segments.

Laminectomy was performed (Dr. Elsberg) on October 16, 1914. The spinous processes and laminæ of the seventh, eighth and ninth dorsal vertebræ were removed in the usual manner. When the dura was opened there was an escape of a large

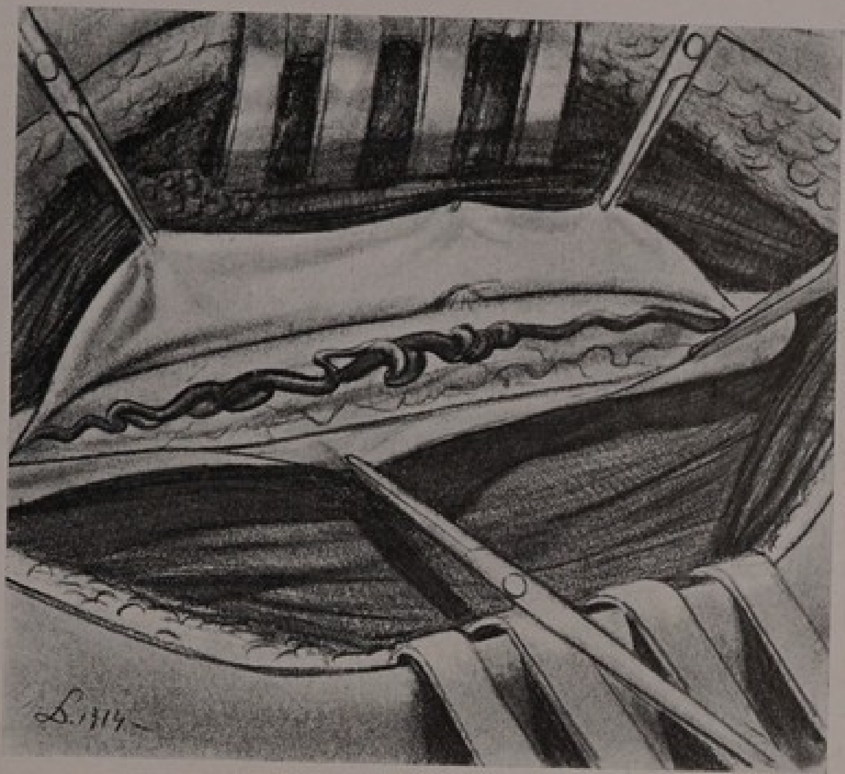


FIG. 105.—Abnormal varicose vein on the posterior surface of the cord.

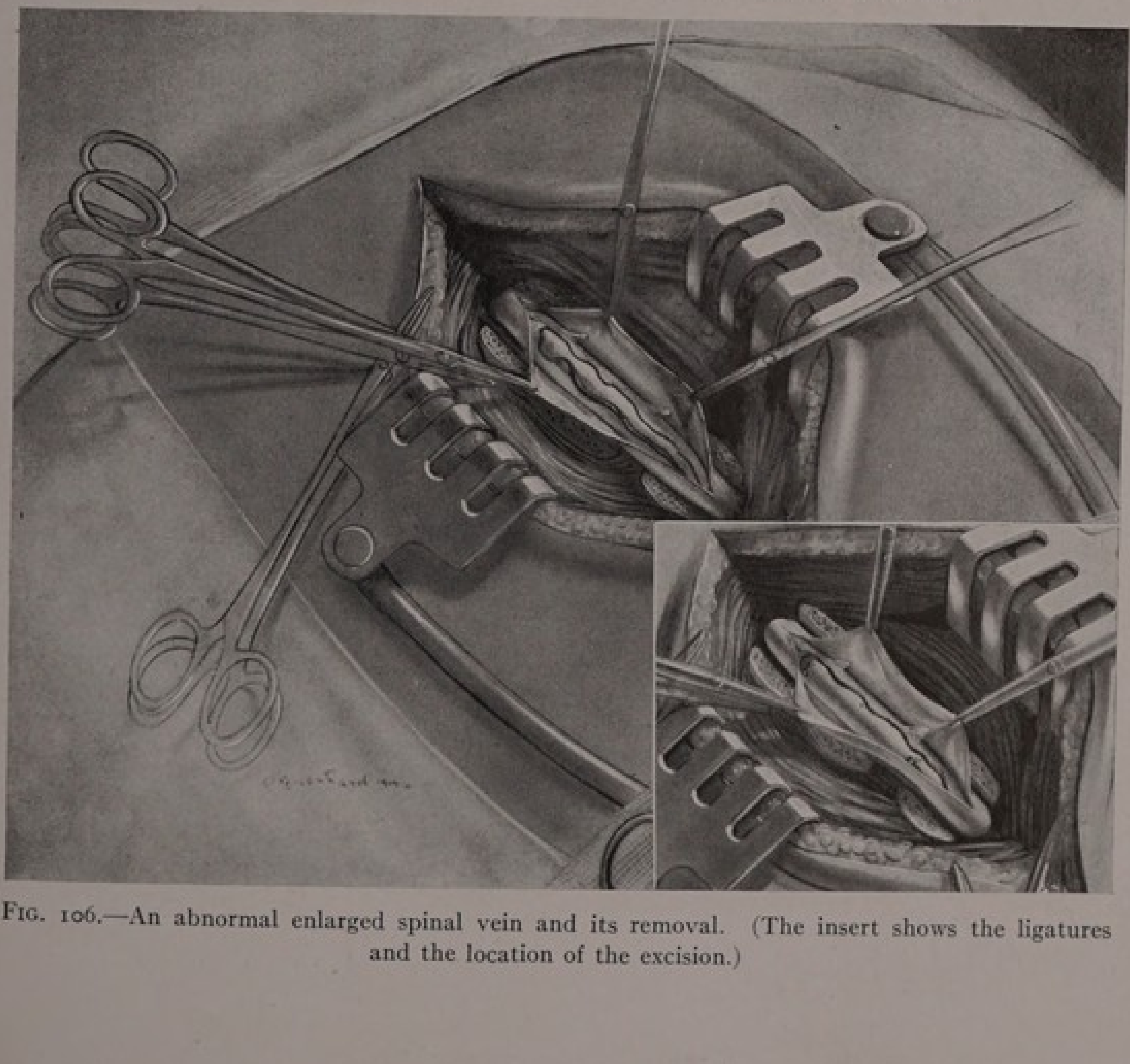


FIG. 106.—An abnormal enlarged spinal vein and its removal. (The insert shows the ligatures and the location of the excision.)

amount of cerebrospinal fluid. Surfaces of the cord were found normal. The fifth and sixth dorsal spines and laminæ were then removed and the dura incised in an upward direction. It was then seen that the right posterior spinal vein ran a normal course, while the left was much enlarged and ran, together with the eighth left posterior root, through the opening in the dura (Fig. 104). The vein was almost again as large as the nerve root. The vessel was tied off at the dural opening and about 2 cm. of it excised. The wound was closed in the usual manner.

Convalescence from the operation was uncomplicated. The patient was out of bed in two and a half weeks; the symptoms improved rapidly; by November 2 all of the sensory and most of the motor symptoms had disappeared. Three months later he was entirely well.

It may be that in the patient whose history has just been given the result was due to the decompressive effect of the laminectomy rather than to the excision of the enlarged vein. Pearce Bailey and I have shown that the free opening of the spinal canal, and the entrance of air into the subdural space, has a very striking influence upon the spinal cord and may, and often does, affect some change which temporarily or permanently benefits or checks the symptoms of local spinal disease. This may be the explanation for the improvement in the last two patients above referred to. In the present state of our knowledge of abnormalities of the posterior spinal veins, it seems to me advisable to excise the enlarged part of the vein whenever possible.

# CHAPTER XVI

## FRACTURES AND DISLOCATIONS OF THE VERTEBRÆ, WITH INJURY TO THE SPINAL CORD AND NERVE ROOTS. BULLET AND STAB WOUNDS OF THE CORD

### RECENT INJURIES OF THE CORD

For the proper understanding of the symptoms that may follow a fracture or dislocation of a vertebra a thorough knowledge of the mechanism of dislocations and of fractures of the vertebral column is necessary. This subject is always fully considered in text-books on general surgery, and I shall give only a résumé of the main facts so that the symptoms and the treatment of the spinal cord lesions may be fully understood.

Injuries to the vertebræ occur either through direct or indirect violence. Those due to direct violence follow a blow or fall upon the back, a run-over accident, etc. The arches of the vertebræ and the articular and transverse processes are primarily affected; if the violence of the injury is sufficiently great, the bodies of the vertebræ are also involved. The larger number of injuries are, however, caused by indirect or by a combination of direct and indirect violence, by trauma in the long axis of the body (blows or falls on the head, falls on the feet from a height), by overextension, overflexion or overrotation of the spinal column. The vertebral injuries occur in many combinations, so that it is often impossible to recognize any regularity between the force which inflicts the damage and the lesion which results from it. The many joints and bony processes surrounded and held together by strong ligaments and large muscles are an explanation for the remarkable strength of the vertebral column, its wonderful elasticity, and its resisting power to injury. If, however, through an unfavorable position of the column at the moment of the trauma or through the excessive degree of the force, some part of the bony or ligamentous structures gives way, then the very features of strength may become factors of weakness.

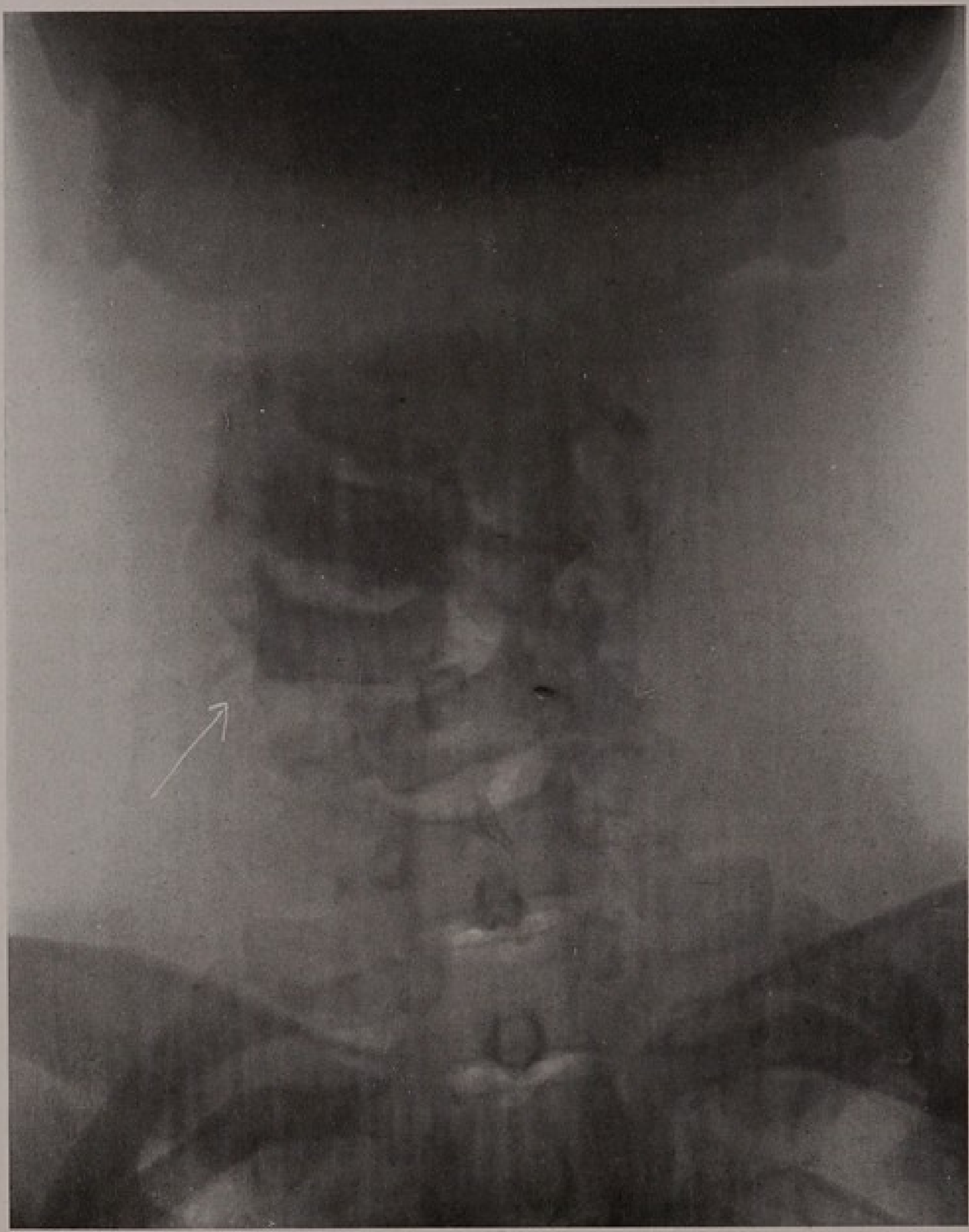


FIG. 107*a*.—X-ray of fracture dislocation of the fourth and fifth cervical vertebræ. The patient was a professional high diver who fell a distance of 80 ft. He presented no symptoms excepting stiffness of the neck and slight weakness of the right arm. (I am indebted to Dr. Ernest Fahnestock for permission to use this and the following plate.)

If the ligamentous structures yield temporarily, a dislocation of one vertebra upon another (which may be reduced of itself with the cessation of the force) will occur. Either because the ligaments have been torn or because bony prominences have become interlocked or entangled, the dislocation may persist.

If the force is very great but the ligaments resist, the bones or part of them must yield and a vertebral fracture results. The bones may remain in an abnormal position or the fragments may slip back into their normal relation to each other.

Very frequently, however, there is a combination of overstretching or of rupture of ligaments and of fracture of the bones. The bodies of the vertebræ are either fissured or the anterior part is crushed so that the body becomes wedge-shaped. Under these conditions there is a great tendency for the vertebra above to be dislocated forward so that the spinal canal is encroached upon and the cord injured. The spinous processes and laminæ of the vertebræ may be fractured and dislocated in a great variety of ways, and with fractures of the spines and laminæ injury to the spinal cord and nerve roots by sharp fragments of bone is very frequent.

The spinal canal is formed by the vertebræ and by the ligaments which connect them; it will be of interest to inquire what effect upon the size and shape of this canal the injuries we have outlined will have.

If the dislocation of the vertebræ or of the fractured fragments is momentary, the bones at once returning to their normal relation to each other, the deformation of the spinal canal is also only momentary.

If, on the other hand, the changed relation of bones or of fractured fragments persists, deformation of the spinal canal must of necessity follow. If the body of a vertebra is flattened or crushed, the spinal canal is shortened by as much as the vertebral body is diminished in size; if with this shortening there is also a change in the longitudinal axis of the bones or fragments, then the canal becomes narrowed or its general direction becomes changed and an angulation occurs. In this type of injury the canal is bent and narrowed, flattened from before backward or from side to side, and the intervertebral foramina are reduced in size.

If a vertebra or a fragment which involves part of the wall of the spinal canal is dislocated, a deformity of the spinal canal must follow and some part of its wall become uneven. The greater the dislocation, the more is the lumen of the canal changed or narrowed. With a great amount of dislocation, the lumen of the spinal canal at one point may be entirely obliterated. The long posterior ligament which covers the posterior surfaces of the bodies of the vertebræ offers a great resistance to an injury of the dural sac and the spinal cord from in front. If the ligament remains intact, a sharp angulation of the cord over a prominence of a fractured and dislocated vertebra can not occur; when the ligament is torn, the fractured vertebra can be dislocated backward into the spinal canal.

If instead of dislocation or fracture of bone, or of a combination of both of these, there is only a rupture of a ligament, this ligament may project into the canal and cause a deformation of part of its wall. From all this it is evident that many combinations occur and that the changes in the shape and size of the spinal canal may vary within wide limits.

In the cervical region the spinal canal is large, the vertebræ are relatively small, the arches thin, and the bones are more freely movable upon each other than in the dorsal and lumbar regions. In the middle and lower dorsal and in the lumbar spine the canal is relatively small, the vertebræ are large, their processes short and thick and held together by strong ligaments. In the cervical region a less degree of violence may cause a dislocation or fracture than in the lower dorsal and lumbar spine. Dislocations are frequent in the cervical region (first to seventh, most often fourth to sixth), but a dislocation without fracture is rare in other parts of the spine. Fractures occur in every part of the vertebral column, most often in the midcervical, upper and lower dorsal and upper lumbar regions.

The real importance of a spinal fracture or dislocation depends upon the amount of harm that has been done to the contents of the spinal canal—the spinal cord and its nerve roots. The cord is suspended in the dural sac by the nerve roots and the dentate ligament; it is surrounded and protected by the fluid in the subarachnoid space, by the dura, and by the extradural fat. The cord, therefore, has considerable range of motion and is elaborately protected against injury.

The nerve roots, especially the roots of the cauda equina, may be

FIG. 107*b*.—Lateral view of the case shown in Fig. 107*a*.

entirely divided or torn by the violence of a trauma or by sharp fragments of bone; more often, however, they are compressed or contused. Very often the injured roots belong to higher segments of the cord, on account of the oblique course of the nerve roots in the lower dorsal and lumbar regions.

The spinal cord may not be injured, although the canal has been markedly narrowed or deformed. It is surprising how often the X-ray will show marked changes in the spinal canal in patients who do not present cord symptoms. In some instances marked cord symptoms are supposed to be due to spinal concussion, but careful microscopical examination will always show evidence of intramedullary lesions. If the cord has been bruised, it becomes swollen and bluish in color due to edema and to small intramedullary hemorrhages or to the rupture of a larger blood vessel (hematomyelia). This acute edema may cause all the symptoms of a complete transverse crush of the cord; it is of a very destructive nature and may, unless quickly relieved, result in disintegration of the cord in its transverse diameter.

Without having been actually injured, the cord may be compressed and flattened by pressure of dislocated or fractured bone, or by a large amount of blood in the subarachnoid or extradural spaces. These patients may at first present all of the symptoms of a transverse lesion, but recovery may take place after the blood has been absorbed or bony fragments have been removed.

**The Symptoms of Spinal Lesions after a Vertebral Trauma.**—From all that has been said, it is evident that the symptoms may vary within wide limits. The patients may, however, be divided into two classes:

1. *Those who present from the beginning the signs of a complete transverse lesion of the cord*, with loss of motor and sensory power up to the level of the lesion, disappearance of cutaneous and tendon reflexes and loss of control of the bladder and rectum. If the patients actually have a complete transverse lesion, the symptoms are usually permanent and death occurs after days or weeks, or after the expiration of a longer time. If the fatal outcome is delayed, death results from sepsis due to rapidly enlarging bed sores, cystitis and pyelitis, or from progressive ascending softening of the spinal cord. The patients soon begin to have irregular fever and a rapid pulse, and they usually die with the signs of hypostatic pneumonia.

In a certain number of cases the signs and symptoms of complete transverse division of the cord begin to disappear after a few days, and more or less improvement occurs. I have seen several instances in which the patients recovered entirely. In most of the patients some loss of motor and sensory power with muscular atrophies remains.

2. *Patients who Present the Symptoms of a Partial Injury to the Spinal Cord.*—When only a part of the spinal cord has been injured, the paralysis and sensory loss below the level of the lesion are not complete, although within a few hours or a few days all the signs of a transverse crush of the cord may be observed. In the patients with a partial lesion a certain amount of motor and sensory power remains. In some instances there are very slight sensory changes, but the motor loss is very marked; in others there is a typical Brown-Séquard picture; in still others some muscles are paralyzed while others are weak, and sensory loss is marked in some of the areas of distribution of the posterior spinal roots. Marked and rapidly advancing atrophy of groups of muscles is of almost usual occurrence.

The cutaneous and tendon reflexes may be entirely lost for the first twelve to twenty-four hours, but very soon there is a marked spasticity of the affected limbs with increase of all the reflexes. Control of the bladder and rectum is very often lost at first, retention of urine and constipation being almost the rule. Severe root pains are very much more frequent with incomplete transverse injuries, but I have seen excessively severe root pain in a patient with undoubted complete transverse crush of the upper dorsal cord. Some of the patients with a partial injury of the cord soon begin to improve, motor and sensory power returns, the control of the bladder and rectum is regained; finally the patient is left with some weakness and spasticity of one or more limbs, with some atrophied muscles and sensory disturbances. Very few patients recover entirely, the degree of improvement depending upon the amount of injury to the cord.

**Clinical Symptoms at Different Levels of the Cord.**—In the majority of instances fractures and dislocations of the first and second cervical vertebræ are immediately fatal. Cases of recovery have, however, been observed (Borchard, the writer, etc.) and, in rare instances, the fracture has produced few if any symptoms and has been recognized only after an X-ray examination has been made. The patients may remain alive for a few hours or days with marked bulbar symptoms and with pain in the distribution of the upper cervical nerves. Death may occur suddenly as a result of a movement of the head, as in sneezing or coughing.

Fig. 108.—The position taken by a patient with fracture of the spine at the fifth cervical level.

Fractures of the third and fourth cervical vertebræ, with injury of the spinal cord, cause death in most cases from respiratory paralysis (phrenic nerve).

Injuries in the cervico-dorsal region, opposite the cervical enlargement of the cord, usually present very characteristic symptoms. There may be a more or less complete paralysis of the muscles of the lower extremities and the trunk, with a partial paralysis of the muscles of one or both upper extremities. The lower the injury to the cervical cord, the smaller the amount of motor loss in the upper extremities. Thus if the fifth and sixth cord segments are not injured, the deltoid, biceps, brachialis anticus and the supinators are not involved, although the muscles of the forearms and hands may be paralyzed. As Thorburn has pointed out, these patients have their upper extremities in a very characteristic posi-

FIG. 109.—The position taken by a patient with fracture of the spine at the seventh cervical level.

tion—the arms are abducted, the forearms flexed and rotated outward (Fig. 108), while if the lesion is in the sixth and seventh vertebræ, the arms are somewhat abducted and the elbows flexed upon the chest (Fig. 109).

If the injury is below the first dorsal vertebra the power of the upper extremities is often entirely preserved. Distinct weakness of the triceps is, however, often observed.

The sensory disturbances are due to nerve root and to cord involvement. Severe pain in one or the other shoulder and down the arm is prominent in injuries of the sixth cervical to first dorsal vertebræ, and there may be marked root hyperesthesias or root anesthesias over the shoulder, in the axilla or on the radial or ulnar sides of the upper extremities. If the cord lesion extends up to the fifth or sixth cervical segment,

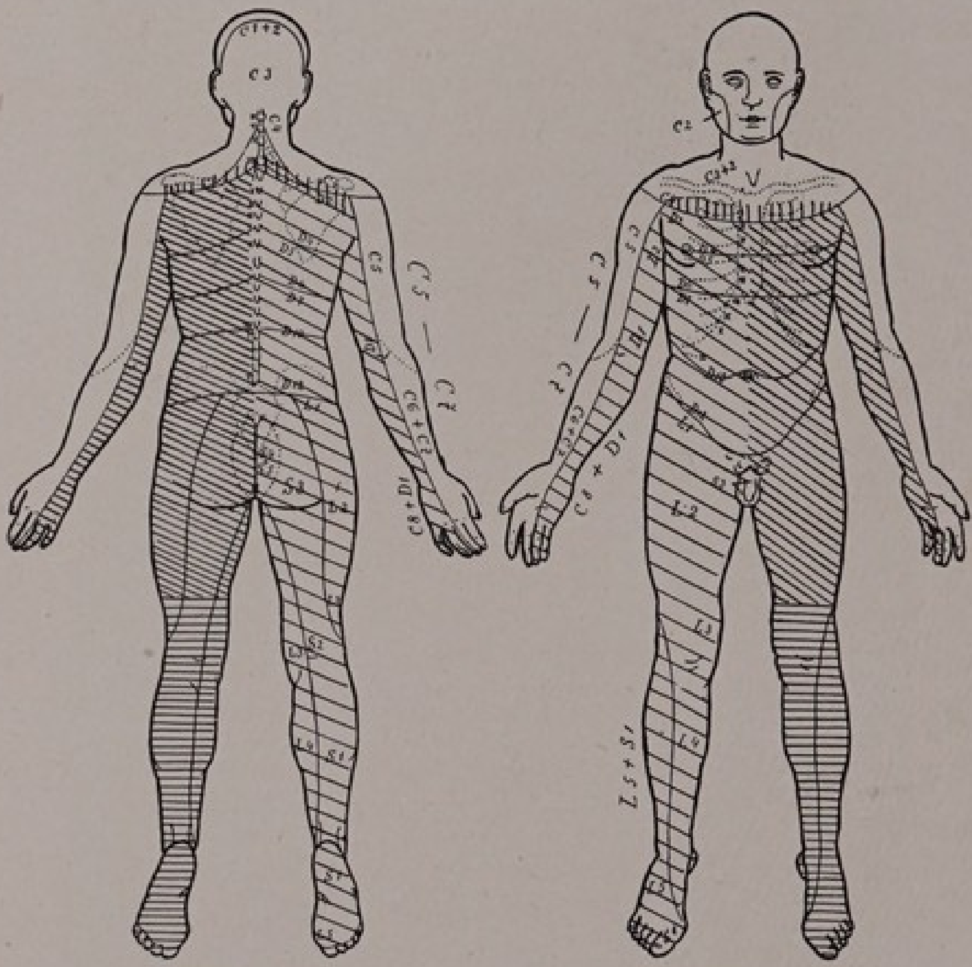


FIG. 110.—Sensory disturbances in the case of a patient with a fracture of the seventh cervical vertebra. Verticals: hyperesthesia; horizontals: complete loss of all sensation; oblique lines: diminution of sensations.

the sensory disturbances will affect also the radial side of one or both forearms; if the lesion does not extend above the seventh cervical segment, only the ulnar sides of the upper extremities are involved (Fig. 110).

Priapism is very frequent in injuries of the lower cervical cord, while oculo-pupillary symptoms (spinal miosis, sinking back of the eyeball) are frequent in lesions involving the first dorsal segment.

The symptoms from injuries of the dorsal and lumbar cord and the cauda equina will be easily understood from what has been said in Chapter V concerning the diagnosis of disease of these parts of the cord.

**The Indications for Operative Interference in Recent Fractures of the Spine.**—A most difficult problem is presented to the surgeon when he is confronted with the question whether there is or is not a complete transverse crush of the cord. In many instances the indications for treatment will depend upon the decision he arrives at. Operative interference in a complete transverse crushing of the cord is useless and frequently harmful, but an operation may be urgently necessary if there is no complete transverse lesion. The difficulty is to determine whether there is a transverse crush or whether the symptoms are due to concussion of the cord or to an acute edema of the cord tissue.

There are undoubted cases on record in which some of the reflexes were preserved or where some of the reflexes returned in spite of the presence of a complete lesion. In the majority of instances, however, a complete motor paralysis and loss of sensation below the level of the injury, with loss of all cutaneous and tendon reflexes and paralysis of the bladder and rectum, point to a spinal cord injury of such severity that immediate operative interference is contraindicated. If the symptoms are due to spinal concussion in which considerable lengths of the cord are affected, a local operation will do little if any good, and it may do much harm.

If, on the other hand, the symptoms are due to an incomplete crush or to compression of the cord, there will surely be some improvement within the first few days, and then operative interference will offer much better chances of success.

When some motor, sensory or reflex power remains immediately after the trauma, and a complete motor and sensory paralysis later supervenes, operative interference should not be delayed, especially if compression of the cord by dislocated or fractured bone or by blood has been demonstrated.

Severe root pains may make a laminectomy necessary under conditions that will be mentioned in what follows.

**The Treatment of Recent Fractures and Dislocations of the Spine.**—The manner in which I have been accustomed to treat the patients is the following:

If the patient is conscious, the level of paralyses and sensory disturbances is determined, and the condition of the reflexes ascertained. If the patient is unconscious, the condition of the reflexes are the main signs of the cord lesion which we can obtain. The patient should be disturbed as little as possible in order to avoid any increase of the cord injury. Very often it is inadvisable to palpate the back in order to feel for any irregularity of the spinous processes, because the necessary change in the position of the patient might increase the injury to the cord. The upper extremities are first examined. If they are found affected, then the level of the lesion is in the cervical cord. If they are normal, then the sensory and motor levels on the chest or abdomen may give us the desired information. The abdominal reflexes and the knee and ankle jerks are then looked for. If complete motor, sensory and reflex loss has occurred, operative interference is not indicated. The patient is kept quiet on the back, or a long, broad, well-padded posterior splint is carefully pushed under the back and fastened with an abdominal binder. By means of this splint it is possible to turn the patient partly to one or the other side. If the fracture is in the cervical region, the splint must extend beyond the head, and the patient's head must be bandaged to the splint and supported on each side by a sand bag. Every possible precaution must be taken against decubitus, and the bladder and rectum must be cared for. A lumbar puncture should be done to determine whether there is a large amount of blood in the spinal canal. The removal of blood from the spinal canal by lumbar puncture will sometimes be followed by a marked improvement in the spinal symptoms. Within a few hours of the time when considerable blood had been removed by spinal puncture, I have seen a partial return of power and of the reflexes in the lower extremities in a patient who had all of the symptoms of a complete transverse crush of the cord. As soon as possible X-ray pictures of the spine must be taken. This can usually be satisfactorily done while the patient is on the posterior splint. If the X-ray shows marked compression of the cord, and if within twenty-four to forty-eight hours there is some return of motor or sensory or more particularly of reflex power in the affected extremities, then operative interference is indicated without delay. Operative interference should be especially quickly done if the X-ray has demonstrated that the arch of a vertebra has been fractured and is projecting into the spinal canal.

The patient should be transported to the operating room on the splint, anesthetized, and then carefully lifted on to the operating table. The utmost care should be taken in placing the patient in the position required

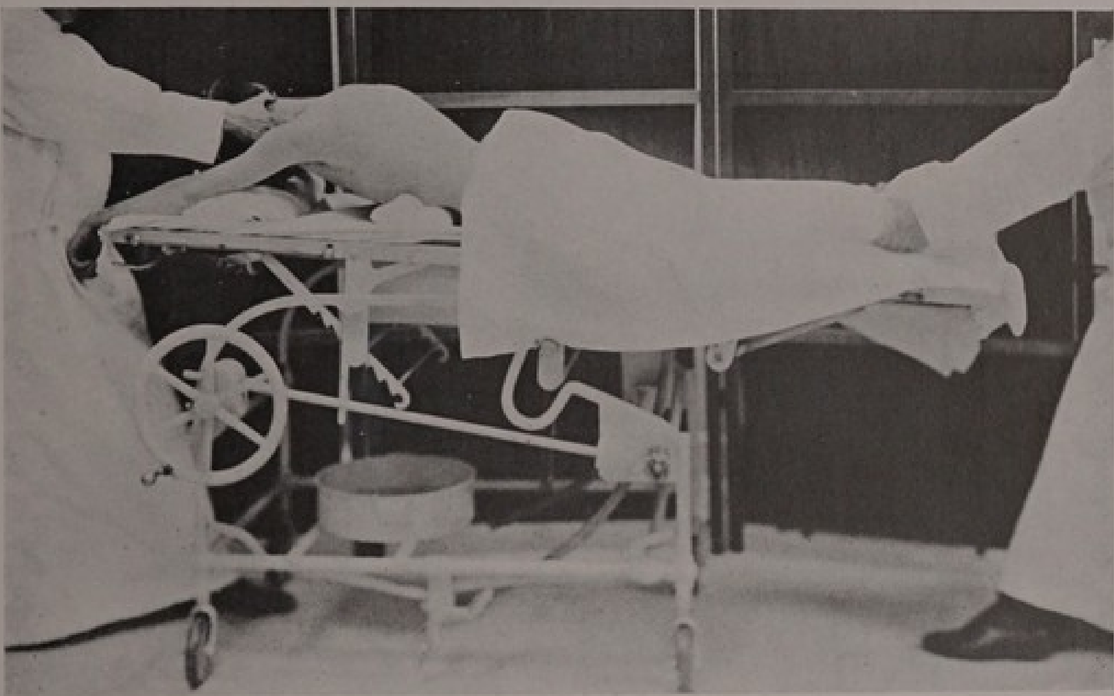


Fig. 111.—The extension procedure in dislocation of the vertebræ.

for the laminectomy, so as to disturb the affected parts of the vertebral column as little as possible.

The operative procedure will depend upon the nature of the injury. If there is a dislocation of the vertebræ, very careful attempts at reduction may be made by extension and manipulation. The operator grasps the patient's head or shoulders while an assistant makes a steady pull on the lower extremities (Fig. 111). If this is not successful, an open operation must be done. Very often the spines and laminæ must be removed as in a typical laminectomy, all fractured fragments being carefully taken away. The dura should always be incised and the cord exposed, but the most extreme caution should be observed in this procedure. As soon as the dural sac has been opened and fluid blood or blood clots removed by gentle irrigation with saline solution, the cord should be very carefully raised by traction of a cut dentate slip or a divided nerve root. If the long posterior vertebral ligament has been

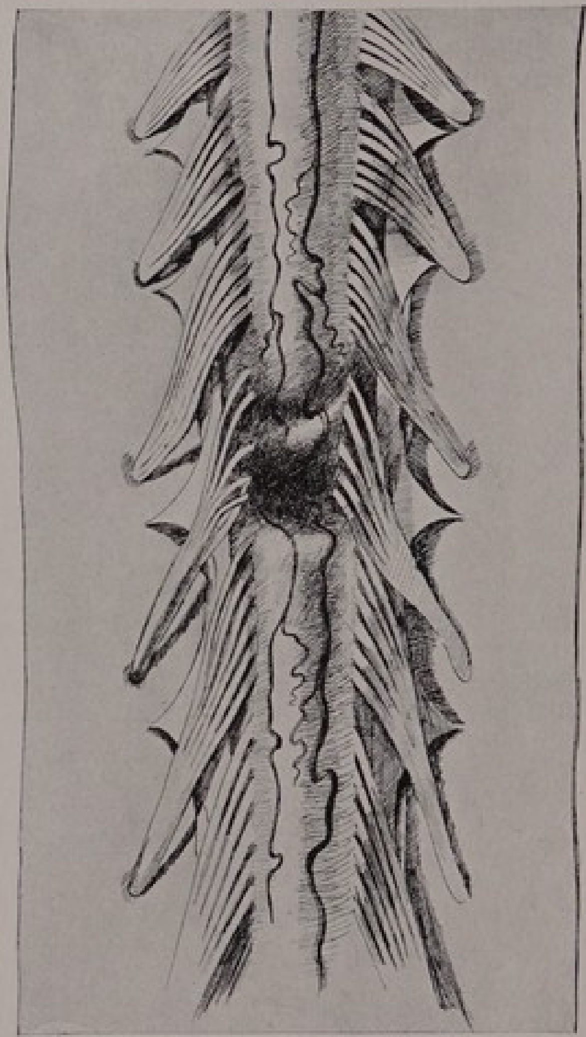


FIG. 112.—Appearance of the crushed cord (Bailey).

torn, and there is a prominence of bone through the dura, this must be removed with small rongeurs. If the projection from the posterior surface of the body of a vertebra is extradural, the dural sac must be carefully drawn to one side and the bony prominence removed extradurally. During this procedure there may be considerable oozing of blood from the extradural venous plexuses on the posterior surface of the bodies of the vertebræ, but this oozing can usually be easily controlled by small gauze packings.

The appearance of the crushed or contused cord varies. It may appear of normal size and color, although it is found to be abnormally soft at one spot. More often, as soon as the dural sac is open, a distinct transverse depression with yellowish or reddish-brown discoloration of the cord is observed (Fig. 112). Sometimes the cord appears swollen, at other times it seems diminished in size. Its consistency is always altered; it is usually less firm than normal, although if there is very marked edema it may feel unusually firm. In very recent cases only a small area of the cord may appear changed; in cases of longer duration three to six segments of the cord have undergone more or less of the change I have described.

If the cord is swollen and edematous, I believe a small incision should be made into it near the posterior median septum. In his experiments Allen has shown that the effect of this incision is a most beneficial one, drainage from the cord tissue into the subdural space being made possible, and the dangerous cord edema being controlled. After as many of the clots as possible have been washed out from the spinal canal, the dura, muscles, fascia and skin are closed in the usual manner and a dressing and posterior splint applied.

If a collection of blood within the substance of the cord is suspected, the cord should be aspirated in the manner described in Chapter XVIII. No attempt should be made to remove broken-down cord tissue, as the removal of softened, almost fluid, cord tissue always has a most deleterious effect upon the adjacent parts of the cord.

If one or more posterior nerve roots have been much injured, it is advisable to divide the affected nerve roots after the surgeon has determined that there is no pressure upon the roots at the intervertebral foramina.

If the lumbar vertebræ have been fractured and the symptoms and signs of injury to the roots of the cauda equina (*q.v.*, page 63) are prominent, the laminectomy should freely expose the roots of the cauda equina. Any nerves that have been divided should be sutured with fine silk.

One may ask, where is the pressing need for operation in patients with "incomplete" cord symptoms? Is it not better to wait and see how the case will progress? It is true that from the standpoint of danger to life no hurry is necessary. But our aim should be to have, if possible, a perfect functional recovery. The constant pressure of bone will cause degenerations in the cord which can never be recovered from; the same is true of intraspinal blood clots, and I have already spoken of the danger of edema of the cord. Most satisfactory results can be obtained by early operation—complete recovery of function—, and good, but incomplete, recoveries follow late operations. In experienced hands the danger of a laminectomy is small. The operation can be done very quickly—under local anesthesia, if necessary. The treatment after the operation does not differ essentially from that after any other operation upon the spinal cord. Nursing is of paramount importance, especially the prevention of cystitis and of bedsores.

The drop-foot may be controlled to a certain extent by having the feet kept at right angles by sand bags. The patient should be placed upon an air or water bed, the sheets kept free from wrinkles or bread crumbs, and hot-water bags should not be used. Especial care must be taken of the buttocks, malleoli, heels and lower portions of the back, and careful attention to the condition of the skin is of primary importance. Prevention is more easy than cure. If sores develop, every effort must be made to protect them from pressure and to get them to heal by the proper treatment. Catheterization must be done with extreme care, for even under the most careful asepsis, cystitis is only too apt to develop. Constipation can be controlled by laxatives and enemata; if there is incontinence of feces, the skin of the anal and gluteal regions must be kept as clean and dry as possible.

**Results.**—The prognosis of a spinal injury is always a serious one, and the fatalities are especially numerous in fractures and dislocations of the cervical vertebræ. Death with medullary symptoms may occur at once or within a few hours or days. In more than 50 per cent. of the cases death occurs within the first week, and fully 70 per cent. succumb to the immediate or more remote effects of the injury. Of the patients that recover, relatively few return to complete health. Many are left with bladder or rectal paralysis or weakness, with more or less motor and sensory loss in one or more extremities. Single or double drop-foot and bladder disturbances most often persist after injuries to the lumbosacral cord; good functional recoveries occur most often after cervical injuries. One arm may remain paralyzed or weak, or only some of the motions of the limb may be lost. Atrophies in the small muscles of the hands are very frequent. One or both lower limbs may remain weak and stiff for a long time. While complete loss of sensation over definite areas may persist in these incomplete lesions, a partial loss of sensation, especially of deep muscle sense, is more frequent. In considering the individual results, much depends upon the region of the cord affected and the extent of the injury. The more quickly the symptoms improve, the better is the outlook, and it is rare that a good restoration of function in the limbs is not shown by marked improvement within the first few weeks. Occasionally, however, improvement begins after several months have passed, as in one of my patients who recovered almost completely within one year of the accident.

Bladder paralysis and the early appearance of bedsores make the outlook a grave one, although even these patients may finally recover, the bedsores may heal and control of the bladder be regained. Some patients, who seemed to have a transverse lesion of the cord for many months, finally regained some motor control. If there is marked spasticity, this may be greatly improved by judicious division of posterior roots.

With careful nursing, an individual who has a transverse lesion of the cord may remain alive for many months or years. Sooner or later, however, cystitis occurs followed by ascending infections of both kidneys.

The patients with cervical cord injury often develop a progressive ascending softening of the cord, with which are associated high and irregular fever and a rapid pulse. The occurrence of high fever in injuries of the spinal cord, if not due to cystitis or to bedsores, is always of serious importance, and contraindicates any operative interference.

The disrepute into which operations for recent fracture of the spine with injury to the spinal cord have fallen is due to a great extent to the fact that patients with a transverse cord lesion have been operated upon.

A few years ago De Quervain showed from a large collection of cases that fully three-fourths of the patients with spinal fractures subjected to operation were not benefited and should never have been operated upon. De Quervain collected 218 cases subjected to operation. Of these, 13.8 per cent. were cured, 22 per cent. were improved, 37.2 per cent. were unimproved, 1.8 per cent. made worse, and 25.2 per cent. died from the operation.

Burrell collected 244 cases of fracture of the spine with a mortality of 64.5 per cent. In the cervical region the mortality was 85.7 per cent.; in the dorsal, 76.7 per cent.; in the lumbar, 50 per cent. Of 185 operations for fracture of the spine collected by Lloyd, 50 per cent. died and 34.6 per cent. recovered and were improved. In 82 of the patients the operation was performed quickly after the injury; of these, 72.2 per cent. died and 20.7 per cent. recovered or were improved. Chipault's collection of 167 operations showed that only 21.5 per cent. recovered or improved, a mortality of 78.5 per cent., while Thorburn reported 56 operative cases with 67.8 per cent. mortality. The statistics of others are not even as good as these, some failing to save a single patient who was subjected to operative interference for an injury to the cervical spine, while others had one or two recoveries among a large series of operations. If the cases are carefully selected, the operative results should not be as poor as those quoted and, based upon my personal experience and a study of the literature of the subject, I believe that the results of operative interference are steadily improving. The surgeon who sees many cases and operates only upon the selected ones will have the best results. The greatest improvement will occur in fractures of the lower dorsal and lumbar regions.

### THE REMOTE EFFECTS OF INJURIES TO THE SPINAL CORD AND NERVE ROOTS, AND THEIR TREATMENT BY OPERATION

The belief is now prevalent that the surgeon should be extremely conservative in making the indications for operative interference in fresh fractures of the spine. As a result, the surgeon will see patients many months or years after their injury with the most varying symptoms and signs of cord and nerve root lesion.

Of the patients who have survived after the spinal injury, a certain number remain alive with the symptoms of a transverse lesion for long periods of time. With careful nursing the bedsores gradually heal, cystitis is prevented or kept under control, and life may be preserved for years until the patient succumbs to double kidney infection or to some intercurrent disease.

The patients with signs of a partial cord injury often improve to a marked extent, a certain number of them recovering entirely. Most of the patients, however, improve up to a certain point and are left with weakness or spasticity of an arm or leg, with more or less disturbances of superficial sensation and of deep muscle sense, with some bladder disturbances. Most of the improvement that will occur will show itself within about twelve to eighteen months from the time of the injury.

In others the improvement is marked for a few months; then the symptoms become aggravated, the spasticity and weakness of the limbs increase and bladder and rectal symptoms reappear. In still others the symptoms of cord injury are not marked for weeks or months after the accident, but after a time signs of serious and progressive interference with the cord functions appear.

The progressive symptoms are sometimes due to excessive callus or to new-formed bone which diminishes the lumen of the spinal canal. This new bone formation may cause pressure upon the spinal cord or may distort the spinal canal so that the cord becomes markedly angulated. Sometimes the patients suffer from severe root pains which can be relieved by the removal of new-formed bone or the division of the affected nerve roots. I have recently operated upon a patient who had suffered a fracture of the lumbar spine two years before, but had recovered entirely excepting for an area of anesthesia over the distribution of the third lumbar posterior root on the left side. The patient complained of severe shooting pain over the area of anesthesia which caused him great suffering. At the operation some of the nerves of the cauda equina were found to be bound together by a cicatricial band. The division of the scar tissue and of the affected nerve root at once gave entire relief (Fig. 113).

The patients with an old fracture of the spine are seen because of persistent root pain, persistent loss of control of the bladder, weakness and atrophy of one or more extremities, spasticity of the lower limbs, or sensory disturbances of various kinds.

Persistent root pains can usually be relieved by laminectomy with removal of bone, separation of adhesions and division of posterior

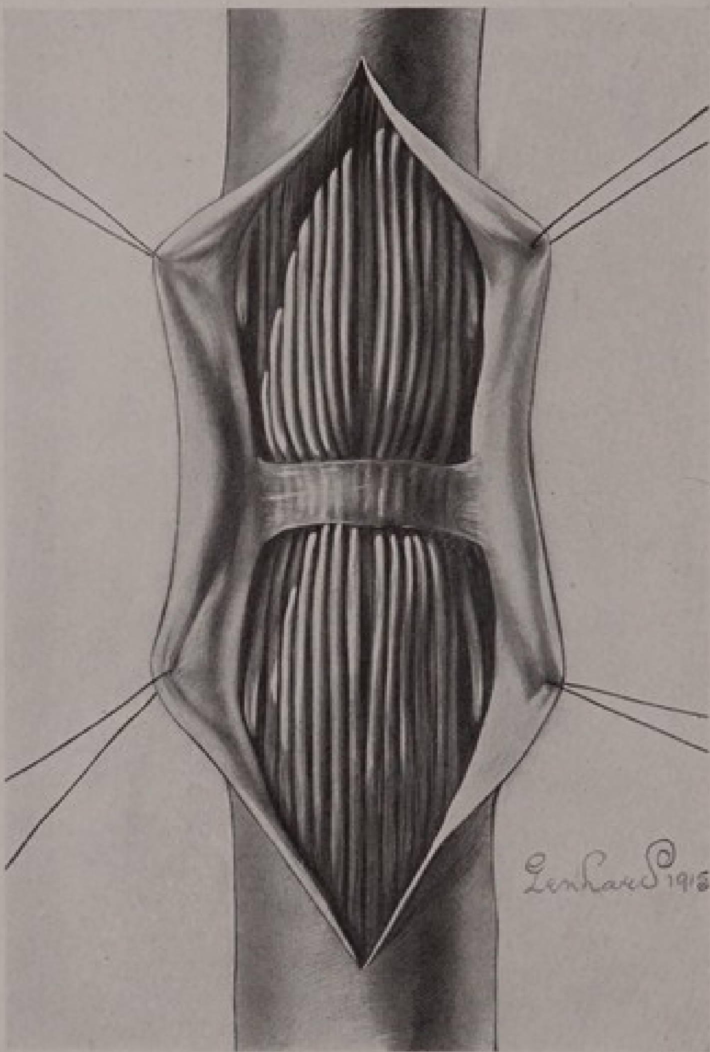


FIG. 113.—Compression of the nerves of the cauda equina by a band, the result of a spinal fracture (much enlarged).

roots. For the bladder disturbances very little can be done, although an intradural nerve anastomosis has been performed between the first lumbar and the third and fourth sacral posterior roots (Frazier) with considerable improvement eight months later. Cadwalader and Sweet made a number of intradural root anastomoses in animals, but they failed to observe either a return of function or a regeneration of the nerve roots that had been divided. All bony prominences should be removed, adhesions between the membranes and the nerve roots separated and localized cysts or hematomyelia cavities in the cord incised.

The patients who are seen by the surgeon one to two years after the injury, and in whom the question of an operation is raised, usually present the following symptoms: If the cervical cord was injured, one or both upper extremities are weak and there is more or less atrophy of the affected limb or limbs with sensory disturbances. The atrophy is generally most marked in the small muscles of the hands, although any of the muscles of the limbs may be affected. Abduction of the arm may be much limited, so that the patient is unable to touch his head with the hand of the affected limb.

If the lower lumbar vertebræ have been injured, there are the signs of an injury to the lumbosacral cord or the cauda equina. More or less weakness of the lower limbs with loss of the knee and ankle jerks and double drop-foot are often observed. The sensory loss affects some or most of the lower lumbar and sacral areas, with diminution or loss of sensation around the anus, over the gluteal regions, down the back of the thighs, etc. If the injury has involved the lumbosacral cord, both lower limbs are equally affected; if the nerves of the cauda equina have been crushed, the disturbances in the lower limbs are not the same on the two sides. More or less incontinence of urine and constipation is almost the rule.

I have operated upon a considerable number of patients of this kind. All recovered from the operation and most of them were much improved or entirely relieved of their symptoms. In some a narrowed spinal canal was widened; in others pressure of bone upon nerve roots in the intervertebral foramina removed; in still others a marked angulation of the cord straightened out by allowing room for the dural sac and the cord to bulge backward. The accompanying illustrations (Figs. 114–118) show what conditions can be relieved by operative interference.

The operations were often followed by a striking recovery of motor power in the extremities, as the following short histories will show:

Case 1.—Mary G., patient on the service of Dr. Pearce Bailey at the New York Neurological Institute, 1911. Fracture of vertebræ without spinal symptoms eighteen years before. Three months' history of pain and increasing weakness in lower extremities. Unable to walk for six weeks before operation. Examination shows almost complete paralysis of both lower limbs with ankle clonus and Babinski on both sides. Marked loss of all three sensations over the fourth lumbar to third sacral

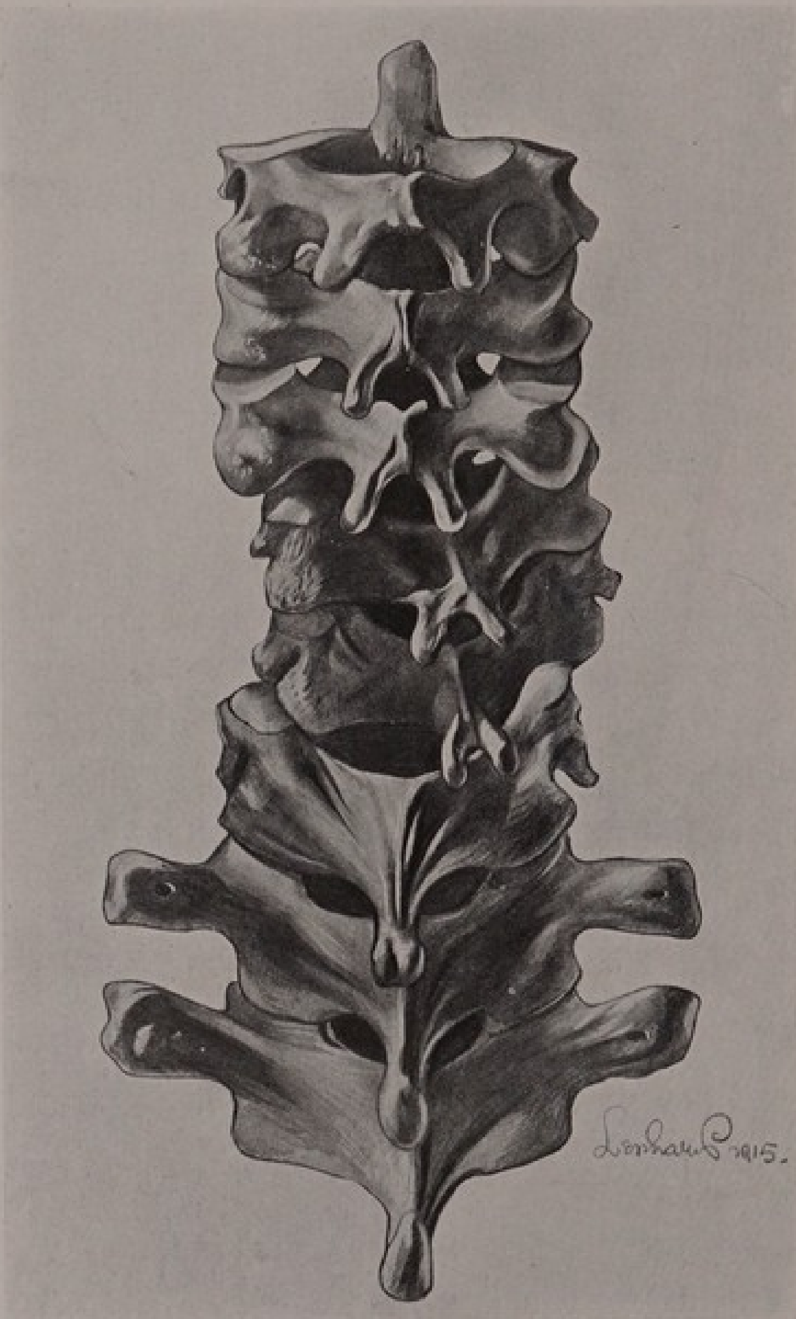


FIG. 114.—Fractured dislocation of the fourth and fifth cervical vertebræ.

segments on both sides. Marked deformity of lower dorsal and lumbar spine, most marked at second lumbar. X-ray examination shows marked thickening of affected vertebræ (Fig. 30, page 80).

At the operation a large amount of new-formed bone, which compressed and bent the cord (Fig. 119), was removed. In the course of three months all of the motor and sensory symptoms, excepting some root pains, disappeared and the patient regained full control of her lower extremities.

CASE 2.—Laura L., thirty-six years of age, service of Dr. Collins at the New York Neurological Institute, 1911. Fell from wagon two years before, after which she was in bed for two weeks. After that was entirely well until six months before admission

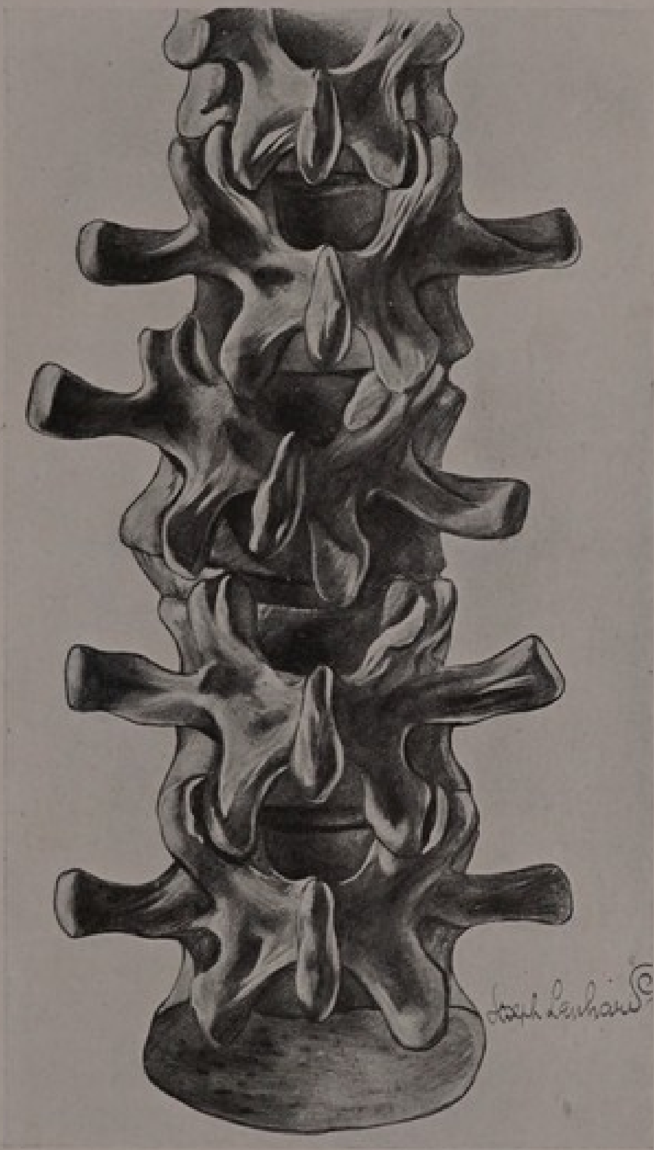


FIG. 115.—Fracture dislocation of the third lumbar vertebra.

to the hospital. Increasing pain and paralyses of lower extremities, so that patient is bedridden. Examination shows very great weakness of both lower limbs, most marked on left side, double drop-foot, absent knee and ankle jerks, atrophy of muscles of left thigh, marked loss of all sensations over third and fourth sacral areas, stiffness of lower dorsal and lumbar spines. Operation, December 28, 1911, showed old fracture and crushing of third lumbar vertebra (Fig. 115) with angulation and compression of roots of cauda equina (Fig. 116). Removal of spines and laminæ of tenth, eleventh, twelfth dorsal and first lumbar vertebræ, thereby relieving compression and angulation of cord.

*Result.*—Great improvement within two months. Power in lower limbs returned; drop-foot disappeared; sensory disturbances disappeared. Three months later patient walked around freely and returned to her housework.

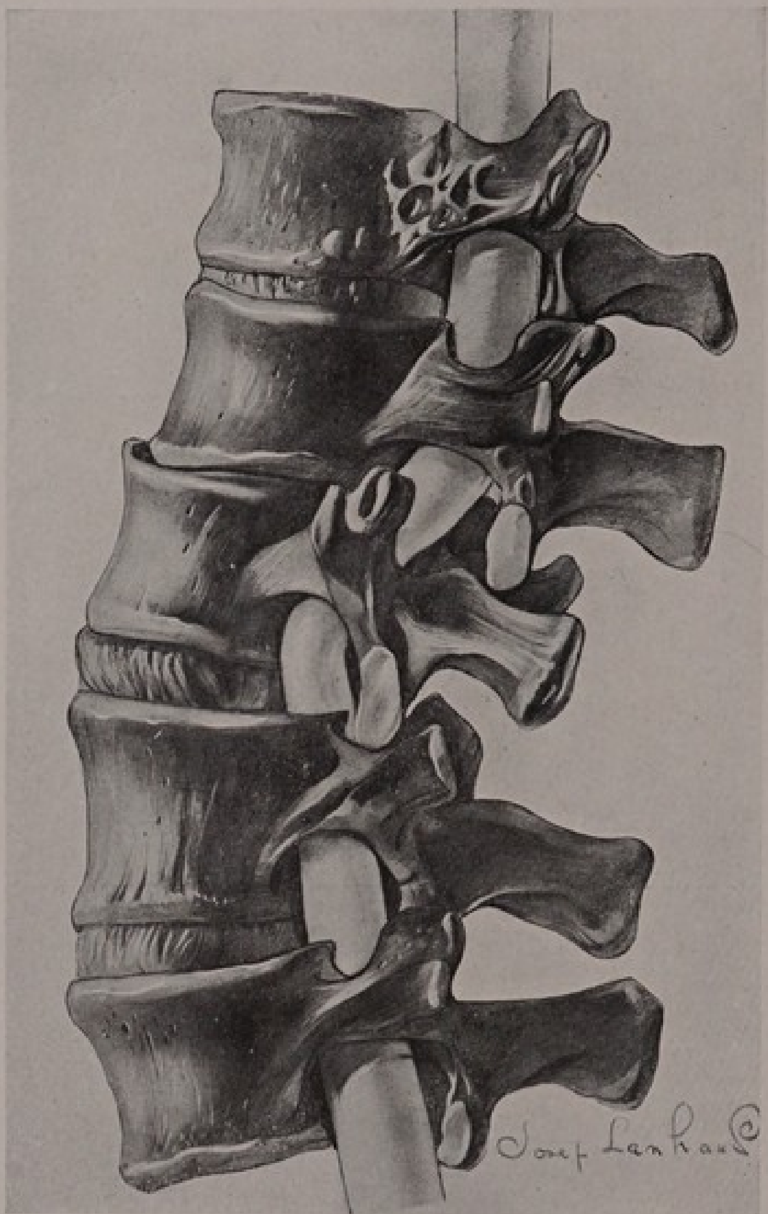



Fig. 116.—Lateral view of the same case as Fig. 115, to show the angulation of the cord.

Case 3—P. H., twenty-seven years of age, patient of Dr. Frederick Peterson at the New York Neurological Institute, 1912. Patient fell down elevator shaft three months before admission, resulting in paralysis of both upper and lower extremities. Gradual improvement for two months. On admission, spastic paralysis of right upper and lower extremities with marked sensory loss on left side of body up to level of fifth cervical segment. Brown-Séquard syndrome. X-ray shows fifth and sixth cervical vertebræ displaced backward with tilting of the fifth on the sixth. Laminectomy, January 26, 1912, shows marked compression and angulation of the cervical cord. Removal of spines and laminæ of fourth, fifth, sixth and seventh cervical vertebræ, relieving the compression of the cord and allowing the dura to bulge backward.

FIG. 117.—Result after operation of the patient (Figs. 115 and 116). The removal of the arches of the third and fourth vertebræ has relieved the angulation of the cord.

*Result.*—Marked and continuous improvement, return of motor power and disappearance of sensory disturbances.

CASE 4.—Alexander G., service of Dr. Peterson at the New York Neurological Institute, 1914. Fell down three stories in 1908, complete paraplegia with loss of control of bladder and rectum for two months. Then gradual return of power. Upon admission, double drop-foot, absent knee and ankle jerks, anesthesia and analgesia over the distribution of fifth lumbar, first, second and third sacrals on left side. Chief complaint is severe pain in the anesthetic area. X-ray shows old fracture of fourth lumbar vertebra. Laminectomy Dec. 4; 1914, removal of arches of second, third, fourth and fifth lumbar and first sacral vertebræ. Spinal canal much narrowed at level of fourth lumbar. Nerve roots, especially those on left side, bound together by a firm band of adhesions (Fig. 113). Division of constricting band and of third and fourth lumbar posterior roots on left side.

*Result.*—Complete relief of the pain

FIG. 118.—Fracture of the sixth and seventh cervical laminæ causing pressure on the dura and cord.

In the lower dorsal and lumbar regions, injury to the spine may cause a rupture of one of the thick ligamenta subflava. These may become inflamed and cause pressure upon the spinal cord or nerve roots. I have operated upon two patients of this kind. Both suffered from severe root pains. Both were entirely relieved by a laminectomy and excision of the swollen ligament. In each case the swollen ligament presented in the wound as soon as the spines and laminæ had been removed.

A thorough after treatment is always important. A few weeks after the operation, massage and electricity, active and passive exercises must be begun, and should be continued as long as there are signs of improvement. Very often the improvement will be slow, but continuous for years, and it is a great error to stop the after treatment too quickly. In

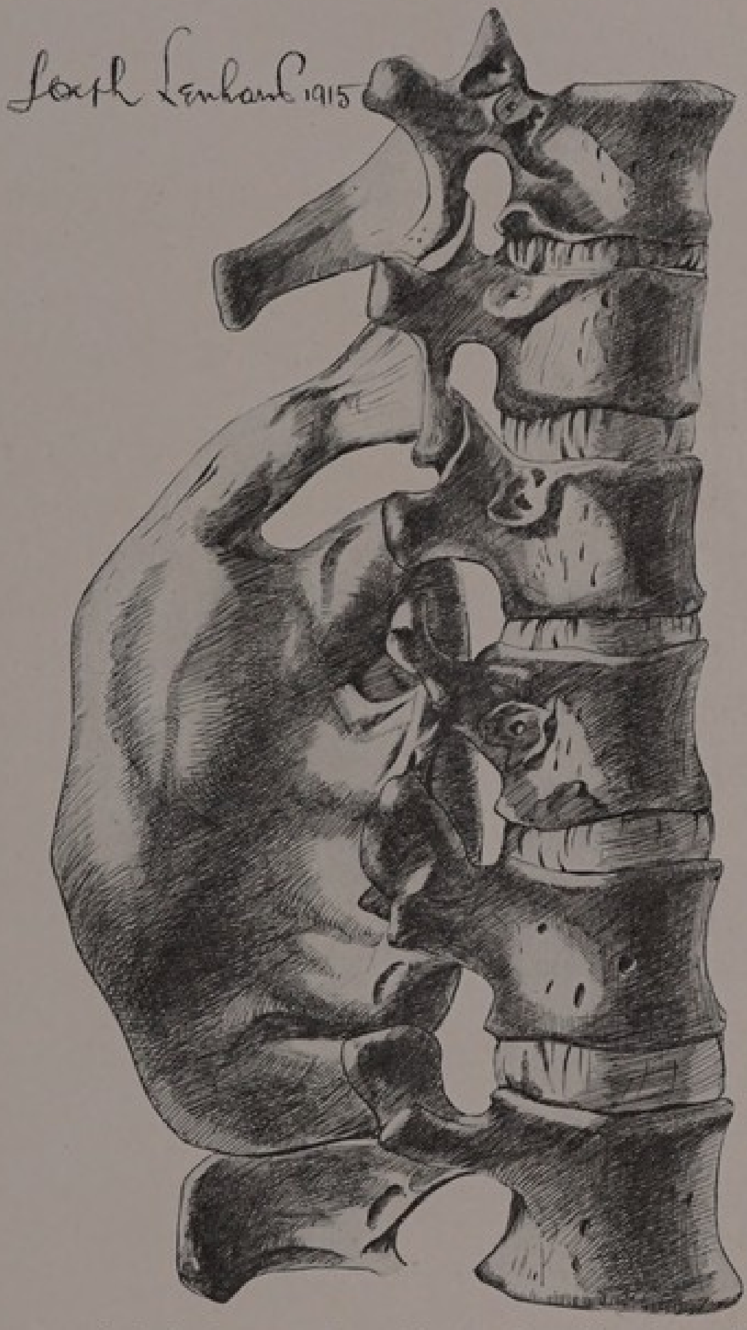


FIG. 119.—Old fracture of the lumbar vertebræ with excessive callous formation, causing marked cord symptoms.

some patients tenotomies or posterior root sections to relieve spasticities may be necessary. Others can be put upon their feet again by means of appropriate splints to the one or the other lower extremity.

Thus walking may be impossible for a patient on account of persistent loss of control of extension at the knee, and this can be compensated by a well-made splint which immobilizes the knee. For drop-foot the patient can wear a shoe which will prevent the stubbing of the toes.

### BULLET AND STAB WOUNDS OF THE CORD

The general symptoms of injuries to the cord by bullets or by cutting instruments are similar to those which are due to spinal fractures, with the difference that the wound is always a compound one and, therefore, the danger of infection is added. With the high velocity of the modern rifle bullet, however, the frequency of infection has become much less, and many wounds heal without suppuration. On account of the great laceration of the soft tissues, wounds that are caused by explosive projectives, especially those due to shrapnel, are almost regularly infected. The injury from the high-velocity bullet may be very exactly limited to one part of the cord and portions of the fiber tracts or entire tracts may be divided with almost anatomical exactness, just as if experimentally produced.

Thus a perfectly typical Brown-Séquard syndrome due to hemisection of the cord, pain and temperature disturbance on one side of the body due to division of the anterolateral tract of the other side, or loss of tactile and deep muscle sense below the level of the injury following division of both posterior columns, etc., have been observed.

The medullary symptoms are due either to actual division of the cord by the bullet, to hemorrhage into the cord substance, to edema, or to secondary inflammation of the meninges. The meningeal inflammatory process may be limited to a small area, so that a localized serous meningitis or pachymeningitis may occur.

When the cord symptoms are due to the penetration into the spinal canal of the missile, the lesion is generally a very grave one with more or less complete destruction of the cord at the affected level. However, cases are known where the bullet entered the spinal canal and remained there, causing little or no injury to the spinal cord (Fig. 120). The presence of the bullet in the spinal canal, as demonstrated by the X-ray, does not, therefore, always mean an irremediable cord lesion. If the symptoms begin to improve within a few days or weeks, a laminectomy should

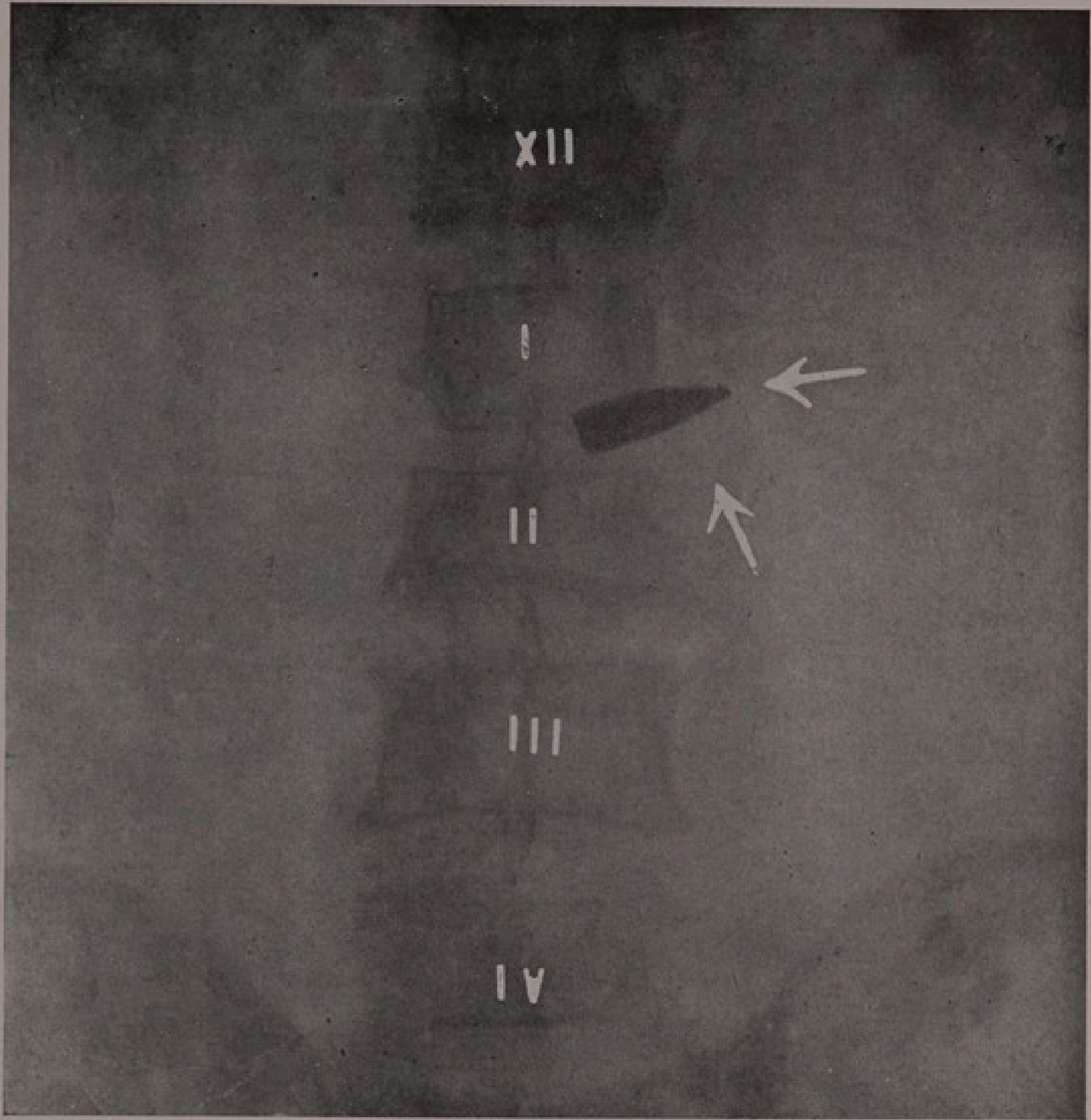



FIG. 120.—X-ray of bullet between the first and second lumbar vertebræ. (Taken by Dr. Jaugeas of the Ambulance of the American Hospital of Paris, and loaned to me by Dr. Richard Derby of New York City.)

be performed and the bullet removed without delay. If the bullet passed through the canal, the X-ray may demonstrate the track of the projectile and may give an idea whether the missile passed through part or the whole thickness of the cord, or whether the cord was only bruised.

In some of the patients the symptoms are not due to direct injury of the spinal cord by the missile but to spinal concussion, and this may occur even though the dura is not injured. As I have mentioned in the consideration of the effects of a spinal fracture, concussion of the cord may be followed by the signs of a complete or incomplete transverse lesion; without any surgical treatment the symptoms—motor and sensory paralyses, bladder and rectal disturbances, etc.—may slowly disappear in the course of a few weeks or months. The explosive effect of the projectile may thus cause a lesion of the spinal cord, although no part of the vertebral column has been injured. The concussion results in intramedullary hemorrhages or in acute edema of the cord tissue, and is often followed by extensive softening. If the intramedullary hemorrhage is a small one, the symptoms of a transverse lesion of the cord will begin to disappear within a few days or weeks unless secondary myelomalacia occurs. Although often followed by softening the same is true of acute traumatic edema of the cord. If it were possible to make the diagnosis of acute intramedullary hemorrhage early, the proper procedure would be to expose the cord at the affected level and to empty the blood by aspiration of the cord. If the edema of the cord could be recognized from the symptoms, a laminectomy and incision of the cord, as suggested by Allen, would without doubt be followed by good results in some instances.

Unfortunately, however, most of the cases present the symptoms of a complete transverse lesion in the beginning and weeks may elapse before the physician can determine that the lesion was not as severe as the symptoms at first indicated.

It is exceedingly difficult, therefore, to give exact indications and contraindications for operative interference in bullet wounds of the spine. With our present knowledge, which will undoubtedly be much enriched by the experiences of the war in Europe, the following general rules may be laid down:

1. When the symptoms are those of a complete transverse lesion of the cord, it is inadvisable to operate unless the X-ray shows that the spinal canal is narrowed or deformed by splintered fragments of bone. In

these cases, however, operative interference should not be attempted, unless some signs of returning power in the limbs appear. In other words, as soon as there is evidence that the cord lesion is an incomplete one, the spinal canal should be opened and fragments of bone or the bullet should be removed. Bullets which have only bruised or compressed the cord have been successfully removed from the spinal canal in a number of instances, and bullets have been extracted from the substance of the cord itself, with good recovery of function, by Braun and by Eisengraber.

2. In incomplete lesions of the cord operative interference should be done within the first few days or weeks of the injury, unless there is suppuration along the track of the bullet, or unless the symptoms are so slight that improvement may be expected without surgical intervention. Not a few of these patients, I believe, will be benefited by the decompressive effect of the operation.

The laminectomy may reveal a lesion which is easily remedied. The dura may be found to be much thickened and infiltrated, and the incision of the thickened portion or its excision may relieve pressure upon the cord. Or the incision of the dura will show a localized collection of fluid between the arachnoid and the dura or underneath the arachnoid, which has compressed the cord and which must be evacuated. Splinters of bone or fragments of the bullet which have caused pressure upon the cord must be removed. The technical procedure does not differ essentially from that of any other spinal operation.

Wounds of the spinal canal by cutting instruments do not differ, either in their symptoms or the indications for their treatment, from the injuries we have spoken of in this section. Foreign bodies, such as knife or sword blades, must, of course, be removed. The surgical indications will depend upon the amount of injury to the cord, and careful neurological examination must determine how much of the motor and sensory loss is due to actual division of cord tissue for which nothing can be done, and how much is due to intra- and extramedullary hemorrhage or inflammation which may be improved by operative interference. Suppuration occurs more often after stab wounds than after bullet wounds, and conservatism is indicated in the former as well as in the latter class of injuries.

## CHAPTER XVII

### TUMORS OF THE VERTEBRAL COLUMN, SPINAL CORD, AND MEMBRANES[1]

#### TUMORS OF THE VERTEBRAL COLUMN

Newgrowths of the vertebræ are either primary or metastatic. Although primary benign tumors do occur, they are very rare. Thus among 140 spinal operations, I have met with only one case of benign tumor of the vertebral column. Exostoses, osteomata, chondromata, fibromata, etc., do occur, but they are infrequent as compared with metastatic carcinoma, or primary or secondary sarcoma.

Carcinoma of the spine is regularly a metastasis from malignant disease in some other part of the body, most often from scirrhus of the breast, less often from carcinoma of the prostate, thyroid, esophagus, etc. Sarcoma is either primary or the bone is affected by direct extension from neighboring structures, or (more rarely) the sarcoma is metastatic.

More than 50 per cent. of all malignant tumors of the vertebræ are secondary to carcinoma of the breast. The vertebral metastasis may appear within a few months after the discovery of the primary tumor, or many years after the radical removal of the affected breast. In one of my patients five years, and in another eight years, elapsed before the beginning of spinal symptoms, and Spiller has reported a case in which the interval was twelve years.

Carcinoma is most frequent in patients past middle age and is most often observed in women. Sarcoma, on the other hand, occurs at any age and is most frequent in children and young adults. I have seen a sarcoma secondary to diseases of the soft parts in a child of two years, and a number of cases of primary sarcoma of the arches of the vertebræ in young male adults.

Carcinomatous disease most often affects the bodies, while sarcoma

[1] In addition to the growths of the spinal cord and membranes only those tumors of the vertebræ which give rise to cord or nerve root symptoms will be considered.

almost regularly attacks the arches of the vertebræ. Therefore, carcinoma is more apt to cause early root symptoms than sarcoma, while a visible or palpable tumor is more frequent in the latter disease. In eight of ten patients with sarcoma of the vertebræ that I have examined, a tumor was seen or felt; only one of a very large number of patients with metastatic carcinoma had a palpable tumor in the back.

The **clinical symptoms** of tumors of the vertebræ are due almost entirely to the changes in the nerve roots and the spinal cord. In the large majority of instances, pain is the first and for a long time the most important symptom. Sometimes persistent girdle sensation occurs very early. Every patient past middle life who complains of persistent neuritic pain or who has a bilateral sciatica, and every woman who, after an operation for cancer of the breast, suffers from pain in the back or in one of the extremities must be suspected of metastatic malignant disease of the vertebræ. In the beginning the patient complains of pain in the back in the dorsal or lumbar region, or in one or other shoulder or hip. The pain soon becomes very severe and is made worse by movement, so that the patient holds the spine rigid and avoids movement as much as possible. A kyphosis or scoliosis may develop. At this stage physical examination may fail to show any organic changes, the X-ray may be negative, the pain is the only evidence of trouble. Antirheumatic remedies, hot-air treatment, massage are of no avail; excepting for the pain, the patient seems in perfect health. The root pains are usually excessively severe, so that the least movement—sneezing, coughing or the like—causes excruciating suffering. The patient will remain in one position for hours or days, and the very movement of the bed clothes brings on the pain. Occasionally, remissions in the symptoms occur; the patient may be free from pain during part of each day, or the pain disappears for days or weeks at a time, to return later with undiminished severity. Tenderness of one or more spinous processes or of some part of the back is frequent at this time.

Sooner or later the patient begins to show the effect of the pain; constantly increasing doses of morphine are soon required to make her even passably comfortable. After a few months or more cord symptoms begin to show themselves. These have the character of an increasing compression; they grow worse rapidly, so that it is not unusual for the patient to become paraplegic within a few days. In some instances the progress of the disease is not very rapid. Many months may pass, and the only evidence of a cord lesion is an increase of the tendon reflexes in the lower extremities. The cord symptoms most often develop very rapidly, and when a complete paraplegia with bedsores has occurred, the fatal outcome is—fortunately for the patient—not long delayed.

The cord symptoms are not always due to pressure upon or invasion of the substance of the cord. Complete paraplegia may occur without any macroscopic and with few microscopic changes in the cord, and in these cases we are accustomed to explain the cord affection as "toxic" in character.

The location of the root pains and the extent of the paralysis will, of course, depend upon the location of the malignant newgrowth. Metastatic carcinoma most often affects the lateral and posterior parts of the bodies of the vertebræ in the lower cervical and upper and middle dorsal regions. The disease may affect a large number of bodies, but I have seen it limited to the body of one vertebra.

Thus far I have spoken only of malignant bone disease, on account of the rarity of other bone affections. Exostoses, chondroma, fibroma, gumma, echinococcus cysts of the vertebræ have been described. I have seen one patient with a chondroma of the vertebræ which caused symptoms from pressure upon the roots of the cauda equina, and Oppenheim has described a similar case. The general symptoms of benign tumors of the vertebræ which cause spinal symptoms are very like those of spinal tumors. The progress of these tumors is generally slow, and the tumors can often be demonstrated on the X-ray plate.

### EXTRADURAL AND INTRADURAL SPINAL TUMORS

Tumors which arise from the outer surface of the dura are comparatively rare, while those which originate from the inner surface of this membrane are more frequently met with. Most spinal newgrowths, however, arise from the arachnoid or pia mater or from the cord itself.

The tumor forms most often encountered are sarcoma, psammoma, endothelioma, fibroma, glioma, lipoma, syphiloma and tuberculoma. Most of these growths have a tendency to be circumscribed; the glioma is often and sarcoma sometimes an infiltrating growth. There may be multiple sarcomata in the membranes; they arise, most often, from the conus and nerves of the cauda equina. Metastatic carcinoma sometimes occurs within the dura, but is very rare. With the exception of multiple sarcoma and carcinoma, the growths are usually single, and if they can be entirely removed, there is little or no tendency to recurrence.

The **symptoms** of spinal tumors are in many cases very characteristic; the variations depend upon their location and relations. Thus a tumor which grows near or under posterior roots will, at first, cause typical root pains, followed by sensory disturbances over a root area; a growth on the posterior or lateral aspect of the cord may first give pain in the back; a growth on the anterior aspect of the cord will have a painless beginning, perhaps with motor symptoms (cramps in muscles, isolated muscle palsies). The first symptoms of growths within the substance of the cord are often subjective sensations of numbness and tingling in one of the extremities.

If the tumor begins in a part of the cord which is the center for important reflexes or special functions, these may be disturbed early in the disease. Thus, bladder disturbances may be the first symptoms of a growth in the lumbar cord; respiratory disturbances are early symptoms in high cervical lesions. Some spinal tumors never give root symptoms, while others cause very marked root and few cord symptoms by the time that the diagnosis can be made.

For weeks, months or years root symptoms may dominate the clinical picture of the disease. The patients are treated for long periods for neuralgias or for muscular rheumatism. There may be abdominal symptoms which are vague and indefinite, and the patients seek treatment for a variety of abdominal affections. Sometimes operations upon the abdomen, appendicectomy, hysterectomy, nephrorrhaphy, have been performed on account of the persistent abdominal symptoms. When treatment is unavailing, some of the patients are considered to be neurasthenic or hysterical.

After a varying period of time (one-half to three years), however, symptoms of an affection of the spinal cord appear. The patient notices that an arm or leg of one side is becoming weaker or stiffer and, perhaps, that the original pain begins to extend down over one extremity. The weakness and stiffness gradually become worse. Then the limb of the opposite side begins to be affected and soon becomes as weak as the other

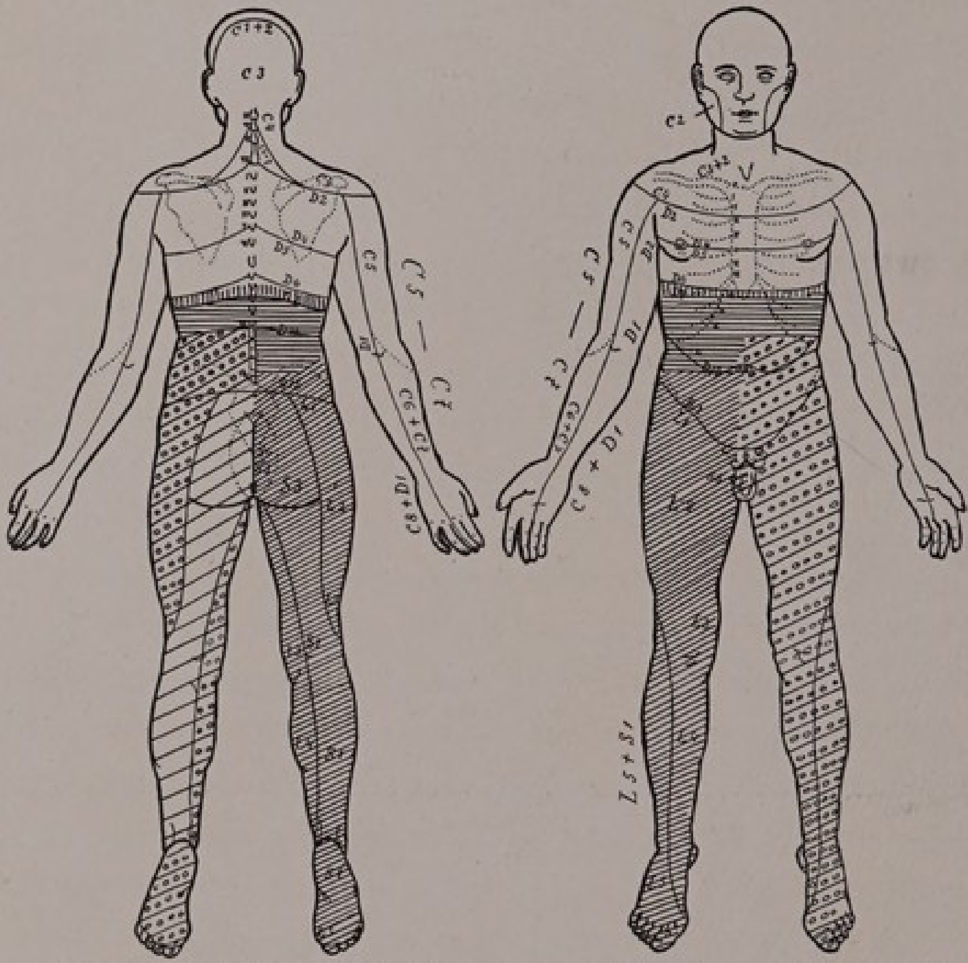


FIG. 121.—Sensory chart of a patient with an extramedullary tumor at the seventh and eighth dorsal segments. Verticals: hyperesthesia; horizontals: loss of all sensation; oblique lines: diminished sensation of touch and pain; circles: diminution of thermal sensibility.

limb. At about this time the patient may notice that the one or the other limb feels "numb" and that sensation is diminished. The diminution in feeling may affect the tactile, pain and temperature senses. Unless the tactile sense is markedly disturbed, the patient may remain unaware that pain and changes of temperature are not felt as well as before.

If the individual is seen early in the course of his disease, a typical Brown-Séquard symptom complex may be observed. This is, however, rare; in most instances there are more motor symptoms on the side of the root pains (the side of the tumor) and more sensory disturbances on the opposite side. Very often the sensory disturbances are the same on both sides of the body, the motor loss, however, more marked on one side (Fig. 121). The sensory disturbances usually extend up to the level of the affected cord segment. Above this level there may be an area of hyperesthesia or anesthesia of radicular origin on one or both sides of the body. If the sensory examination is carefully made, one can usually demonstrate that the area of disturbed pain and temperature sensation extends 1 to 2 in. higher than that for tactile sensation. All of the root areas below the level of the lesion need not be equally affected; in some areas the sensation may be normal, in others it may only be diminished, while in still other areas the sensation is entirely lost.

The early motor signs consist of exaggeration of reflexes in the lower extremities with, possibly, ankle clonus on one or the other side and other signs of interference with the pyramidal tracts. If the tumor is in the cervical region, there may be also early changes in the motor power and reflexes in the upper extremities. There is no spinal disease in which more spasticity and greater exaggeration of reflexes are found than in new-growths which compress the spinal cord. Under conditions to which I have already made reference, one or the other of the reflexes may disappear, if the lesion of the cord is at the level of the center of the reflex arc which controls the reflex (see also Chapter V, page 60).

At any time during the growth of a spinal tumor, disturbances in the functions of the bladder and rectum may appear. These consist of occasional attacks of incontinence, of constipation, and of lack of control of the rectum after a laxative has been taken. The bladder and rectal disturbances may be one of the first or among the last symptoms to appear, and incontinence or overflow of the bladder and constipation or incontinence of feces always occur in complete paraplegia. The root symptoms usually disappear soon after the cord symptoms have become prominent, and the chief complaints of the patient are pain in the back and weakness, numbness and painful contractions of one or both lower extremities.

When the pressure of the newgrowth has caused a complete transverse destruction of the cord, all the reflexes, excepting the réflexes de défense disappear, control of the bladder and rectum are lost, and bedsores and other trophic disturbances ocur.

This description of the symptomatology of a spinal tumor is more characteristic of an extramedullary than an intramedullary growth. The general course of an intramedullary tumor is similar to that of an extramedullary one with the differences to be mentioned below. Variations from the typical clinical course are, however, frequent.

For the main differences in the symptoms and signs at different levels of the cord and cauda equina, the reader is referred to what has been said in Chapter V.

### THE DIFFERENTIATION BETWEEN EXTRADURAL, EXTRAMEDULLARY AND INTRAMEDULLARY TUMORS

In many instances it is exceedingly difficult, if not impossible, to determine before an operation the part from which the newgrowth has originated.

Exclusive of the growths which arise from the vertebræ, the most frequent forms of extradural tumor are fibroma and sarcoma. The fibromata are usually small growths which may give few symptoms for a long time. If the tumor grows under a nerve root, there may be very severe root pains. On the other hand, the signs may be so slight that the disease will remain unrecognized for a long time. The patient may complain of symptoms after unusual muscular exertion or after violent exercise. The extradural fibromata rarely cause any bone absorption that can be recognized on the X-ray plate.

Extradural sarcoma (arising from the dura or periosteum) is a tumor that grows slowly at first but soon causes pressure upon the arches of the vertebræ and absorption of bone. The X-ray picture will usually show that part of one or of several laminæ have been absorbed. These growths are especially frequent on the lateral surface of the dura and may cause early root symptoms and early muscle atrophies. In one of my patients, the only symptom for more than one year was an atrophy in the small muscles of one hand.

*Extradural growths* are usually characterized by very indefinite sensory and motor symptoms for long periods of time. Even when the motor signs of compression of the cord are distinct, the sensory symptoms may be vague and ill defined, and both sensory and motor symptoms may vary from day to day.

*Extramedullary tumors* often begin with root pains as an early and persistent symptom, and the progression is generally slow until marked cord symptoms appear. These may have a Brown-Séquard character, and a dissociation of sensations on the side of greatest sensory loss is of frequent occurrence.

There may, therefore, be great divergence from the usual clinical course of these newgrowths, so that in every case in which there is a spastic paraplegia with sensory level symptoms, the possibility of an extramedullary neoplasm must be kept in mind.

In almost one-third of the patients upon whom I have operated for extramedullary newgrowths, there was no history of early root pains. Some of the patients declared that they had never had pain of any kind, while others made the statement that pain had appeared only after other symptoms had been present for one or for several years. Pain in the back or in the neck was a rather frequent complaint in my patients. I have often been struck by the fact that the pain complained of was in the lower limbs, although the tumor was found high up in the dorsal region.

Increasing weakness of the lower extremities for six months was the only complaint in one of my patients. In this case sensory disturbances appeared after lumbar puncture with the removal of a small amount of fluid.

I have seen and operated upon extramedullary tumors, with most indefinite and slight motor and sensory disturbances, and we have more than once been surprised when we have looked back upon our cases to see how atypical the symptoms have been.

*Intramedullary tumors* have most frequently a painless beginning, although numbness and tingling may be early symptoms. In not a few instances there are early root symptoms. The old rule that a painful beginning signifies extramedullary disease will have to be modified to read: "a painful beginning is most often met with in extramedullary newgrowths."

Sensations of heat or of cold are frequent in the lower extremities; one of the limbs may be affected before the other, but both may be attacked at the same time.

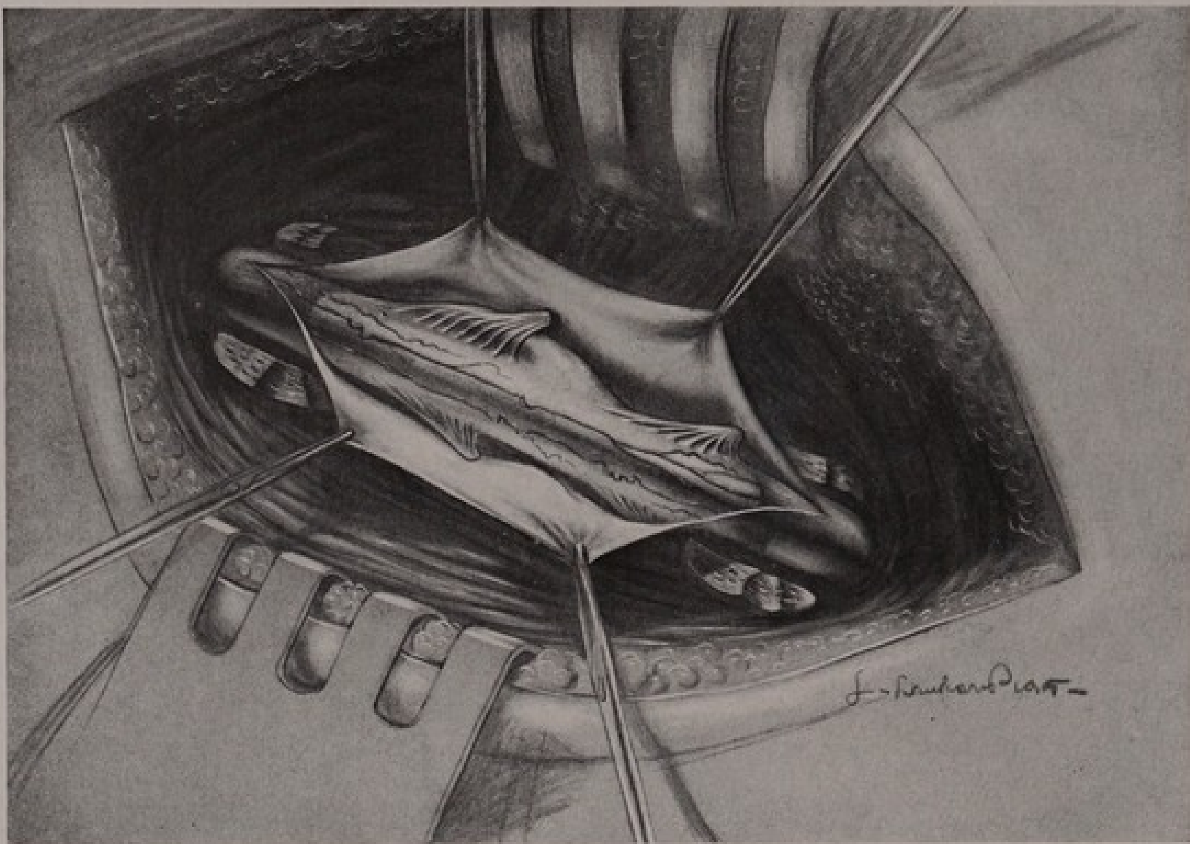


Fig. 122.—Intramedullary spinal tumor which has bulged out the lateral part of the cord.

The differentiation between extra- and intramedullary tumors can be made in the majority of instances; in some patients, however, the question whether the disease is on the outside of the spinal cord or in its substance can not be answered by the neurologist before the surgical interference. Fortunately, spinal surgery has been advanced so much that many intramedullary growths must be subjected to operation.

The accompanying figures (Figs. 122 and 123) represent an intramedullary tumor in the lateral column of the lower cervical cord in which there were early and persistent root pains. The pain was due to pressure of the swollen cord upon the eighth cervical and first dorsal posterior root. The tumor was successfully removed by the method of extrusion. Dissociation of sensations, if it occurs over the entire area of sensory disturbance, always means disease within the substance of the cord.

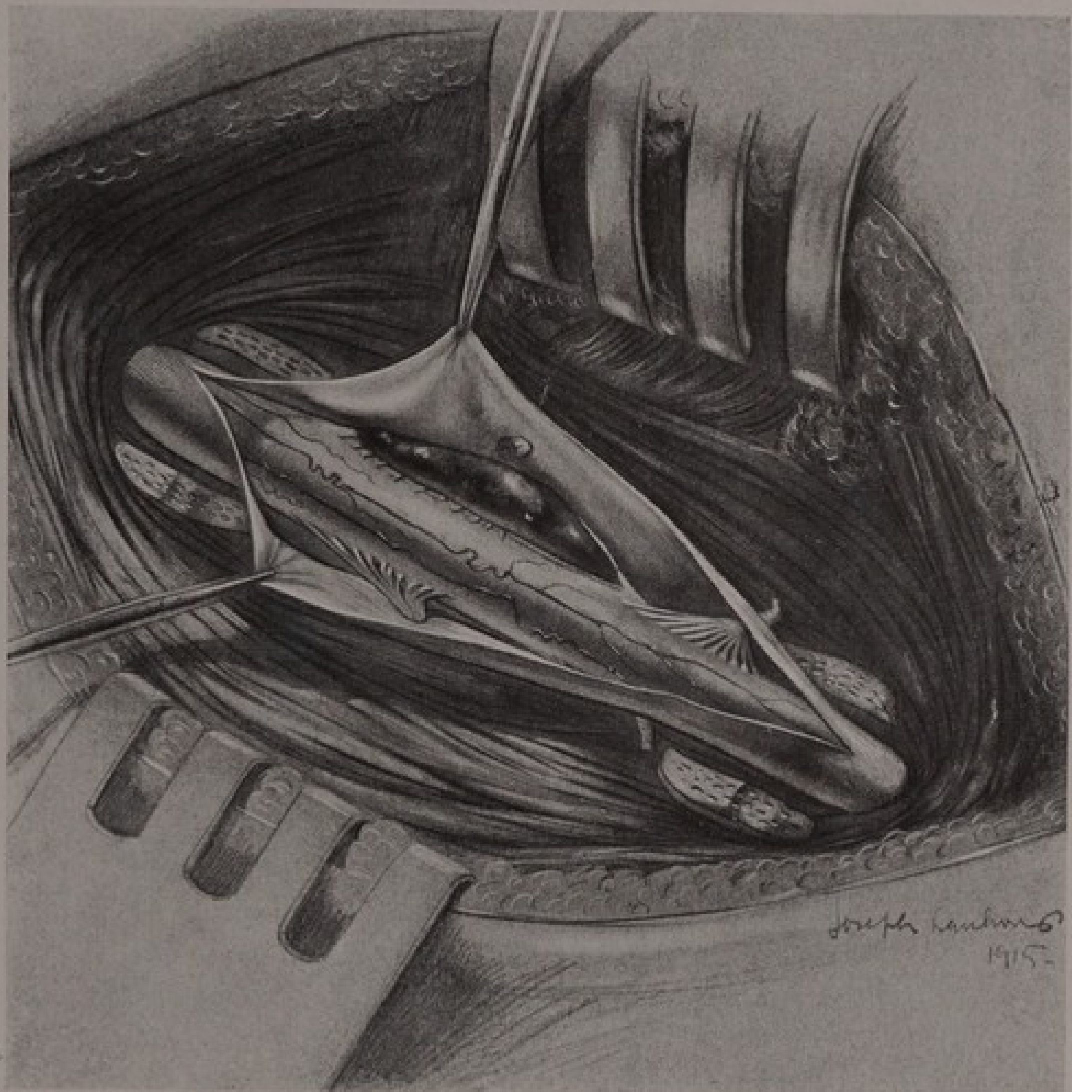


FIG. 123.—The extruded growth one week after laminectomy and incision of the cord.

Here again, the rule is not an absolute one, because marked disturbances of all three sensations may and do occur in intramedullary tumors. Muscle atrophies occur much earlier in intramedullary than in extramedullary disease. Not a few tumors within the substance of the cord enlarge in an upward and downward direction, and in these there may be a gradual upward shifting of the level of sensory and motor disturbances.

As extramedullary tumors almost always enlarge in a transverse diameter, this upward shifting of the level symptoms increases the probability that the case is one of intramedullary tumor. We must,

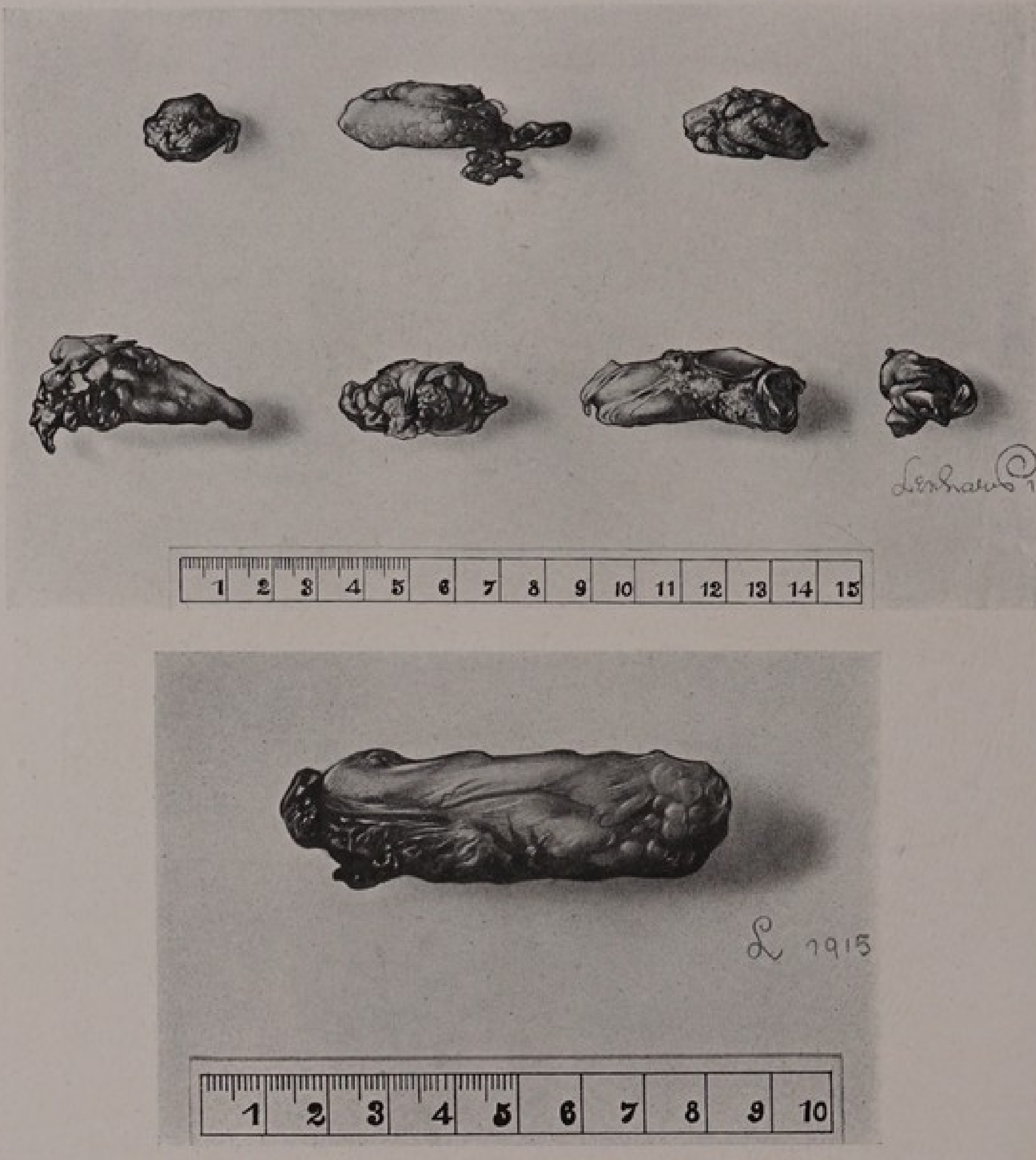



Fig. 124.—Extramedullary spinal tumors removed at operation.

however, not forget that a collection of fluid above the growth may give higher level signs.

Intramedullary tumors are not by any means as rare as they are believed to be by some authors. Thus Allen Starr, quoting from Schlesinger, states that among 302 tumors of the cord, 125 were within the cord substance. These included sarcoma, tuberculous tumors, gumma, glioma, lipoma, cysticercus, neuroma, cholesteatoma, myxoma, teratoma, adenoma, endothelioma, etc. My own operative experience is limited to forty-four cases. Of these ten were extradural, twelve were intramedullary, and twenty-two were extramedullary. These growths were fibroma, sarcoma, glioma, psammoma, lipoma, endothelioma and tuberculous tumors (Figs. 124–128). Many of these intramedullary growths infiltrate the cord


FIG. 125.—Extramedullary and intramedullary tumors removed at operation. The lower two tumors were intramedullary.

substance and increase in size by extending upward and downward, but some enlarge in their transverse diameter, are encapsulated and of small size. Gowers says that "these tumors in some cases blend with the substance of the cord, but in other instances they are bounded by an area of softening which often isolates even invading growths." According to Flatau and Gowers, many tumors are sharply limited. Flatau states that the comparative frequency of extramedullary and intramedullary tumors is as 2.6 to 1 (57 intramedullary tumors in 213 cases).

Although one can not estimate from the reports the frequency of localized and encapsulated intramedullary growths, the fact that one frequently finds illustrations and descriptions of such tumors in the literature is

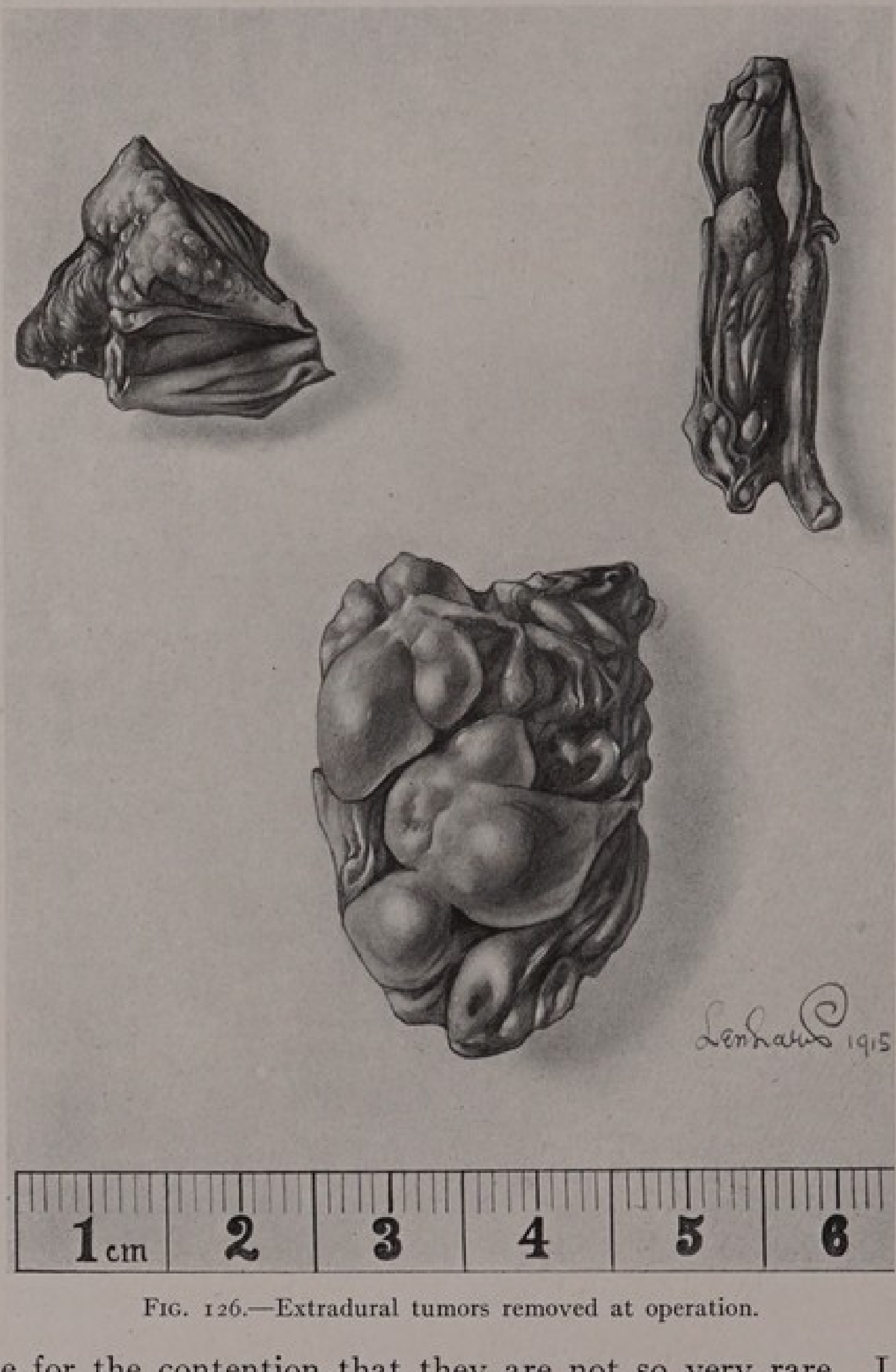



Fig. 126.—Extradural tumors removed at operation.

evidence for the contention that they are not so very rare. Localized tumors have been found at operation by Krause, Röpke, Elsberg, and Beer, and many others. Localized cysts have been found by Krause and myself.

Extramedullary growths may be found in any part of the spinal canal, but they are most frequent in the dorsal region. Intramedullary growths, on the other hand, are most often met with in the cervical (and

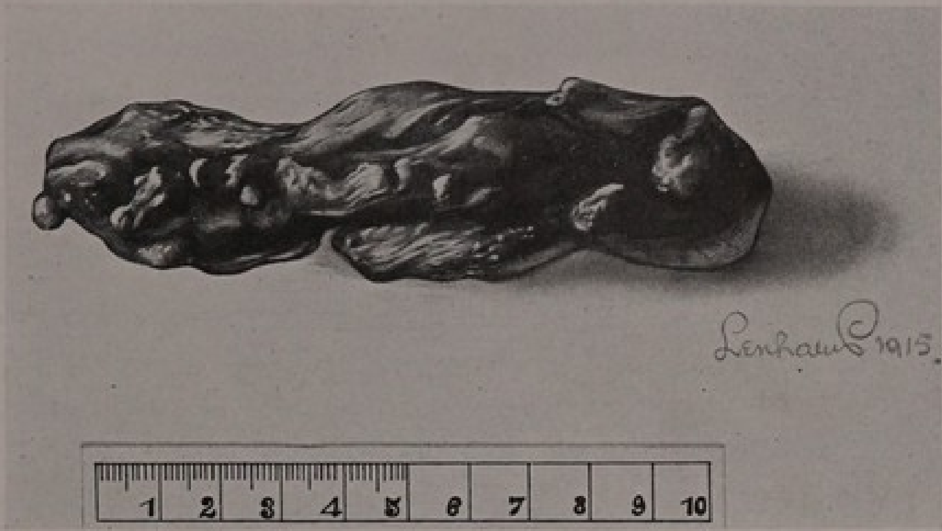



Fig. 127.—Giant tumor of the conus removed at operation.

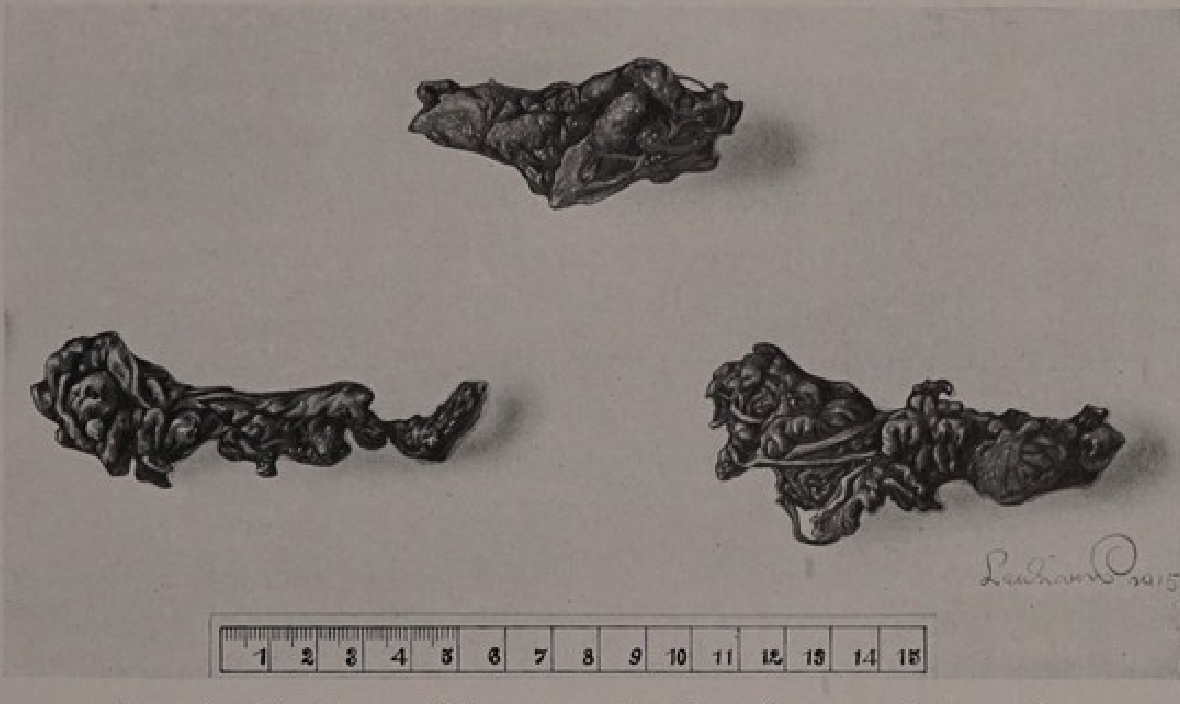



Fig. 128.—Giant tumors of the conus and cauda equina, removed at operation.

upper dorsal) cord. Thus, among my forty-four operative cases, there were thirty-two extra- and twelve intramedullary tumors. Of the thirty-two extramedullary tumors, seven were cervical, eleven dorsal, one lumbar, four involved the conus and the roots of the cauda equina, in two patients there were multiple tumors, in seven there was a metastatic growth of the vertebræ. Of the twelve intramedullary tumors, nine were in the cervical, one (a metastatic tumor) was in the upper dorsal, and one (a tuberculoma) was in the lower dorsal cord.

In the cervical cord, the infiltrating glioma or sarcoma was frequent (four cases) but not quite as frequent as the localized intramedullary growth (five cases).

The most frequent tumor in the conus and cauda equina (Figs. 127 and 128) is the giant endothelioma or endothelial sarcoma of which five cases were recently described by Dr. Collins and myself (Am. J. of the Medical Sciences, March, 1914).

## THE DIAGNOSIS OF THE LEVEL OF THE TUMOR

(See also Chapter V, page 60)

This subject has been considered in detail in the chapter on the differential diagnosis of spinal lesions. I have stated in that chapter that it is usually possible to correctly diagnosticate the upper level of the growth and sometimes also the lower limits.

Root pains and root hyper- and anesthesias are very reliable signs of the upper level of a neoplasm and of the side of the cord on which it lies.

Tumors in the upper cervical region may cause pain in the back of the head (occipitalis major) or pain on the top of the shoulders. In the lower cervical newgrowths, root pains occur in some parts of the forearms or hands; it is not rare for the symptoms to begin in one finger. I have observed a case in which the first painful sensation occurred in the index-finger of one hand, as a result of pressure upon the lower root bundles of the seventh cervical posterior root. Tumors at or below the level of the first dorsal segment seldom cause any symptoms in the upper extremities, and root pains are frequently wanting. Intercostal neuralgia, however, may be the only evidence of posterior root compression in the upper dorsal region. Irritation of the seventh to twelfth dorsal posterior roots may give rise to a variety of abdominal disturbances; indefinite abdominal symptoms, therefore, should always make the physician think of the possibility of a lower dorsal root pain.

Hyperesthesia over the area of distribution of a posterior root, especially above the level of other sensory disturbances, is very frequently met with. Such a root hyperesthesia may be the only positive localizing sign of a spinal tumor. Associated with signs of disturbances in the pyramidal tracts, it may suffice to make the diagnosis of the level of a lesion. Thus I have correctly localized and removed a spinal tumor from a patient, who, aside from exaggeration of the reflexes of the lower extremities and slight sensory disturbances in both feet, had a zone of hyperesthesia which corresponded to the area of distribution of the twelfth dorsal posterior root.

When the tumor compresses the cord at the level of the center for one or the other of the reflexes, the isolated disappearance of that reflex has localizing importance. Thus the disappearance of the upper or the lower abdominals, with exaggeration of the knee and ankle jerks, points to a lesion between the eigthth and twelfth dorsal segments; the disappearance of one or both knee jerks with persistent or exaggerated ankle jerks may localize the lesion at the second to fourth lumbar segments, etc. Similarly the loss of the triceps jerk or paralysis of one or both triceps muscles, at once localizes a tumor at the sixth to seventh cervical segments.

Sometimes there may be an isolated paralysis or weakness of the abdominal muscles on one side, so that a lack of contraction of the abdominal wall on that side is observed. If the patient is told to cough, the bulging of the abdomen on the affected side may be very noticeable. Under the same conditions, differences in the reaction of the muscles of the two sides to the faradic current also occur.

As I have already mentioned (see Chapter VIII) the extent of the réflexes de défense can also be of value for the diagnosis of the level of the lesion.

Mistakes in the segment diagnosis, however, may occur. The most frequent error is to locate the growth one or two segments too low, but this is of little practical account as the surgeon must usually remove at least three spinous processes and laminæ and will, therefore, always find the tumor.

Sometimes there is a collection of fluid above the tumor which compresses the cord and gives level symptoms, both motor and sensory, several segments higher than the location of the tumor. This caused the surgeon, in one instance of which I know, to look for the newgrowth three vertebræ too high, and in a patient under my care, the growth was two segments below the level indicated by the sensory disturbances. It is well to remember also that the level of the symptoms may be shifted upward not only by a column of fluid above the tumor, but also by the actual upward growth, as occurs in some malignant tumors in the lower part of the cord and the cauda equina, and in some intramedullary tumors.

The sensory disturbances in the upper part of the affected area may be so slight that they can be recognized only by the most careful and painstaking examinations. Small extramedullary growths on the posterior surface of the cord in the upper dorsal region may cause very little sensory disturbance over five or six segments, and below this a marked diminution or a loss of sensation. It would be very easy to miss the slight sensory disturbance above and to incorrectly localize the growth at a much lower level. This occurred in one patient upon whom I operated. The tumor was found by me one year later at a second operation.

There are undoubted cases, in which, in the early stages of the growth, there are no sensory disturbances up to the affected segment so that a mistake in the level diagnosis might be made, if the patient was subjected to operation very early. I have seen and operated upon a patient who never had any root symptoms, but other very definite localized signs at the tenth dorsal segment were found by several competent neurologists. No tumor was found at the operation at this level. The patient was repeatedly examined during the following years but for a long time the level remained the same. Finally, sensory disturbances up to the first and second dorsal segments appeared, and at the second operation, I removed a small extramedullary tumor which compressed the cord at the first dorsal segment. In cases of this kind it is fair to suppose that at first the small growth compresses fiber tracts which supply only lower sensory areas.

After all has been said, however, mistakes in the diagnosis of the level of a tumor should be of rare occurrence. Thus in sixty-one cases of localized spinal disease that have been subjected to operation, I failed to find the disease at the suspected level in only the two instances I have mentioned above. These gratifying results were mainly due to the careful examinations that were made for me by the neurologists with whom I have had the good fortune to be associated.

### THE RECOGNITION OF THE RELATIONS OF THE TUMOR TO THE SPINAL CORD

In a large number of cases, after careful examinations, it is possible to determine what parts of the cord are pressed upon by the newgrowth Tumors on the posterior or posterolateral surface of the cord are apt to begin with root pains and to have relatively marked disturbances of tactile and deep muscle sense. If the neoplasm is growing more on one than on the other side, the disturbances of temperature and pain are more apt to be marked on the contralateral side. If the growth lies in front of the dentate ligament, the motor symptoms are very apt to be out of proportion to the sensory loss and extramedullary tumors in this location may cause very decided dissociation of sensations. Tumors on the anterior surface of the cord may, for a long time, give only motor symptoms; early muscle paralyses and atrophies occur in newgrowths in front of the cord.

Tumors of the cauda equina are relatively rare; the most frequent form is the large endothelioma or endothelial sarcoma which fills up the lower part of the spinal canal and surrounds the nerves of the cauda equina (Figs. 127 and 128). These growths are soft and of a brownish color, are not very vascular, and frequently cause surprisingly slight sensory disturbances. The tumors increase in size very slowly and their symptomatology is characterized by persistent pain in the small of the back, loss of knee and ankle jerks, atrophy of the lower limbs, especially of the peronei and tibialis anticus muscles, dropped foot, slight bladder and rectal symptoms and ill-defined sensory disturbances.

The attempt should always be made to make a diagnosis of the relations of the growth to the cord, but in not a few instances, the symptoms are totally different from what should have been expected. Thus I have had a patient who presented no sensory symptoms until three days before the operation, which revealed an easily removable growth lying on the posterior surface of the cord. I have twice seen extradural growths cause a kind of a reverse Brown-Séquard picture—motor symptoms on the opposite and sensory symptoms on the same side as the tumor (Figs.

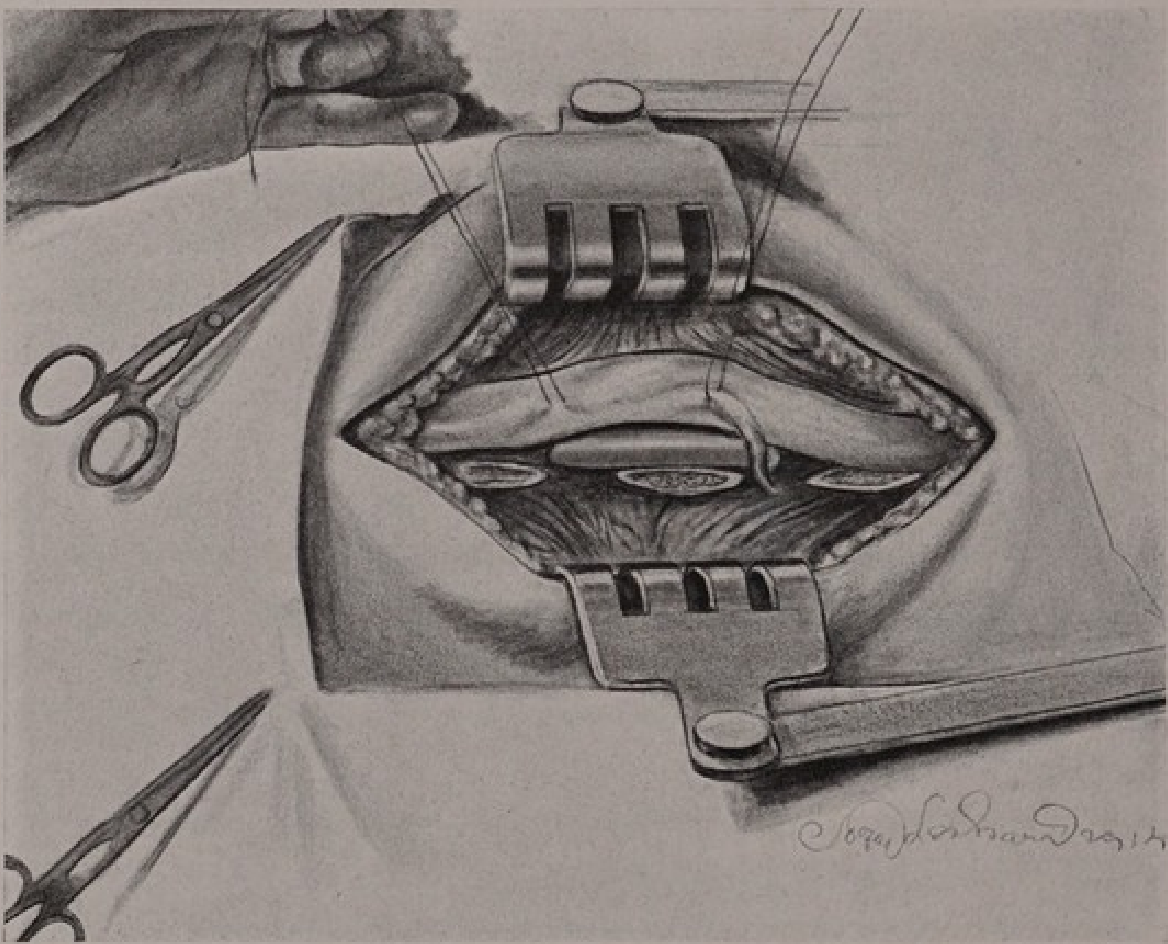


FIG. 129.—An extradural tumor of the spinal cord at the fifth dorsal segment.

129 and 130). In these patients, the operation revealed the fact that the cord was pushed over to the other side by the tumor and by fluid under the arachnoid, so that (Figs. 129 and 131) the contralateral surface of the cord was compressed against the walls of the spinal canal (contre coup). In other words, the condition was analogous to that in the posterior cranial fossa, where a cerebellar tumor on one side pushed the cerebellum over to the other side, pressed the facial nerve of the other side against the

petrous portion of the temporal bone and caused a paralysis of the facial nerve on the side opposite to that of the tumor.

**The diagnosis of the nature of the growth** can seldom be made with certainty. From the clinical signs and symptoms one may be able to say the following. Infiltrating intramedullary growths in the cervical region are most often gliomata; tumors of the conus and cauda equina are most often endothelioma or endothelial sarcoma. Unless the tumor is metastatic, an extramedullary growth is clinically benign.

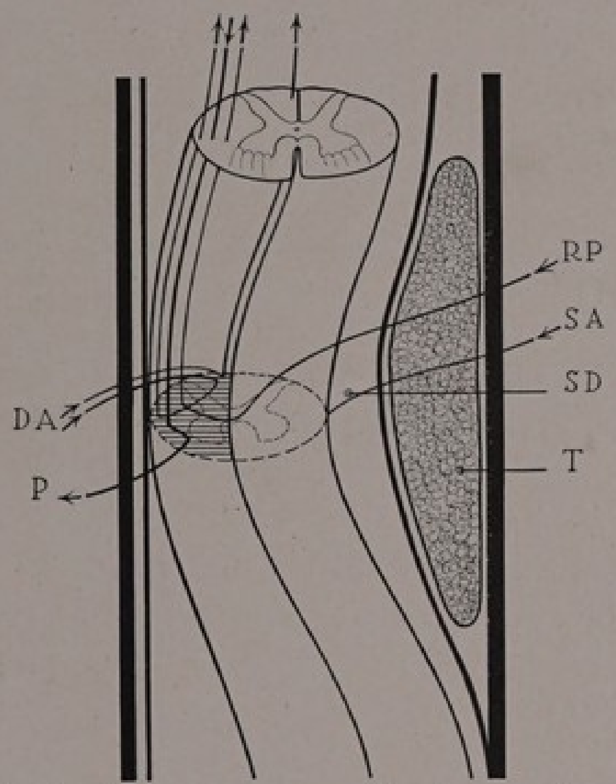



FIG. 130.—The explanation of the symptoms caused by the tumor shown in Fig. 129. T, tumor; SD, subdural space, distended with fluid; SA, loss of superficial sensation; RP, root pain; P, paralysis, DA, loss of deep sensation.

Cysts—simple as well as echinococcus—can not be distinguished from newgrowths. Metastatic tumors in the cord are very rare. Tuberculous tumors are rare and can not be differentiated from other intramedullary growths before the operation.

## THE DIFFERENTIAL DIAGNOSIS OF SPINAL NEWGROWTHS

The diagnosis of malignant disease of the vertebræ causing spinal symptoms can usually be made without great difficulty.

Tubercular spondylitis is more frequent in childhood, although it may occur at any age, and very severe root pains occur more often in malignant disease of the vertebræ. Cold abscesses occur only in tubercular disease, while the history of malignant disease in some other part of the body points to a metastatic newgrowth in the vertebræ.

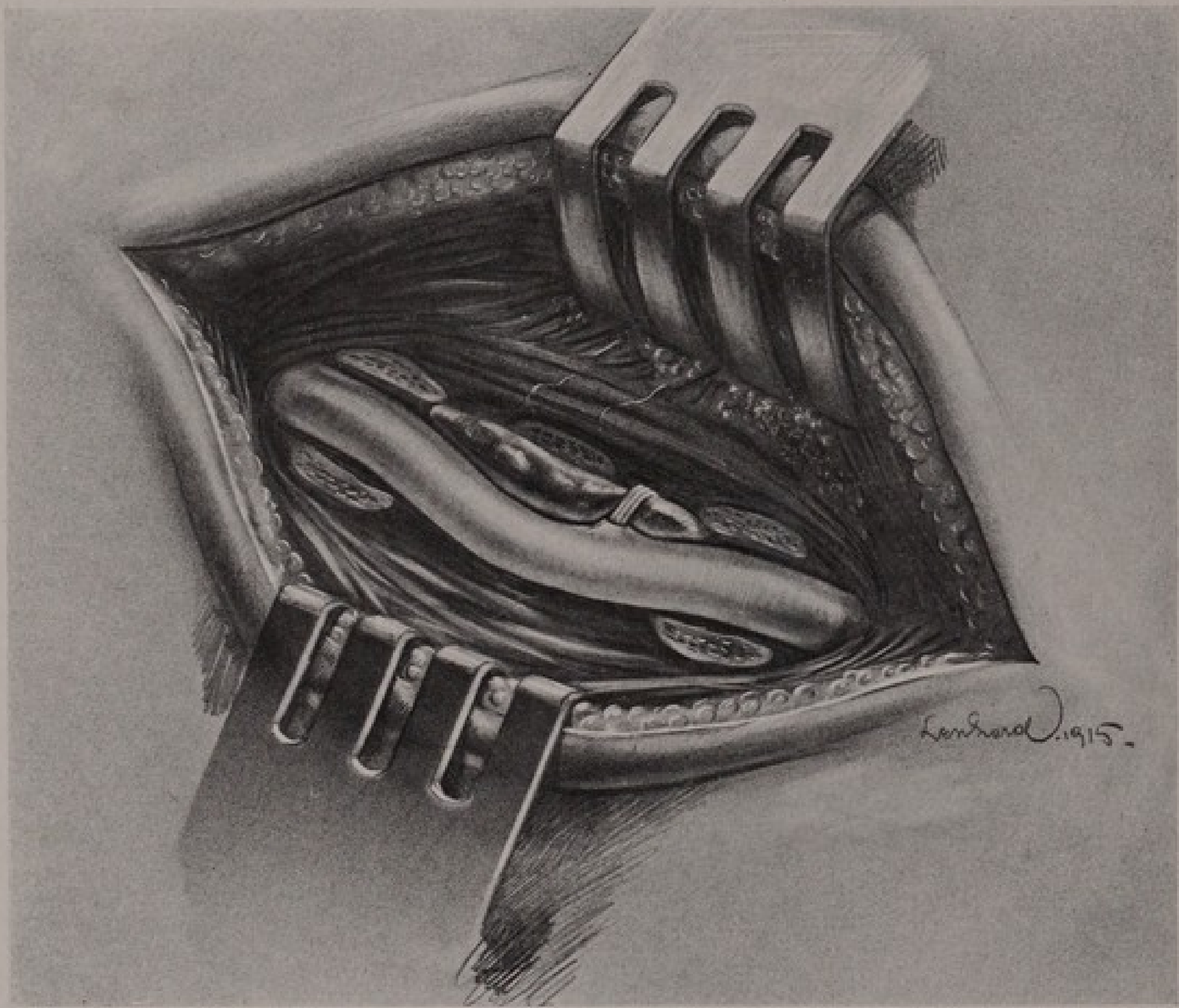


FIG. 131.—Extradural tumor at the level of the tenth dorsal segment which caused reverse Brown-Séquard symptoms.

Occasionally, however, the clinical picture of Pott's disease (*q.v.*) may be similar to that of a malignant newgrowth of the arches of the vertebræ, and I have once operated upon a patient with sarcoma of the arches of the cervical vertebræ who had been treated for a long time for cervical Pott's disease. The presence of tubercular lesions in other parts of the body, the more frequent occurrence of fever in Pott's disease and the changes in the bodies of the vertebræ seen in the X-ray picture will generally suffice to make the differentiation between the two diseases possible.

Sometimes metastatic malignant disease of the spine may present all of the symptoms of a true spinal cord tumor. I have had under observation a patient in whom the diagnosis of a spinal cord growth seemed certain, until the X-ray picture demonstrated typical malignant disease of the laminæ of two vertebræ and other tumors in several of the ribs. Important aid can be obtained, therefore, from an X-ray examination, and this should never be omitted.

The more rapid progress, the sudden appearance of paraplegia, and the other features of malignant vertebral disease that have been mentioned above, will usually permit one to make a correct diagnosis of carcinomatous or sarcomatous bone disease.

The differential diagnosis between spinal cord tumors and some forms of multiple sclerosis may present great difficulties. Obstinate root pains, definite level symptoms, and even the Brown-Séquard symptom complex may occur in sclerosis, and in some patients, an exploratory operation is necessary to distinguish between the two affections. In general, however, the presence of nystagmus, of beginning optic atrophy, the absence of abdominal reflexes, the presence of spinal symptoms referable to other parts of the cord, and to the brain, will make the differentiation between the two diseases possible. The differential diagnosis between multiple sclerosis and multiple spinal tumors which run their course without root pains may be impossible for a long period of time.

From inflammatory diseases of the meninges, pachymeningitis hypertrophica, circumscribed serous meningitis, and the like, the differential diagnosis can sometimes not be made; at other times it can be made from the cerebrospinal fluid. In tumors there is no increase of cells but the globulin is apt to be increased and the fluid may be yellow in color. In most of the inflammatory processes in the membranes, there is an increase of the cells in the cerebrospinal fluid obtained by lumbar puncture. In some cases, however, the differential diagnosis can only be made on the operating table.

In serous meningitis and in pachymeningitis, the symptoms may point to a lesion of considerable length. There may be root pains referable to a number of posterior nerve roots, so that one has to think of a more extensive lesion than a spinal tumor. Pachymeningitis most often complicates syphilitic and tubercular disease. Some chronic inflammatory processes occur in the cauda equina (neuritis of the cauda equina (Oppenheim, Kennedy and Elsberg) which may have to be differentiated from a tumor of the caudal nerves, but the differentiation is usually possible (see Chapter XIX).

The differential diagnosis between intramedullary tumors and syringomyelia is often difficult and sometimes impossible. Trophic disturbances in the bones and joints are, however, unusual in intramedullary tumors and the extent of cord affected in spinal gliosis is much greater than in tumors within the cord substance. Root symptoms are rarely observed in syringomyelia. The progress of the symptoms in syringomyelia points to an extension of the disease in a longitudinal direction, although this may also occur in intramedullary newgrowths.

The differentiation between meningo-myelitis and spinal cord tumor should generally be made without difficulty. Syphilis of the cord is comparatively rare and gummata are very infrequent. That spinal syphilis must be excluded in every case of suspected spinal tumor need hardly be mentioned. A serum and blood Wassermann test should be made in every case and, if there is any doubt, a dose of salvarsan given.

## THE TREATMENT OF SPINAL CORD TUMORS

**The Treatment of Malignant Vertebral Disease.**—If the diagnosis of malignant disease of the vertebræ has been made, operative interference should be done only as a palliative measure (division of posterior roots, division of the anterolateral tracts (Spiller and Martin)). Many attempts have been made to operate upon primary malignant newgrowths of the vertebræ but it has seldom, if ever, been possible to entirely eradicate the disease. Most of the patients have been operated upon because the diagnosis was uncertain; in many of the patients, the operation was discontinued as soon as the real condition was recognized.

Patients with sarcoma of the spine often stand the anesthesia and operative interference badly, so that in suspected malignant spinal disease the operator must never fail to explain to the patient's family the seriousness of the operation. While there have been patients with malignant disease of the arches of the vertebræ, who were cured after the removal of all the disease, this has been rarely possible because the disease is generally too far advanced. Immobilization of the spine in a plaster-of-Paris splint and morphine are the only means we can use to relieve the patient's sufferings, unless an operative interference upon the spinal roots or the anterolateral tracts of the cord is done. The results from the division of sensory roots for the relief of pain have not been satisfactory; when improvement did occur, it did not last long. Division of the anterolateral tracts has been considered in Chapter XII.

**Operative Interference for Extradural or Intradural Spinal Tumors.**—The removal of an extradural tumor is usually a very simple procedure. After the laminectomy has been preformed and the tumor has been exposed, the growth is carefully peeled out of its bed. If the dura is firmly adherent to the growth, a piece of dura must be excised with the tumor, and the dural sac then closed by suture. If the tumor lies on the lateral aspect of the dura, it may be necessary to divide one or even two posterior roots before it can be removed.

In the removal of intradural extramedullary growths the following facts are of importance:

**The Removal of Intradural Tumors.**—The laminectomy is done according to the method described in Chapter X. The operation should be performed at least two spines and often three higher than the level of sensory disturbances and at least three spinous processes and laminæ should be removed before the dura is opened. If the tumor should not be found in the exposed wound, it must be sought for by careful exploration, as has been described on page 135.

As soon as the tumor is found, its relations to the cord and to nerve roots must be determined, and, if necessary, more bone must be removed so as to expose the growth in its full extent.

The lower end of the growth must always be well exposed before the attempt at removal is made. As soon as the lower end is freed, the tumor can usually be peeled off from its other attachments without difficulty. If the upper end is adherent to adjacent structures, the upper pole of the growth must also be exposed by the removal of more laminæ and the upward incision of the dura.

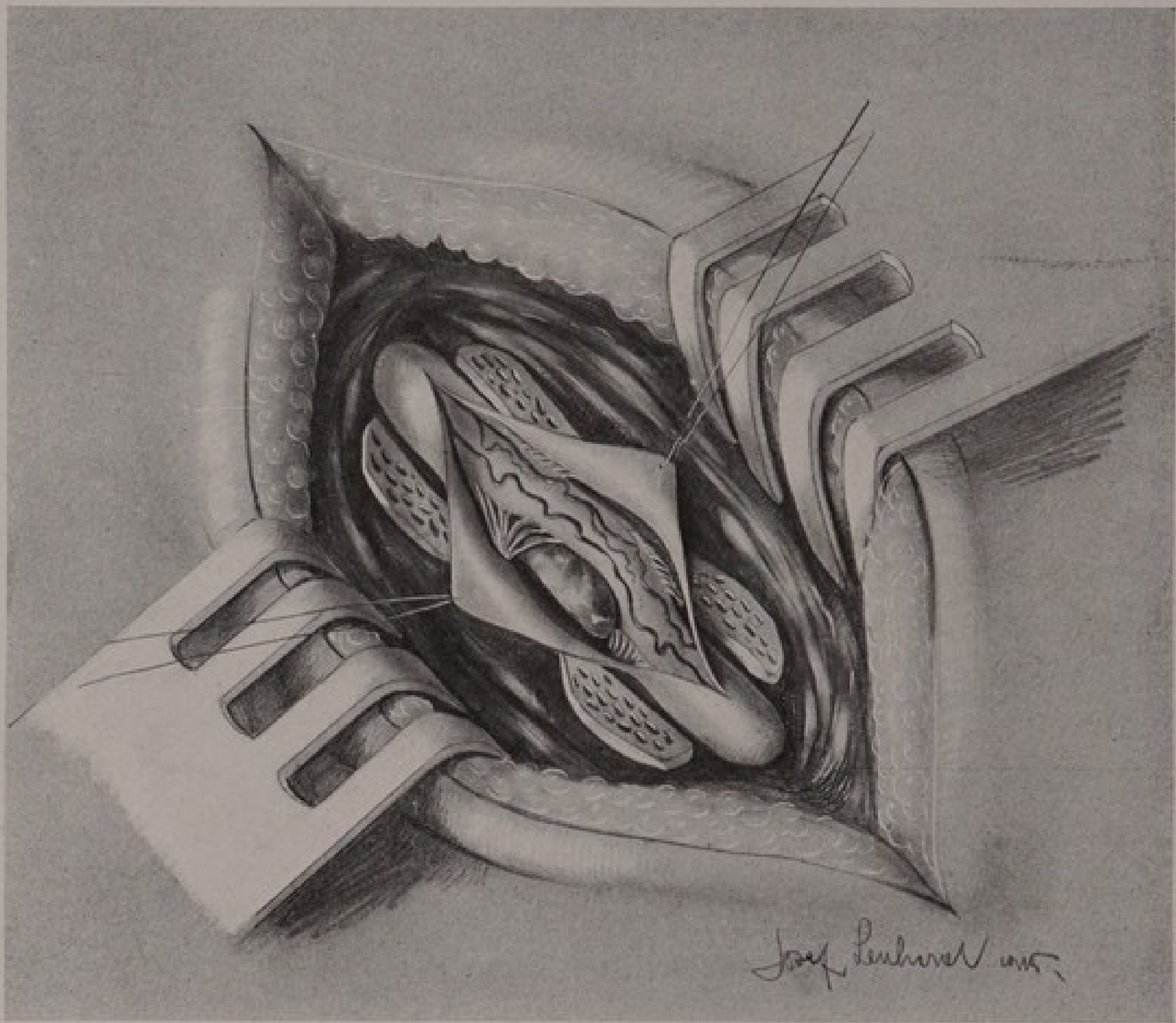


FIG. 132.—An extramedullary tumor at the eighth cervical segment, partially under a posterior nerve root.

Most extramedullary tumors lie superficial to the pia mater; some lie underneath it so that the pia has to be incised before the growth can be removed. If the growth lies under a nerve root (see Fig. 132) or under a slip of the dentate ligament (Fig. 133), the nerve or the ligament must sometimes be divided.

If the growth lies on the posterior surface of the cord, it must be carefully raised from the cord and the fine adhesions to the pia divided.

Great care must be taken not to cause the slightest injury to the cord tissue, and if it is found that the tumor is intimately connected with the cord, a different procedure must be adopted for its removal (see intramedullary tumors).

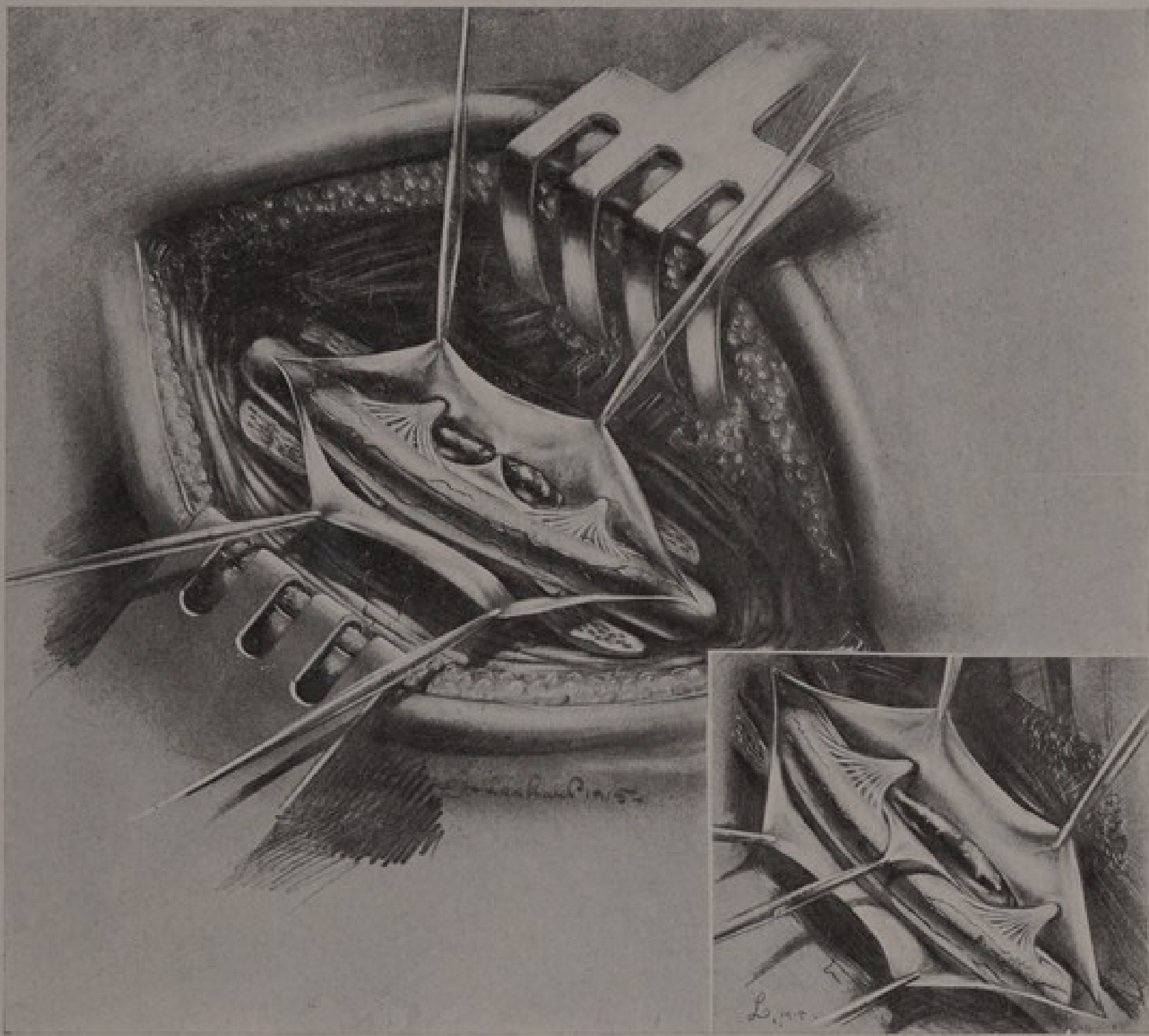


FIG. 133.—Extramedullary tumor under a slip of the dentate ligament. The method for the exposure of the growth is shown in the insert.

Very small blood vessels must be ligated with fine silk and divided. The slightest oozing of blood must be controlled by gentle pressure with bits of cotton. If the growth is firmly adherent to the inner surface of the dura, a piece of that membrane must be excised.

Most extramedullary tumors are easily separated from the cord. Sometimes one meets with a pediculated growth (see Figs. 134 and 135), which can be lifted away from the cord excepting at the base of the pedicle.

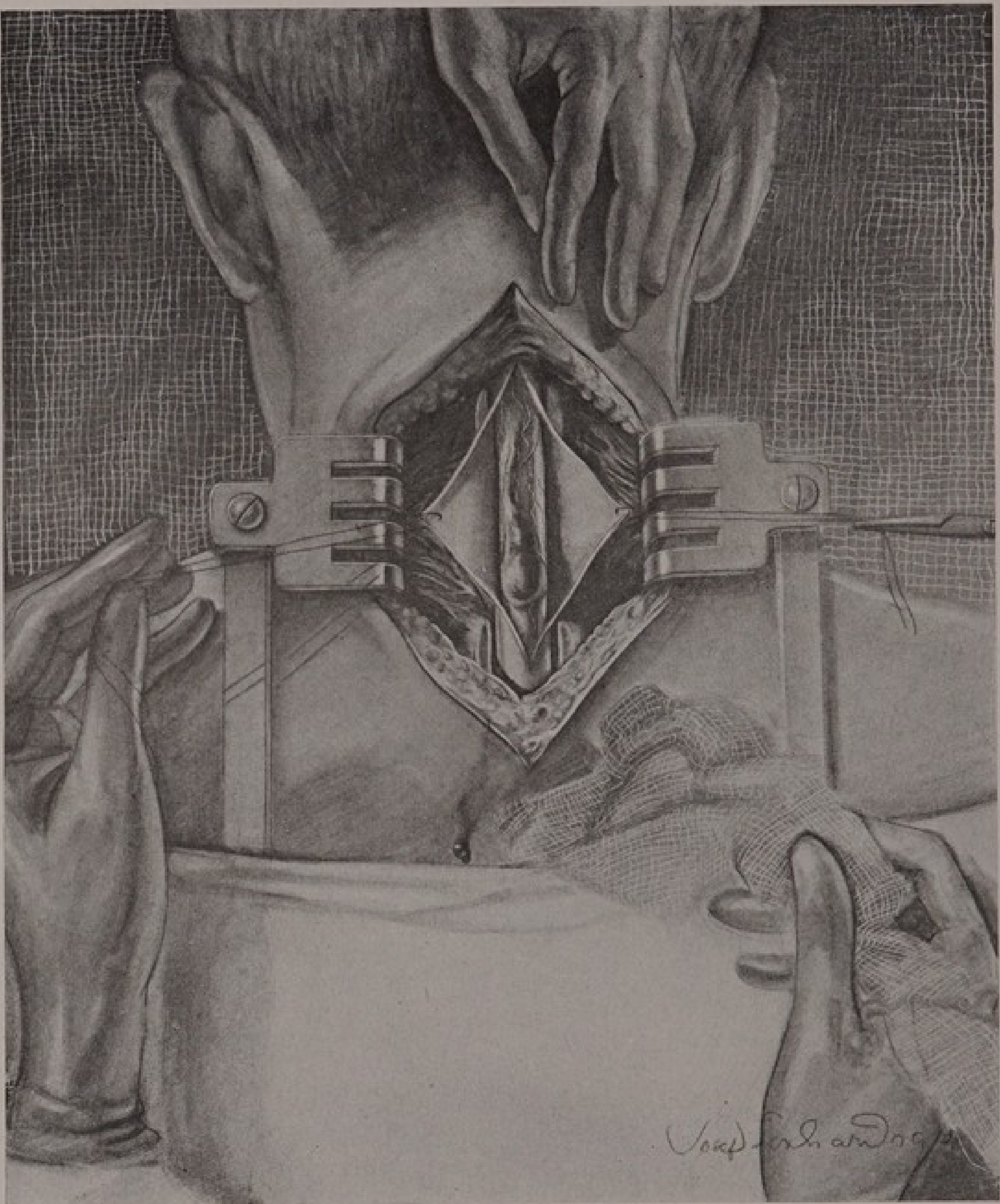


FIG. 134.—A pedunculated tumor of the cervical cord.

Some tumors are so loosely attached to the cord that, as soon as they are exposed, they can be grasped with forceps and carefully drawn out of the spinal canal.

There is seldom much oozing from the bed of the tumor and the little bleeding can always be controlled by small cotton sponges which have been dipped in adrenalin or coagulin (Fonio) and lightly placed upon the oozing spot. Occasionally, the arachnoid membrane below the tumor is

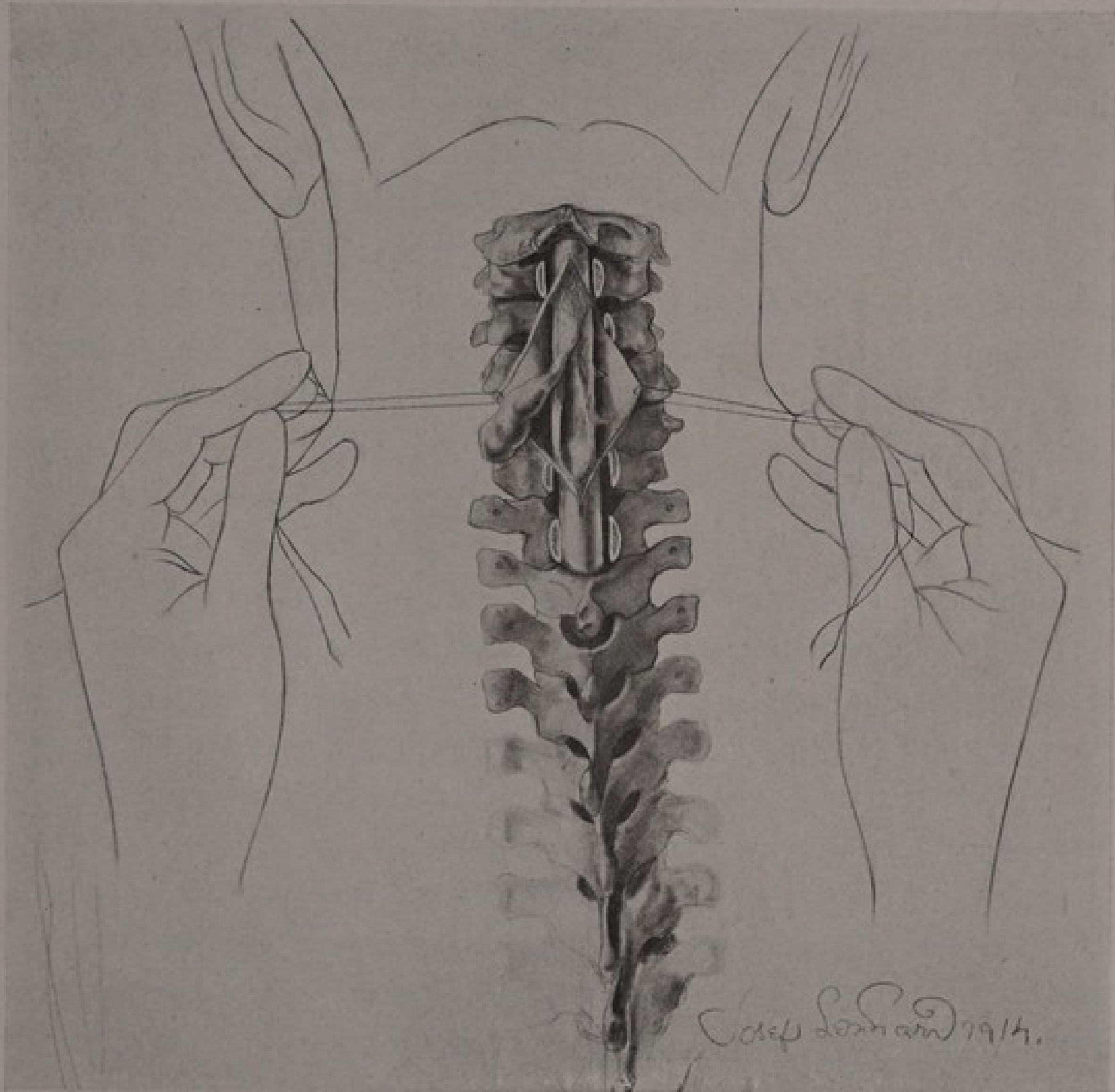


Fig. 135.—To show the relations of the tumor in Fig. 128 after the growth had been raised out of its bed.

much thickened and of a reddish color. This is probably due to a chronic congestion from the pressure of the newgrowth, and will disappear after the removal of the tumor.

The cord may be much flattened by the growth; it is remarkable how much recovery can occur when the cord has been flattened out so as to look like a tape. It is never advisable for the operator to go very far in his investigation of the condition of the cord; the less it is touched or examined, the better.

If the tumor lies on the anterior surface of the cord, the latter must be raised and pulled to one side by means of a slip of the dentate ligament which is grasped with mosquito forceps and cut at its attachment to the dura.

It is always advisable to divide a posterior nerve root which is tightly stretched over a tumor. If such a root is allowed to remain, the patient may suffer from root pains for a number of weeks after the operation.

If the surgeon has to deal with a tumor which lies outside of the cord tissue proper, but in or beneath the pia mater and is hence closely adherent to the cord, no attempt at removal should be made until a later stage, when the tumor will be found to be less intimately connected with the cord (see Principles for the Treatment of Intramedullary Growths).

After the tumor has been removed and all oozing of blood controlled, the dura, muscles, fascia and skin are closed in the usual manner.

**Special Procedures at Different Levels of the Cord.**—When the growth is high up in the cervical region it is sometimes advisable to divide the operation into two stages. At the first operation the growth is exposed; at the second stage, one week later, when the pressure conditions have readjusted themselves, the tumor can be removed with safety.

Formerly I always advised that high cervical tumors should be operated upon in two stages. With a larger experience I have learned that (unless there are or have been respiratory difficulties) the tumor can be removed at the first operation if great care be taken. I have recently removed an extramedullary growth which lay on the posterior surface of the cord above the third cervical segment and which projected into the foramen magnum. The patient never had any medullary symptoms after the operation.

Small growths between the roots of the cauda equina can usually be removed without difficulty. The larger tumors which grow around the conus and roots of the cauda equina, filling up the entire lower part of the spinal canal (giant endothelioma (Collins and Elsberg)), are very difficult to remove without danger to the roots of the cauda, and it is an open question whether the attempt should be made to remove them if they are very large. These tumors are not very vascular, but they surround the nerves of the cauda equina and can be separated from them with difficulty. When the dura is incised, the growth usually bulges markedly; nothing further should be done at this time, but the muscles, fascia and skin closed. If the wound is reopened after one week, the tumor will have been markedly extruded out of the canal and will have become more loosely attached to the nerves. Therefore, if the surgeon considers that the tumor can be removed, the operation should be done in two stages, extreme care being taken, at the second operation, to cause as little injury as possible to the nerve roots. Usually, in spite of all care, small masses of tumor tissue remain behind.

*Two-stage operations* are occasionally indicated in the upper and mid-cervical regions to allow of a readjustment of pressure conditions on account of the proximity of the medulla. In these high cervical operations the dura must not be opened at the first stage, or, if it has been opened, it must be closed by suture until the second stage. In all other two-stage operations the dural sac must be opened at the first operation and must be left open until the second stage. At the end of the first operation, before the wound is closed, in these cases, it is advisable to cover the exposed tumor and cord with cargile membrane.

In all intramedullary tumors and in some subpial growths which are closely adherent to the cord, the operation must be divided into two stages. In the case of intramedullary tumors the cord tissue is incised, and in the cases of subpial growths an incision through the pia is made, the tumor and exposed cord covered by a piece of cargile membrane and the operation concluded for the time being, in order to allow the tumor to become extruded.

Giant tumors of the conus and cauda equina must also be operated upon in two stages, so as to allow the growth to become freed from the caudal nerves to as great an extent as possible.

## THE RECOGNITION AND REMOVAL OF INTRAMEDULLARY GROWTHS. THE ANATOMICAL BASIS FOR INTRAMEDULLARY SURGERY

Intramedullary tumors cause either a fusiform enlargement or they cause a localized bulging on one or the other side of the cord. If the surgeon has a good idea of the appearance of the cervical and lumbar enlargements of the spinal cord, he will never mistake the normal for a pathological increase in size. Intramedullary tumors usually cause so

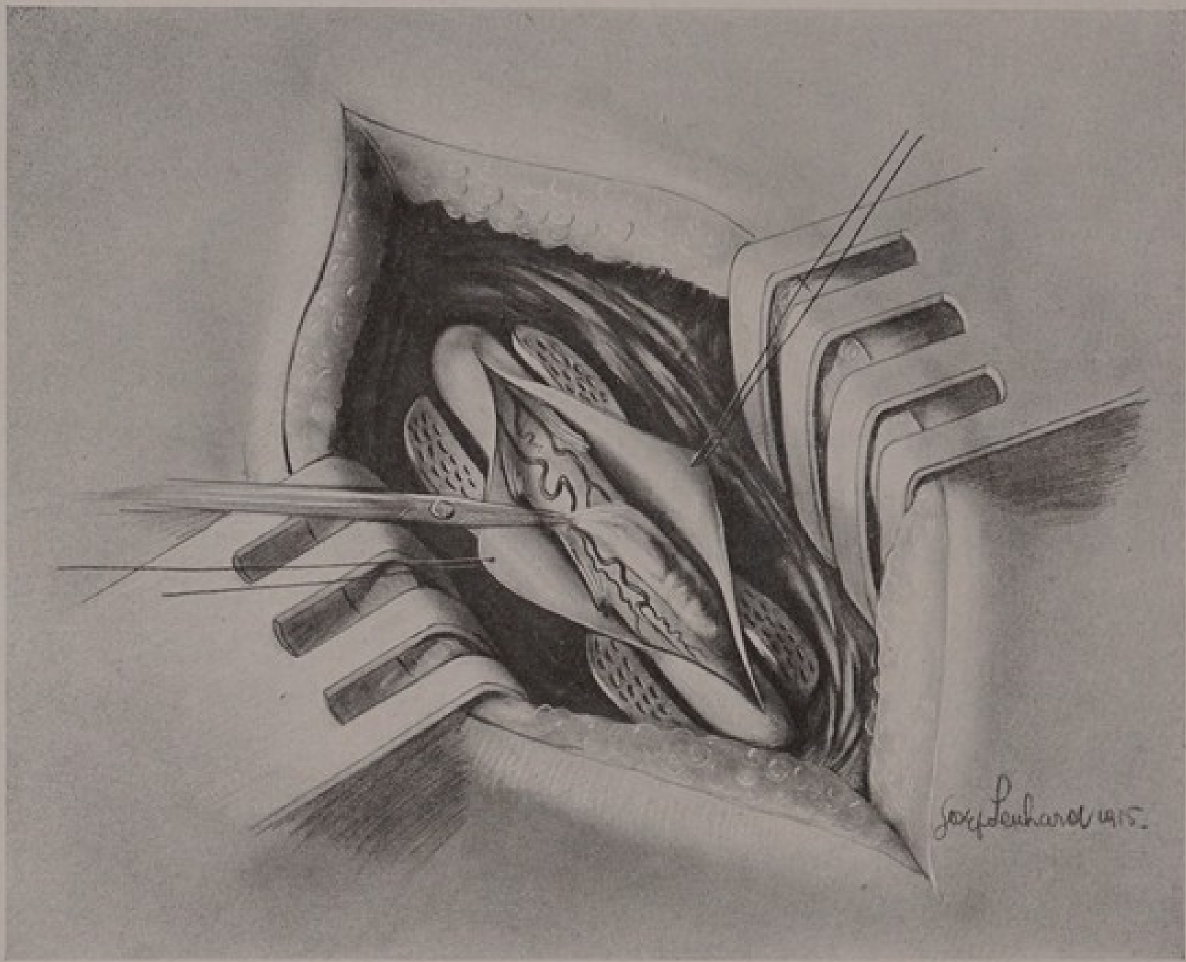


FIG. 136.—A subpial tumor of the cord.

marked an enlargement that the circulation of cerebrospinal fluid is interefered with and a stasis of fluid above the tumor follows.

It is sometimes difficult to differentiate between a subpial growth closely adherent to the cord and a true intramedullary neoplasm (Figs. 136 and 137), especially if an intramedullary tumor has broken through the posterior surface of the cord and has pushed the pia mater before it. It is possible for a subpial tumor to bury itself in the cord to such an extent that it has the appearance of a true intramedullary neoplasm and that cord tissue must be incised before the tumor can be removed. Some cases in the literature which have been described as intramedullary growths probably were of this kind. After the operator has incised the pia which covers the tumor, he may think that he is incising cord tissue when in reality it is the capsule of the tumor. After some experience, it

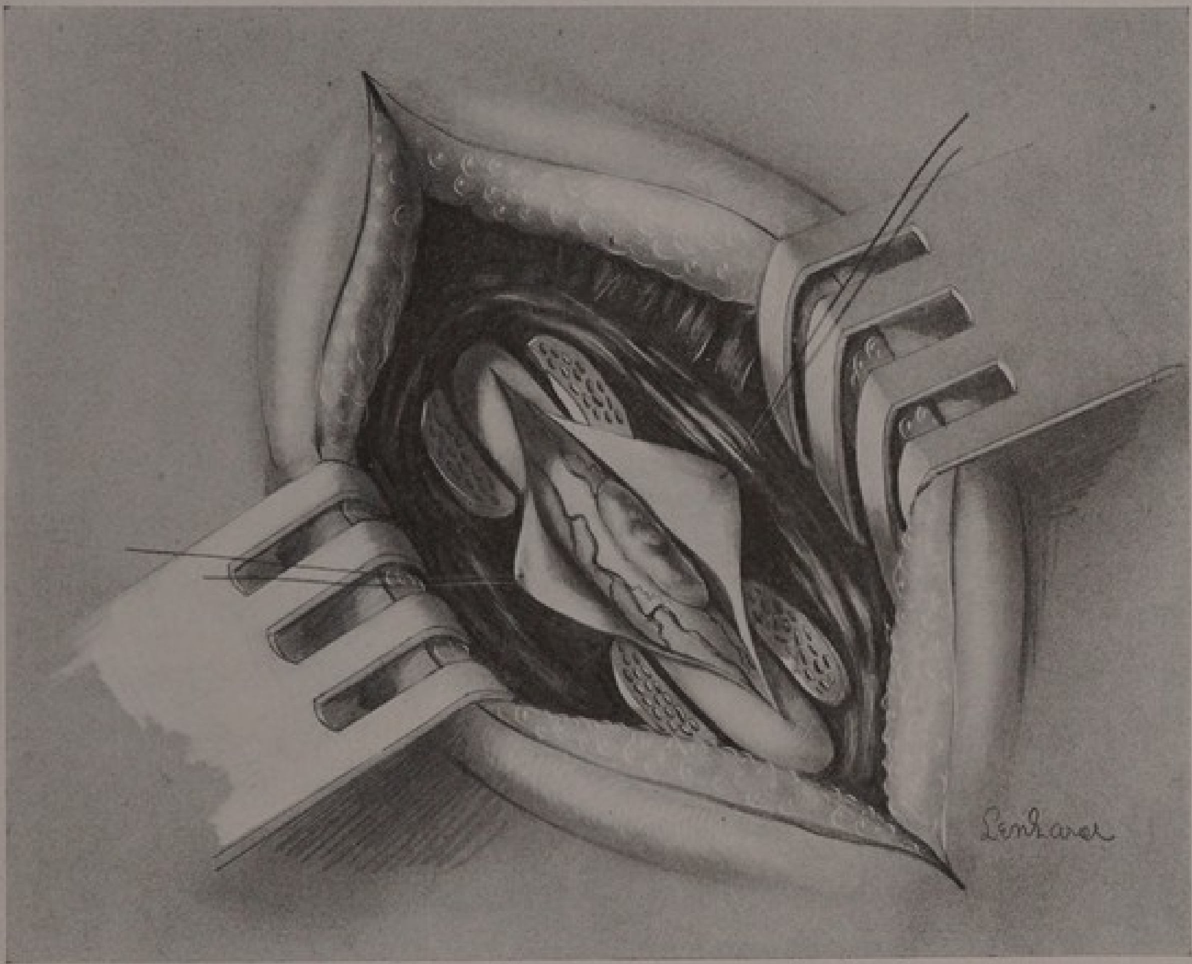


FIG. 137.—A spinal tumor which lies embedded in the cord.

is not difficult to recognize the soft creamy yellow appearance of cord tissue.

Before I describe the method to be followed in the removal of tumors from the substance of the cord, an account of the anatomical basis for intramedullary surgery must be given.

**The Surgical Anatomy of the Spinal Cord from the Standpoint of Intramedullary Surgery.**—Not only from their anatomical position and their physiological character, but also from the ease with which they may be exposed, the posterior columns of the spinal cord are the most favorable for an incision. The fibers in the posterior columns convey principally tactile and deep muscle sensations to higher levels, although the fibers for all varieties of sensation enter the cord in the posterior spinal roots. Our knowledge of the conducting paths for the various sensations is still incomplete; the following is a summary of all that is known.

The fibers for the sensation of pain enter the cord in the posterior roots, and soon pass through the posterior horn and gray matter to the anterior part of the lateral column on the opposite side. The fibers for thermesthesia take a similar course; they do not cross to the other side as quickly as the pain fibers, but require from two to five segments for the complete crossing. The fibers for touch pass partly along the same course as the pain fibers, and partly in the posterior columns on the same side, to the posterior column nuclei at the extreme upper end of the cord. In these columns also lie the paths for deep muscle sense (postural recognition, spacial discrimination, etc.). When one part of the sensory pathway in the cord is interrupted, other tracts may take up the transmission of sensations. Although this is probably true for all kinds of sensation, the tactile sensations especially seem to run in a bilateral path and are not so apt to be markedly affected by a purely unilateral lesion.[1]

The posterior columns, in short, contain mainly fibers (endogenous and exogenous, primary and secondary paths) which contribute to the transmission of tactile and deep muscle (kinesthetic) sensations, and we must next determine the course of these tracts in the posterior columns.

As is well known, the fibers from the posterior roots from below upward enter the cord and lie at first just mesial to the posterior gray horn. Some of these fibers remain in the posterior column, where they divide into ascending and descending branches. The ascending branches give off numerous collaterals to the gray horns until the level of the next root above is reached. Fibers from this second root then take their position on the medial side of the posterior horn, crowding the fibers from the preceding (lower) root more toward the median line (Fig. 138). It will

[1] Rothmann believes that sensory fibers for touch exist also in the anterior columns of the cord.

be seen, therefore, that the fibers finally form a succession of lamellar tracts which in each case lie at first next to the posterior horn and gradually become shifted medianward by those which enter the cord with the higher nerve roots (Schaefer). This arrangement of tracts in the dorsal columns has been studied in the lower animals by Kahler and many others, while degenerations in the tracts of the cord in man have been described in detail by Schaefer, Ziehen, Collier and Buzzard, Wickmann, Schultze, Pétren, and others.

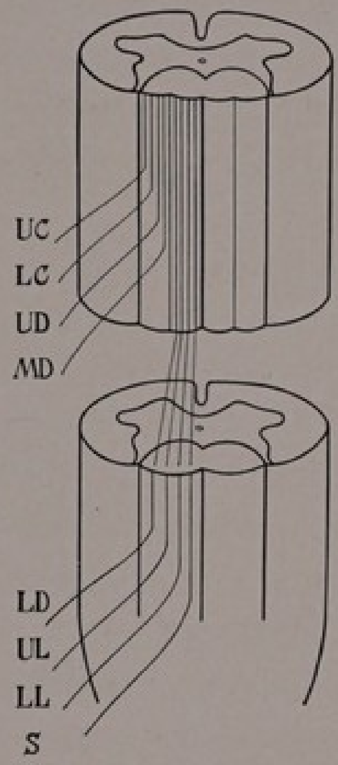



FIG. 138.—The arrangement of the fibers in the posterior columns. S, sacral; LL, UL, lower and upper lumbar; LD, MD, UD, lower, middle and upper dorsal; LC, UC, lower and upper cervical.

As a result of this arrangement of conducting paths in the posterior columns, the fibers from the sacral posterior roots soon come to lie nearest the posterior median fissure; outside of these run the lumbar root fibers, outside of these the dorsal, and so on (Fig. 138).

In the lumbosacral region, the columns of Goll and Burdach are not distinct, and the fibers from the posterior roots occupy a great part of the dorsal column; while in the cervical and dorsal regions, the arrangement is such that the posterior median column (Goll) contains only fibers from the sacral, lumbar, and lowest dorsal posterior nerve roots, while the postero-external column of Burdach contains the fibers from the upper dorsal and cervical posterior roots (Fig. 139). Therefore, in the lumbosacral region an incision may be made anywhere in the posterior column. It is best made a few millimeters away from the median line, so that injury may not be done to the descending tracts (triangle of Gombault and Phillipe, from the third sacral nerve to the conus) in the sacral region, the oval bundle of Flechsig (from the third and fourth lumbar nerves to the third sacral nerve), and the septomarginal bundle of Bruce and Muir (from the first to the third lumbar nerves) in the lumbar region. The

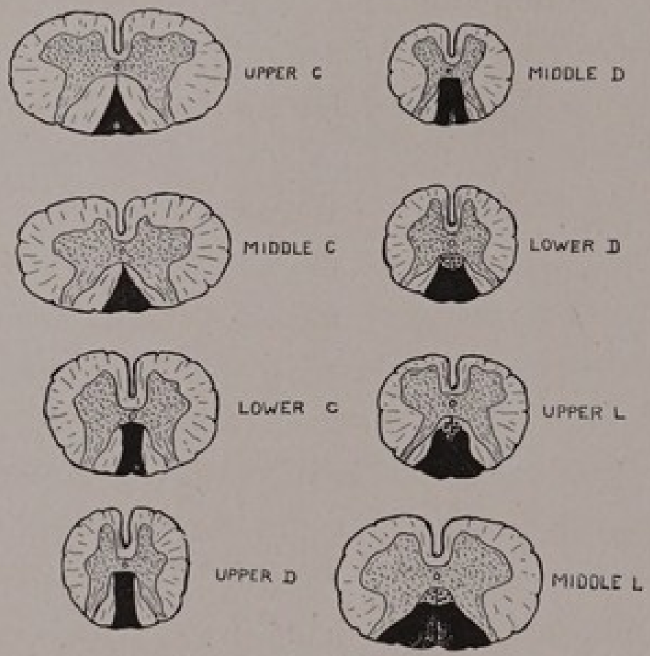



Fig. 139.—The portion of the posterior columns in which degeneration occurs after division of the lowest sacral roots (after Schultze).

incision should not be too near the posterior root zone, lest it do damage to the marginal fibers. The deeper the incision, the greater the probability of injury to fibers from the higher lumbar roots.

In the dorsal and cervical regions the incision should always be made in the posterior median column, and the higher the level, the nearer should the incision be to the median line. In the upper and middorsal regions the incision is best made from 2 to 4 mm. from the median line, while from the level of the midcervical region upward it should be made very near the median line. The accompanying diagram (Fig. 139) shows the areas in the posterior columns of the human spinal cord in which ascending degeneration occurs after injury to the sacral and lowermost lumbar posterior roots of both sides. Within the areas shaded in black, an incision, made in the posterior column of the one or the other side, will cause a minimum of injury to nerve fibers and few or no symptoms.

It is important, also, to remember that in the sacral region there is very little white matter, the bulk of the cord being formed of gray matter. In the thoracic region there is a relatively small amount of gray matter, while in the lumbar and cervical enlargements the gray matter as well as the white columns, are of large size.

**The Removal of Intramedullary Tumors.**—Before the cord is incised it is aspirated with a very fine hypodermic needle, in order to make certain that we have to deal with a solid tumor and not with a collection of fluid.

*Incision of the Cord.*—For the incision of the cord a very fine scalpel, such as the von Graefe knife used by the ophthalmologist, should be used. The arachnoid is first incised and grasped with fine forceps. Then the proper part of the posterior column is selected and an incision made. The incision must be carefully deepened and enlarged, care being taken that it shall be in the long axis of the cord. The enlarging and deepening is best done with a blunt instrument, and for this purpose a small blunt strabismus hook is the proper instrument. The incision in the cord should always be slowly made and should be stopped as soon as there is the slightest bleeding. Sponging should be done with small bits of cotton, with extreme gentleness, so as to make the smallest amount of pressure upon the cord. When a cystic collection of fluid or a small area of softening is opened, no effort should be made to remove the fluid in the cavity by sponging or by pressure.

*Removal of the Growth.*—The attempt to remove a growth from within the substance of the spinal cord, no matter how carefully it was done, would require an amount of handling and a degree of manipulation of the delicate tissue of the cord that would, in the large majority of cases, be followed by a traumatic inflammation that would damage or destroy all the elements of the cord at the spot, and would probably be permanent in its effects. Therefore, although intramedullary growths had been removed in a very few instances with more or less improvement, it was necessary to devise a new method for these intramedullary growths. In 1911 Elsberg and Beer described the method of extrusion, by means of which it is possible to remove a tumor from the substance of the cord with a minimum amount of injury to the cord tissue.

The theory upon which the method of extrusion is based is the following: There must exist within the cord a certain intramedullary pressure, such as exists in all solid and fluid substances. When there is a tumor growth in a part of the cord, the intramedullary pressure must be locally increased. If an incision is made down to the growth, nature will proceed to readjust the pressure conditions, and in so doing will push out, conditions being favorable, whatever has caused the local increase of pressure.


FIG. 140.—Stages in the extrusion of an intramedullary tumor (diagrammatic).

When, therefore, an incision is made down to the tumor in the cord, the tumor will be slowly pushed out of its bed, and will be slowly "extruded" from the cord substance (Fig. 140). Nature will accomplish this process slowly, nerve fibers being slowly pushed to the side while the growth is being extruded, and with far less injury to the cord structure than the most careful manipulations of the surgeon. If these theoretical considerations were correct, the surgeon would have only to incise the cord down to the tumor, and then have to wait for the readjustment of pressure conditions when the tumor should be found outside of the cord tissue. The practical trial of this method showed that the theory upon which it was based was correct, and we have called the procedure "the method of extrusion."

If, then, after laminectomy and incision of the dura the surgeon finds that he has to deal with an intramedullary growth, he should make a short incision about 1 cm. in length in the posterior median column, a

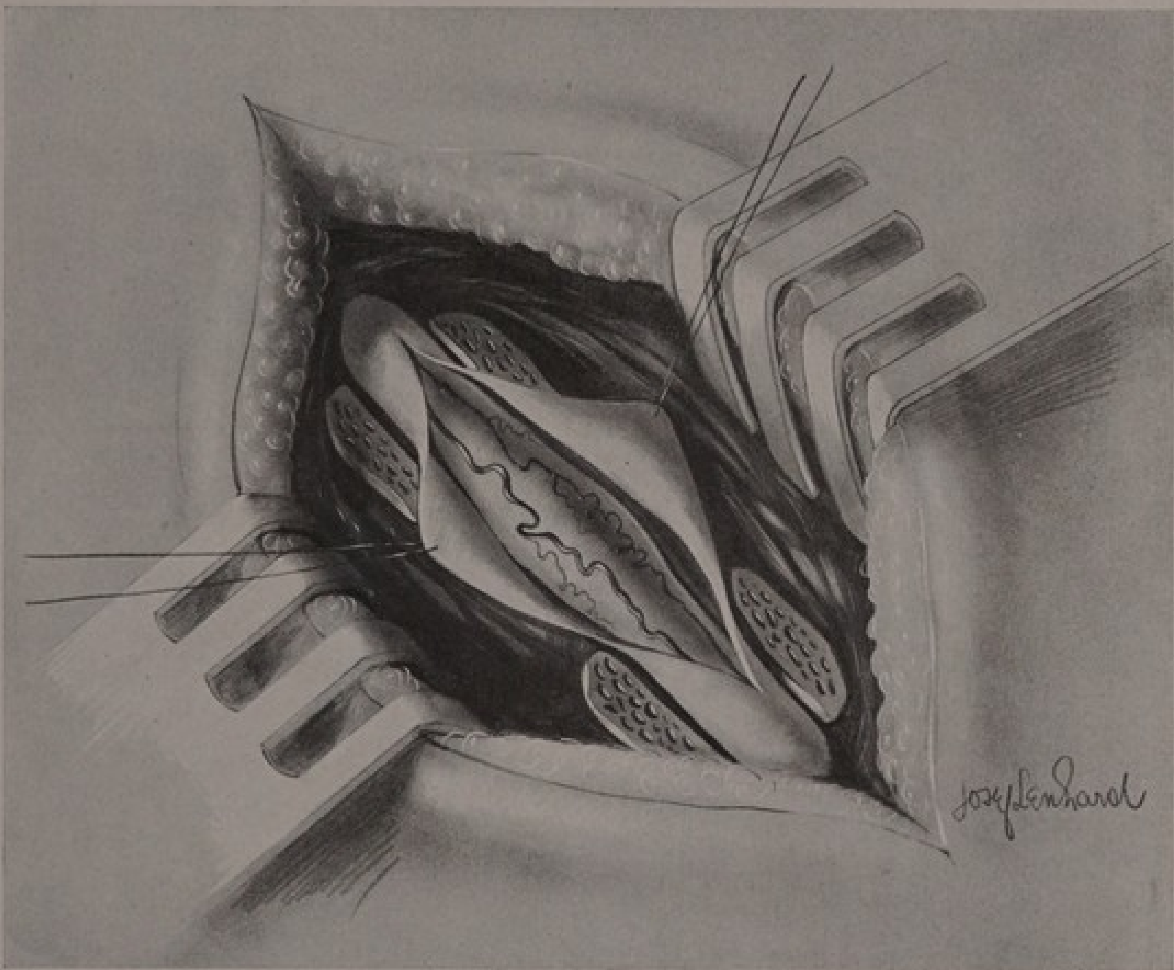


Fig. 141.—I. An intramedullary tumor which caused a fusiform enlargement of the cord. After incision of the cord and extrusion of the growth, the tumor was removed (see Figs. 142 and 143).

few millimeters outside of the posterior median fissure, at the spot where the growth seems to be nearest the surface of the cord. The incision, made in the manner we have already described, should be deep enough to divide the pia and the substance of the column down to the tumor. The tumor will then begin to bulge through the incision. No matter how markedly the tumor protrudes, the surgeon must not attempt to remove the growth for fear of grave injury to the cord. The operation must be concluded for the time being, the dura left wide open, and the muscles, fascia and skin carefully closed, as if the operation was definitely ended. The actual removal of the tumor is left for a second operation.

After about a week the wound is reopened, and the tumor, which will in all probability be found outside of the cord, can be removed by dividing the few adhesions which remain. When the tumor has been removed and all bleeding controlled, the dura, muscles, fascia and skin are closed in the usual manner (Figs. 141–143).

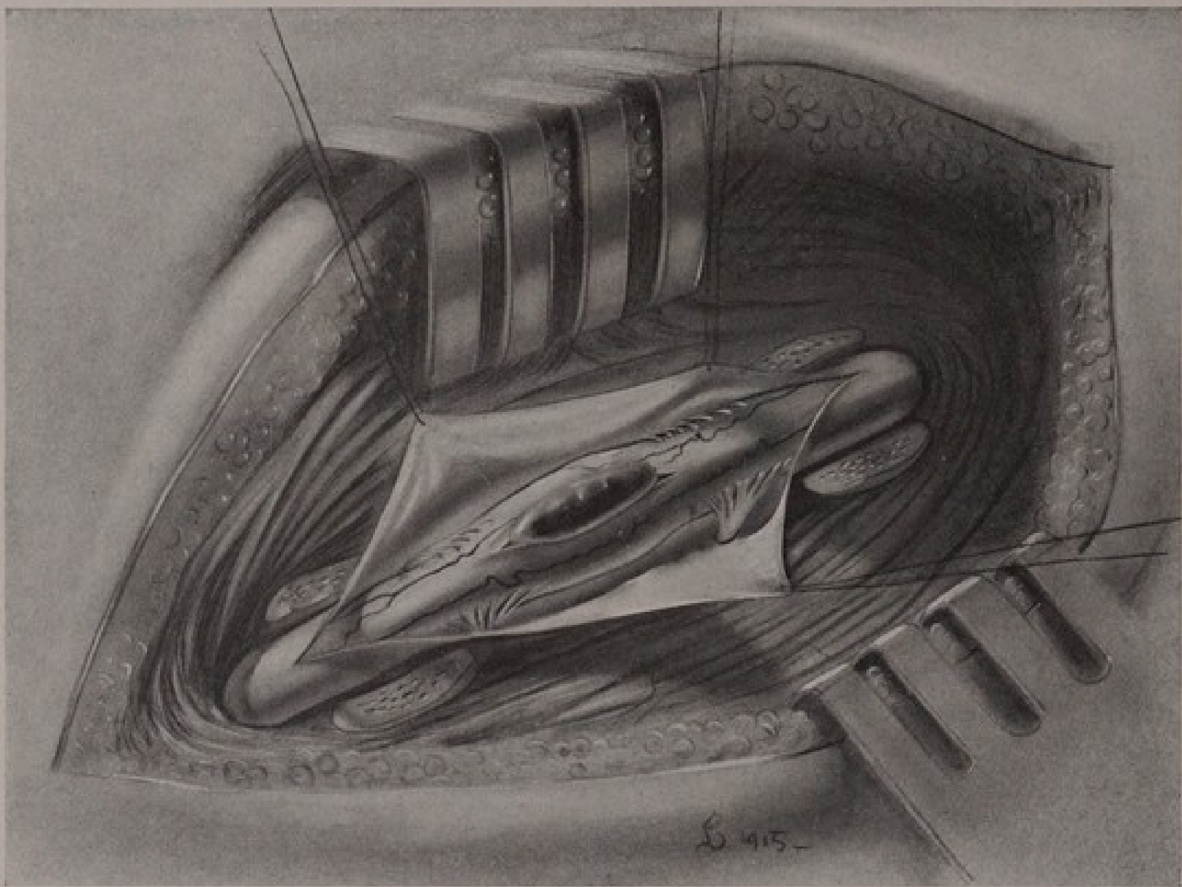


Fig. 142.—Removal of an intramedullary tumor by the extrusion method. II. The cord has been incised and the growth is partly extruded.

If, at the second operation, the tumor is found to be still closely connected with the cord tissue, it is advisable to leave it *in situ* and not to attempt its removal.

At the first operation one can usually determine whether the tumor is a localized one which will extrude sufficiently for its removal, or whether it is a more diffuse growth which extends through a large number of cord segmentis and which will extrude only partially or not at all. If the growth is an infiltrating one, the symptoms may be ameliorated by the incision in the cord; if the growth is very diffuse and is only partially extruded, the patient's symptoms may be made worse for a considerable period of time. The best proof that the extrusion is occurring satis-

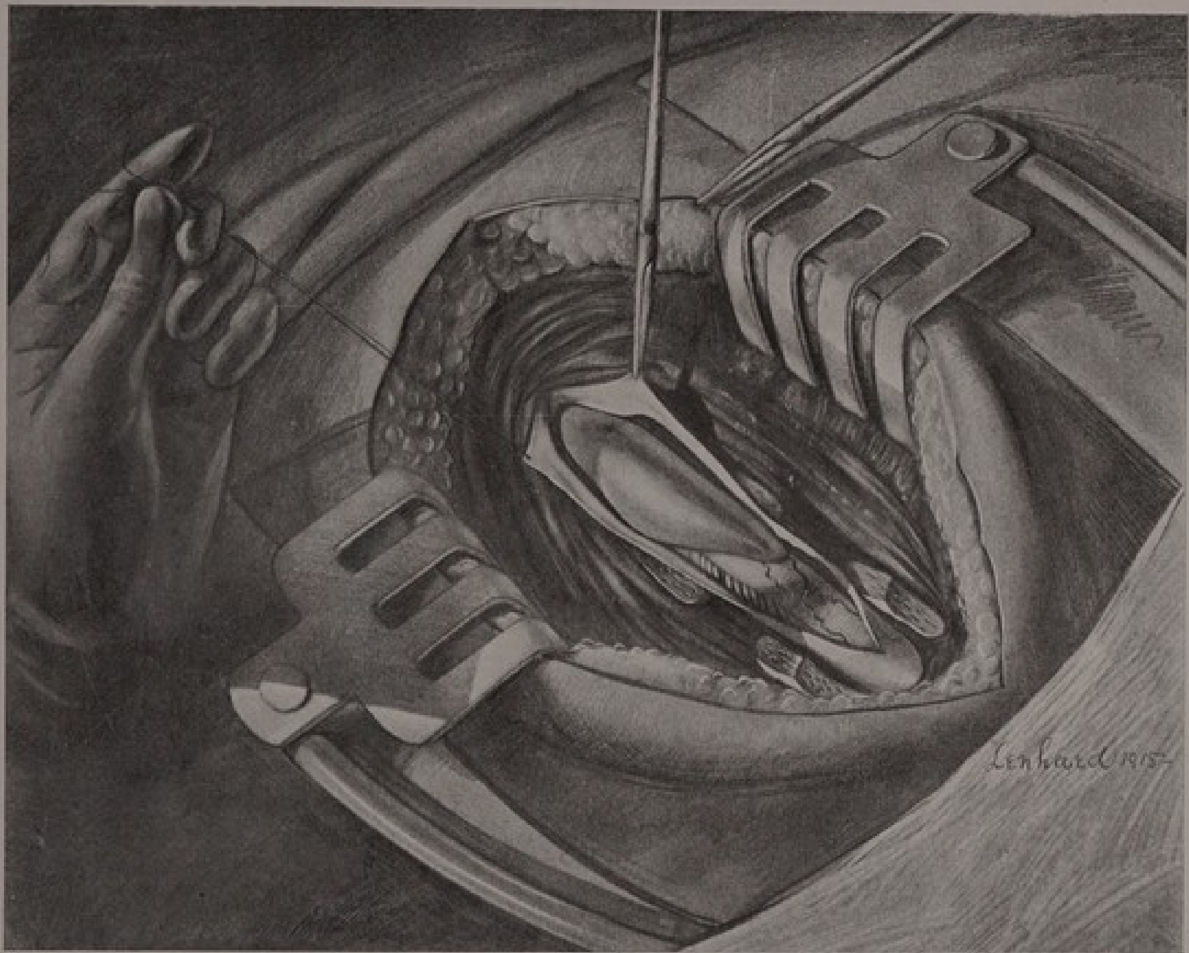


FIG. 143.—Removal of an intramedullary tumor by the extrusion method. III. After one week the growth had been entirely extruded, and was easily removed.

factorily is that after the lapse of a few days the symptoms of the cord lesion begin to improve.

If absolutely no improvement occurs after the incision of the cord, the extrusion of the tumor is not taking place because of its infiltrating character or its intimate connection with the cord tissue. There is a type of sarcoma which arises from the spinal cord and is closely connected with the proper tissues of the cord. In these patients the relief from the first operation is a small one.

If, at the second operation, the tumor is found to be still intimately connected with the cord tissue, no attempt should be made to remove it, or at most only the extruded part of the tumor should be cut away.

Very rarely, a small tubercular nodule is so well encapsulated that it can be removed without injury to the cord, as it will almost "pop" out of the cord after the incision has been made. I have seen one case of this kind (Figs. 144–146).

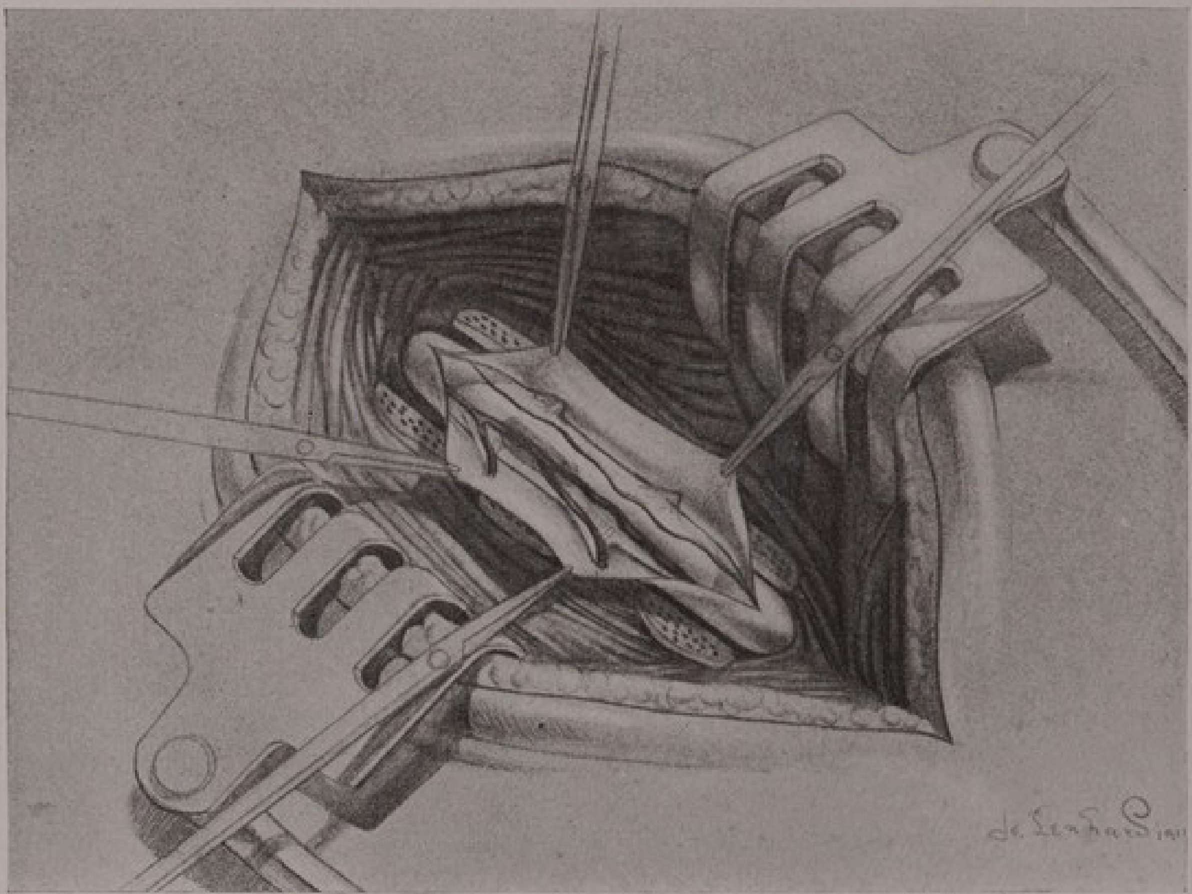


FIG. 144.—Tuberculoma of the lumbar cord. The left posterior spinal vein is much enlarged.

*The general treatment* after the removal of a spinal tumor is a simple one. The patient should be kept on a water bed and, after the first twenty-four hours, should be frequently turned from side to side. If necessary, the bladder must be emptied by catheter at regular intervals. The first dressing should be done and the sutures removed after eight or nine days. After two weeks, electricity, massage and passive movements of the affected extremities are begun. The patient can be allowed out

Fig. 145.—Tuberculoma in the substance of the cord. The partly extruded mass.

Fig. 146.—The cavity in the cord after removal of the tuberculoma (compare with Figs. 144 and 145).

of bed within two weeks after the operation, and should be encouraged to exercise the limbs at regular intervals.

**The Return of Function after the Operation.**—The spinal cord has not only a marked power of resistance, but a considerable power of recuperation after the removal of a long-standing compression. Thus it is not rare to find an astoundingly rapid recovery of sensory and motor power after the removal of a tumor which has flattened the cord almost to a tape-like thinness.

The return of functions will, of course, depend upon the amount of actual destruction of fibers that has occurred. The statement has often been made that the amount of injury to the spinal cord is in direct proportion to the size of the newgrowth. This is incorrect. In my experience the large tumors are more often soft in consistency, while the small ones are frequently very hard. Although the amount of destruction will depend to a considerable extent upon the duration of the compression, the small (and hard) growths more often cause an irremediable lesion of the cord than the larger ones which have a less firm consistency. The pain may disappear at once after the operation. The improvement in motor, sensory and bladder symptoms is often noted within a few days of the removal of the growth.

At first, all of the symptoms may be exaggerated, but improvement begins within a few days. In very many instances the knee and ankle jerks, which were exaggerated before the operation, become much depressed or can not be obtained, but they reappear within twenty-four hours.

I have seen beginning return of power in the extremities within one day of the surgical interference, and have seen a patient with complete paraplegia able to walk two months after the removal of an extramedullary tumor.

Whether the sensory disturbances improve more rapidly than the motor, or *vice versa*, will depend upon the location of the tumor. In general, the improvement in both sensation and motion occurs simultaneously. In some patients all of the sensory signs will have disappeared when exaggerated reflexes, ankle clonus and spasticity of the lower extremities are still present. When there has been a marked loss of deep muscle sense (bathyanesthesia), this loss is very apt to persist longer than any other symptoms.

The improvement is more rapid after the removal of an extramedullary than an intramedullary growth. Some patients recover entirely within a few months of the operation, so that it is impossible to find any evidence of a previous sensory or motor loss. In other patients the improvement is slow, requiring many months or even several years for all abnormal symptoms and signs to disappear. After the removal of an intramedullary growth by the method of extrusion, early marked improvement is rare. Several months usually pass before the first motor changes are observed, and I have seen six months elapse before the first signs of returning sensation appeared. If the motor and sensory loss from an intramedullary tumor has been marked, it will surely require one to two years for great improvement to occur. Sometimes marked spasticity remains. A posterior root section may be necessary before good control of the lower extremities is obtained.

After the removal of an intramedullary growth, a temporary complete paralysis below the level of the lesion with loss of reflexes may occur. These symptoms will, however, disappear within one to two weeks.

## NON-OPERATIVE METHODS IN THE TREATMENT OF TUMORS OF THE VERTEBRAL COLUMN AND SPINAL CORD

In irremovable malignant disease of the vertebral column, treatment by the X-ray and by radium should be tried, although the outlook for relief is up to the present time a poor one. A few cases have been reported in medical literature in which X-ray treatment diminished the size of the growth or lessened the root pains, but I know of no case in which by this means a complete cure was effected. Several of my patients received X-ray treatment for considerable periods of time, but there was no improvement in any of them. I have never seen any benefit from the use of Coley's toxins.

The only means we possess for the relief of these patients is morphine, unless division of the anterolateral tracts is performed. Occasionally, the patients may be made a little more comfortable by immobilization of the affected portion of the spine in a plaster-of-Paris jacket. The patient must be kept on a water or air mattress; if there is retention, the bladder must be emptied at regular intervals or a permanent catheter inserted.

Up to the present time, our hopes that the X-ray or radium might do some good in infiltrating intramedullary growths have not been realized.

### RESULTS OF THF SURGICAL TREATMENT OF TUMORS OF THE SPINAL CORD

There is no more satisfactory operation in surgery than the removal of an extramedullary tumor of the cord. The patients usually stand the operation very well, if it be done rapidly, and recovery is prompt. The recovery from the paralytic and other symptoms will occur very rapidly if the case has come to operation early. I have seen complete recovery in three to four weeks.

The only patients in whom we may expect a complete recovery—and by a complete recovery I mean the disappearance of all of the symptoms and of all evidences of loss or disturbance of function—are those who are operated upon early in their disease. We can not expect a patient who has been paraplegic for many months or years to recover entirely any more than we can expect a patient who has had a marked long-standing choking of the disc from a brain tumor to recover without some post-neuritic atrophy. If the diagnosis is made early and the operation not delayed, complete recovery will occur within a short time—often only a few months. If more or less marked motor and sensory loss has existed, it may take years before all of the signs disappear, and some signs, such as ankle clonus, exaggeration of some reflexes, etc., may remain. If the pressure upon the cord has existed for many years, the cord may have been so much injured that improvement is impossible. Even if the pressure has existed for a number of years, however, considerable return of power and sensation may occur, although it may require many years for the improvement. There is nothing more unfortunate than to have a patient remain paralyzed, after the removal of an extramedullary growth has been easily accomplished, because the diagnosis was not made early enough.

The mortality from the operation has varied in the hands of different operators. Thus Horsley operated upon twenty successive patients without a death; in twenty-six operations by Fedor Krause, there was a mortality of 37 per cent. Harte collected records of ninety-two operations for spinal tumor with an operative mortality of 47 per cent. McCosh claimed that the mortality should not exceed 10 per cent. I have operated upon twenty-two extramedullary tumors without any mortality from the operation.

Intramedullary tumors have been removed with great improvement in the symptoms by Ropke (one case), von Eiselsberg (one case), Schultze (one case), Elsberg and Beer (three cases, one death), Elsberg (six additional cases, one death), and several other surgeons.

As the danger from an operation for an extramedullary tumor is very small, what can we promise the patient or his family as to ultimate recovery? The result will depend upon the amount of injury that has been done to the cord by the pressure of the tumor. If the symptoms have been slight, the recovery may be complete within a few months. If more marked sensory and motor loss existed, it will take many months or several years before the patient will be well. Not so infrequently, however, a rapid improvement in sensory and motor symptoms will follow the removal of an extramedullary growth which had caused paraplegia for several years. The longer the paraplegia has existed, the less the chance of complete recovery. The longest time after which I have seen a paraplegic recover sufficiently for the patient to be on his feet without assistance has been three years.

Sometimes on account of the long spinal compression, a marked spasticity remains; in these cases great improvement may follow the division of the appropriate posterior roots.

# CHAPTER XVIII

## HEMATOMYELIA. SPINAL GLIOSIS AND SYRINGOMYELIA. ABSCESS OF THE CORD

In some diseases of the spinal cord the symptoms are due both to the destruction of cells and nerve fibers by the pathological process and to the compression of the spinal cord by blood, cystic fluid, pus, or new-formed tissue. The treatment of diseases of this nature has been most unsatisfactory, and in the large majority of instances the therapeutic results have been extremely poor. It is generally recognized that known methods of treatment have no influence at all on these diseases.

This is the present status of the therapeutics of hematomyelia, of spinal gliosis and syringomyelia, and of the much rarer lesion—abscess of the spinal cord. With the advances in intramedullary surgery, however, the question has arisen whether the injury due to a long-standing compression of the cord by blood, by fluid from cystic degeneration of glia tissue and by the gliomatous masses themselves could not be relieved by surgical means. That the proper treatment of abscess of the cord, if the diagnosis could be made, should be a surgical one can not be gainsaid. I firmly believe that the time is near at hand when the deleterious effects of collections of blood or fluid in the cord tissues will be controlled by means of aspiration or drainage of the fluid or blood. Up to the present time my own experience has been a small one, but it has been large enough to justify great hopes for the future. In order to fully understand the aims of and the results to be sought for from the surgical procedures I shall describe, a short account of these diseases is necessary.

### HEMATOMYELIA

In this affection there has occurred a rupture of a normal or diseased blood vessel within the substance of the cord, with destruction of tissue, and the formation within the cord of a cavity or cavities filled with blood.

Hematomyelia occurs most frequently after trauma, although it may follow an infectious disease. The trauma may be a severe one—a fracture of the spine, a blow on the back of the neck or the back—or a mild one; it has occurred after slight bodily exertion. The cervical and lumbar enlargements are most frequently affected, although the lesion has been observed in all parts of the cord.

The bleeding may occur in either white or gray matter, but it is far more frequent in the latter, and is especially often seen in one of the posterior horns (Fig. 141). I have seen one patient in whom the blood was exclusively in the white matter of one posterior column. Ordinarily, the cavity in the cord is a small one and extends over three to six segments; it may be of considerable length; many cases are on record where the larger part of the cord was affected (Minor, Levier, etc.).

While death from the hemorrhage may occur very quickly, the course of the disease is usually prolonged. The sudden onset of the symptoms, after a more or less severe trauma, is very characteristic. After a few hours, during which the patient complains of pain in the back, a paraplegia or quadruplegia suddenly occurs; all sensation and all reflexes are lost below the level of the lesion. Bedsores may develop rapidly and the patient succumb after a few weeks from sepsis or bilateral kidney infection.

Some patients begin to improve after a few weeks. The blood begins to be absorbed, and motor and sensory power returns to a greater or less degree. At this time, also, muscle atrophies become evident. The improvement may continue until the patient has almost fully recovered, but in most instances more or less motor and sensory disturbance remains. The amount of recovery will depend upon the completeness with which the blood has been absorbed. A hydromyelia may remain or connective tissue cells fill up the cord cavity and form the starting point of a spinal gliosis.

If the patients are seen a few months after the onset of the disease, the symptoms of which they complain and the signs presented are the following:

When the lesion is in the cervical cord, there is usually a weakness and atrophy of the upper and a spastic paraplegia of the lower extremities. The sensory symptoms are of the dissociated type—persistence of tactile and absence of pain and temperature sensations,—but they will vary with the amount of destruction and the parts of the cord affected. If the hemorrhage has occurred into the gray matter of one side, there may be motor loss on one and sensory loss of the dissociated type on the other side. If the hemorrhage has involved only the white matter, there will be the signs characteristic of a lesion in that part of the cord. More often both gray and white matter are affected, and the motor and sensory loss is irregular and diffuse. Nevertheless, it is usually possible to recognize the general level at which the hemorrhage has occurred.

The differential diagnosis between hematomyelia and other diseases of the cord can usually be made from the history and the course of the symptoms. In many instances the bleeding into the cord tissue is followed by a softening which soon causes symptoms of a transverse cord lesion. If such a lesion is exposed at operation, the cord will be found to be markedly softened and sunken in at the location of the lesion. If the soft area is carefully aspirated, thin turbid fluid may be obtained.

The diagnosis of hematomyelia can usually be made, although a few months after the beginning of the symptoms gliomatous changes may already have taken place.

Whenever a hemorrhage occurs into the cord, a certain amount of cord tissue is destroyed, but in many cases the amount of destruction is not very large. Much of the injury to cells and fibers is due to a long persisting compression of the sensitive cord tissues, and not a little to the cicatricial contraction that follows. The paralysis of the upper extremities is, to a varying extent, due to direct injury of the cells in the gray matter which are connected with the nerves to the upper extremities, and therefore the recovery of power is never a complete one. Excepting in very extensive disease, the paralysis of the legs is due to pressure upon the pyramidal tracts by the effused blood and the consequent edema, and may be recovered from to a great extent. On this account the removal of the effused blood by aspiration or by drainage after incision of the cord should contribute not a little to the improvement which can occur.

## SPINAL GLIOSIS AND SYRINGOMYELIA

In syringomyelia, or more properly spinal gliosis, there is a diffuse or localized proliferation of glia tissue in the gray matter of the spinal cord. If the growth of gliomatous tissue is localized, it may form a long, thin intramedullary tumor much like a pencil in appearance. The gliomatous

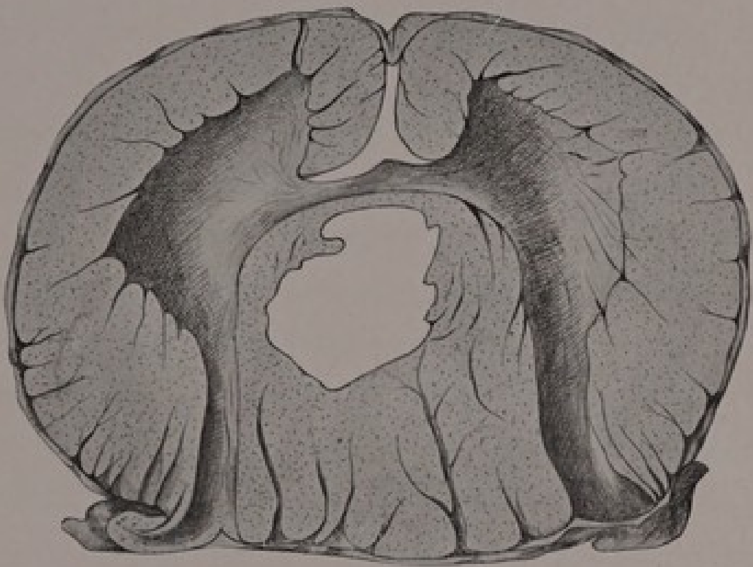


Fig. 147.—Cross section of the cord in a case of hematomyelia (Bailey).

growth has a great tendency to undergo cystic degeneration and to form cavities filled with fluid (syringomyelia, hydromyelia) in the cord substance (Fig. 148).

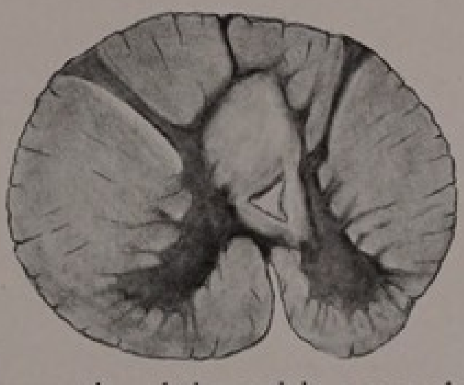


Fig. 148.—Cross section of the cord in a case of syringomyelia.

The lesion is most often found in the posterior gray horns, and is very apt to extend into one or both posterior white columns by the side of the posterior median septum. The cervical cord is most often affected, although the disease may extend down into the dorsal cord or upward into the medulla oblongata (syringobulbia). The disease is supposed to be due to some congenital anomaly, but the frequent occurrence of the disease after trauma (hematomyelia, etc.) makes the connection between spinal gliosis and trauma a very close one. Gliomatous infiltrations and cavities in the cord may occur with chronic myelitis, spinal syphilis, and with spinal newgrowths.

The disease usually affects young adults and begins without pain or with slight paresthesiæ. Its progress is very slow and it may extend over a period of twenty, thirty, or forty years. The patient may be totally unaware of his disease until the small muscles of the hands are markedly atrophied. The occurrence of burns or ulcers of the fingers, spontaneous fractures of the bones of the upper extremities or recurring dislocations of the shoulder may bring the patient first to the surgeon.

The location of the disease explains the symptoms—progressive atrophy of the muscles of the upper extremities, dissociated sensory disturbances, vasomotor and trophic changes in the skin, bones, and joints. The earliest atrophies are generally observed in the small muscles of the hands, although the shoulder muscles are occasionally first affected. The atrophies in the upper extremities are usually unsymmetrical, and one hand may be wasted and present the typical "claw hand" appearance while the other is still normal. Subjective sensory disturbances are usually slight and consist of numbness, coldness or burning sensations in the upper or lower limbs.

At the same time that the muscle atrophies occur, the typical disturbance of sensation is observed. This syringomyelic or dissociated sensibility consists of a diminution or loss of pain and thermal sensibility, with normal or almost normal tactile and deep muscle sensation. The sensory disturbances are radicular or segmental in character, and may occupy the areas of distribution of the posterior spinal roots in one or both upper limbs, in the trunk and in the lower extremities. The amount and distribution of the sensory disturbance will, of course, depend upon the extent and location of the lesion in the cord.

The vasomotor signs may consist of coldness, pallor or increased sweating. There may be ulcers or blebs on the hands and arms (often due to burns that are not felt); spontaneous and almost painless fractures of the radius or ulna or, more rarely, of the humerus; arthropathies in the joints of the upper limbs. Recurring dislocations of the shoulder are of frequent occurrence. The cervical sympathetic is often affected with a resulting inequality of the palpebral fissures, miosis, and sinking backward of the eyeball.

Sooner or later the weakness and atrophies in the upper limbs interfere with the use of the hands, and a spastic paraplegia of the lower extremities makes locomotion difficult. Finally—perhaps after very many years— the patients become helpless, and remain in this condition until some intercurrent disease terminates their life. The progress of the disease is a very slow one, and there are some individuals in whom the disease remains stationary for a number of years.

For the reasons that have been mentioned in the chapter on spinal tumors the differentiation between syringomyelia and spinal cord tumor is sometimes difficult.

Especially difficult may be the differential diagnosis between an intramedullary tumor and a gliosis, all the more as localized gliotic tumor masses occur in syringomyelia.

The more rapid course, the early occurrence of bladder and rectal symptoms, and the more rapid involvement of the lower extremities are characteristic of a growth within the cord. If the trophic disturbances are very marked (Morvan's type) the disease may resemble some forms of leprosy and of Raynaud's disease. I have seen one patient in whom the diagnosis of syringomyelia was made for several years, until a double cervical rib was recognized as the cause of the patient's symptoms.

In some cases of syringomyelia without sensory disturbances it may be at first difficult to exclude an amyotrophic lateral sclerosis or a progressive spinal muscular atrophy, but the appearance of sensory disturbances makes the differentiation possible.

In some instances, also, early compression of the cord in cervical Pott's disease may present symptoms very like those of syringomyelia—atrophies in the muscles of the hands, sensory disturbances, etc. The sensory disturbance is seldom of the dissociated type, however, and sooner or later signs of local compression of the cord and the other characteristics of tubercular disease of the vertebræ will be found.

There are a large number of other conditions which may simulate a spinal gliosis, but it is beyond the scope of this volume to discuss them in detail, and the reader is referred for further information to works on neurology.

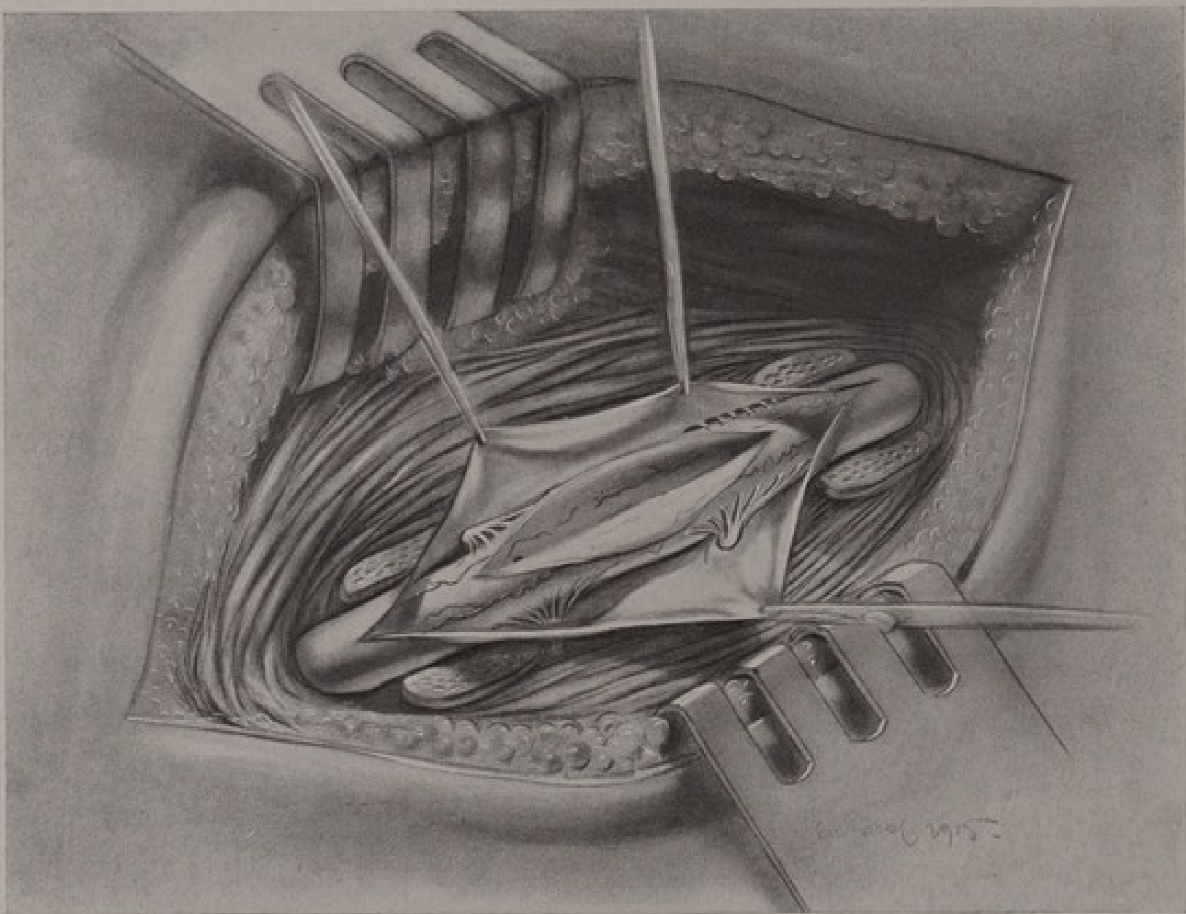


FIG. 149.—The appearance of the cord after a hydromyelia cavity has been incised.

I have given this short account of the symptoms and course of syringomyelia because there are some cases in which the drainage of a hydromyelia cavity and an incision into the gliomatous tissue for internal decompression may be justified. As in hematomyelia, some of the symptoms are undoubtedly due to compression of cord tissue by gliomatous masses or by collections of fluid, and in a case of this kind the possibility of improving the patient by surgical means must be considered. I have had several patients in whom the incision of the cord near the posterior median septum has been followed by a marked improvement, which has lasted for a number of years.

In two of my patients an exploratory operation was performed, because the differential diagnosis between gliosis and intramedullary tumor could not be made. The operation demonstrated that both patients had a spinal gliosis, and in both a decompressive incision was made in the cord at the lower cervical level. The operation was followed by marked improvement in the power of the upper extremities. One of the patients was a tailor who had been incapacitated from his work for several years. Three months after the surgical interference he had regained so much power and sensation in his hands and arms that he was able to resume his work as a tailor. The other patient had a collection of fluid in the center of the cord, and his improvement was also very marked (Fig. 149).

The operation is permissible, I believe, only in those patients who have distinct level signs with evidences of spasticity in the lower limbs.

## ABSCESS OF THE CORD

The spinal cord is rarely the seat of an abscess, only twenty-eight cases of true abscess of the cord having been reported. The suppuration may be secondary to a spinal trauma or it may be a metastasis from a suppurative lesion in some other part of the body. Abscesses in the spinal cord soon give rise to purulent meningitis and usually present the symptoms of an acute transverse myelitis.

If the diagnosis of an abscess of the spinal cord could be made, the rational treatment would consist of the incision of the cord and the evacuation of the pus from the cord substance.

## CHAPTER XIX

### INFLAMMATORY DISEASES OF THE SPINAL CORD, MEMBRANES AND NERVE ROOTS. SYPHILIS OF THE CORD

Although the differential diagnosis between myelitis and an intramedullary tumor may be difficult, myelitis (unless as a secondary process) has little surgical interest, and is never an object for surgical interference. Formerly the diagnosis "primary transverse myelitis" was often made, but it is now recognized that, excepting for the traumatic variety, chronic transverse myelitis is rarely a primary condition. There is no question, however, that cases do occur; they may cause symptoms of a gradually increasing affection of the spinal cord at a definite level, and may thus counterfeit a spinal disease which can be remedied by surgical interference.

Secondary transverse myelitis very frequently follows an inflammation in the meninges, for a spinal meningitis can not exist for any length of time without secondary degeneration in the spinal cord.

The early recognition and treatment of disease in the meninges is, therefore, of very great importance.

A large number of writers, Schlesinger, Oppenheim, Krause, Spiller and Musser, Horsley and others, have described inflammatory affections in which adhesions are formed between the meninges Collections of cerebrospinal fluid under pressure may be found in closed cavities between adhesions. If a low grade of inflammation continues in the walls of these cavities, the fluid may increase in quantity and may exert pressure both upon the nerve roots and upon the spinal cord. Krause speaks of acute and chronic circumscribed meningitis, of circumscribed adhesive arachnitis, and of chronic fibrous pachymeningitis, but such distinctions are only justifiable for the purposes of classification, and most of these pathological conditions are not to be considered clinical entities.

There are a large number of diseases that are accompanied by an inflammatory process in the meninges. In tuberculosis of the vertebral column with extradural collections of cheesy pus, a thickening and infiltration of the dura is very frequent, and adhesive inflammations between the pia, arachnoid and inner surface of the dura are often observed. Adhesions between the membranes occur in other inflammatory diseases of the vertebræ (osteomyelitis, arthritis deformans, etc.), in intradural new-growths, in various degenerative processes of the cord itself, in neuritis of the spinal roots, especially of the roots of the cauda equina. Chronic adhesive meningitis is of frequent occurrence in syphilitic diseases of the spinal cord and nerve roots.

For the purpose of description, four conditions may be considered: (1), pachymeningitis; (2), adhesive or serous meningitis or meningo-myelitis; (3), syphilitic meningitis; and (4), neuritis of the nerves of the cauda equina.

## PACHYMENINGITIS

While an inflammatory process may occur in any part of the spinal dura, it is most often met with in the cervical region as the so-called hypertrophic cervical pachymeningitis, first described by Charcot. The layers of the dura are affected by a slowly advancing, inflammatory process which results in a localized or more diffuse thickening. The membrane may be five to ten times as thick as normal, and the thickening may be so localized as to form an actual tumor which causes compression of the nerve roots and the cord exactly similar to an extramedullary neoplasm. The lesion is found most often in the lower cervical region, but considerable areas of the dura may be involved (cases of Clarke, of Mills and Spiller, etc.). The process may be primary in the dura, but it is often secondary to chronic osteomyelitis and to tuberculosis of the vertebræ, to syphilis and to other diseases of the spinal cord.

The symptoms vary with the location and the extent of the inflammatory process. Early and persistent nerve root symptoms—root pains, root paresthesias and root anesthesias—regularly occur. When the cervical dura is the seat of the disease, the patients often complain of pain in the back of the neck, of neuralgic pains in the upper extremities along the course of the ulnar and median nerves. Weakness, paralysis and atrophy of the muscles of the upper extremities, especially of the small muscles of the hands, are early symptoms.

The progress of the disease is usually a very slow one; many months or years may elapse before the thickening of the dura becomes great enough to cause pressure upon the cord and cord symptoms. If the dura is affected in the dorsal region, the symptoms will be those of a lesion at the affected level. Localized hypertrophic parchymeningitis causes a clinical picture very similar to that of an extramedullary spinal tumor. This is especially the case in the lower cervical and upper dorsal regions, and most mistakes in diagnosis have occurred at these levels of the cord. In many patients the differential diagnosis can not be made before operation. If the inflammatory process is more extensive, involving a large part of the cervical and dorsal dura, the very diffuseness of the early root symptoms must make the physician suspicious of the real nature of the disease. Occasionally the increased number of cells in the cerebrospinal fluid obtained by lumbar puncture will be a valuable diagnostic aid. In the patients I have operated upon, the cell count was in every instance a normal one.

As hypertrophic pachymeningitis is a frequent accompaniment of syphilis and of tuberculous bone disease, the Wassermann reaction and the X-ray examination may be of aid in arriving at the correct diagnosis.

**Operative Findings and Treatment.**—The diffuse forms of pachymeningitis are not amenable to operative treatment unless the severity of the root pains and the spasticity of the lower extremities require root sections. In a large number of the patients, however, distinct sensory and motor level symptoms occur. All of these patients should be subjected to operative interference.

As soon as the laminectomy has been performed, the operator will become aware of a marked thickening, rigidity, and discoloration of the dura. If the disease is localized, as many spines and laminæ as are necessary in order to expose the entire lesion must be removed.

In tubercular bone disease or chronic osteomyelitis of one or more laminæ, a chronic inflammatory thickening of the outer surface of the dura may be met with, which may cause compression of the cord underneath.

If a chronic abscess is found in the bone, the dura should not be incised, for fear of causing an infection of the leptomeninges. It is often possible to peel off the thick organized tissue from the outer surface of the dura. For this purpose, normal dura must be exposed below and the attempt must then be made to peel off the pathological tissue. If this

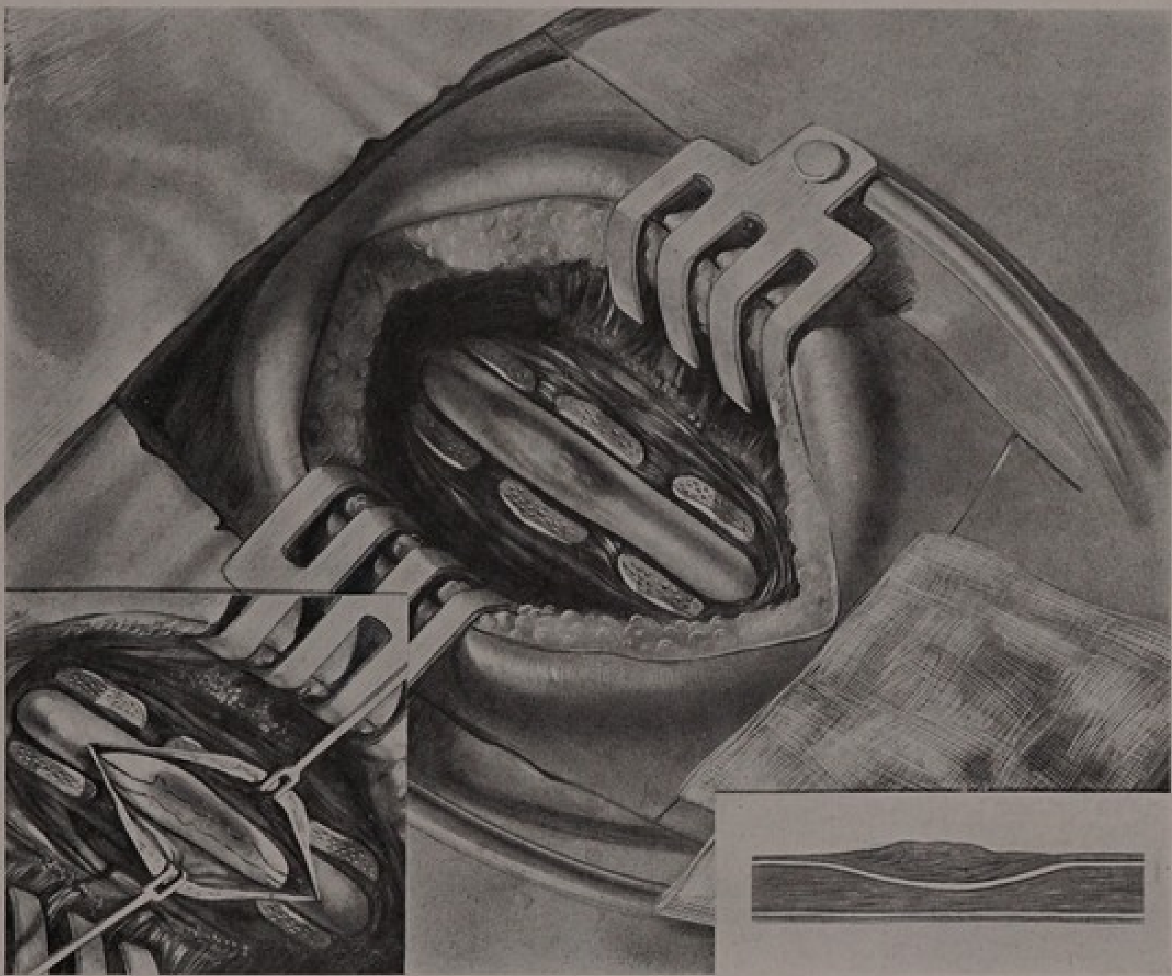


Fig. 150.—Localized cervical pachymeningitis. The insert to the left shows the thickened dural edges held open, and the depression in the cord. The insert on the right side gives a diagrammatic idea of the thickened dura which compressed the cord.

can not be accomplished, the thick tissue may be carefully incised without penetrating into the subdural space, and the pressure upon the cord underneath thus relieved. Considerable decompression is, however, obtained by the laminectomy itself. If there has been a chronic infection of the dura from the adjacent bone disease, it is allowable for the surgeon to drain the affected portion. I have seen marked root pains and marked spasticity disappear after this partial decortication and drainage of the dura.

If, however, there is no evidence of a bone focus and therefore no danger of carrying infection into the meninges, the dura will have to be incised; great care must be taken not to injure the cord which may be adherent to the inner dural surface. The operator will often be surprised by the amount of tissue he will have to divide before the dural was

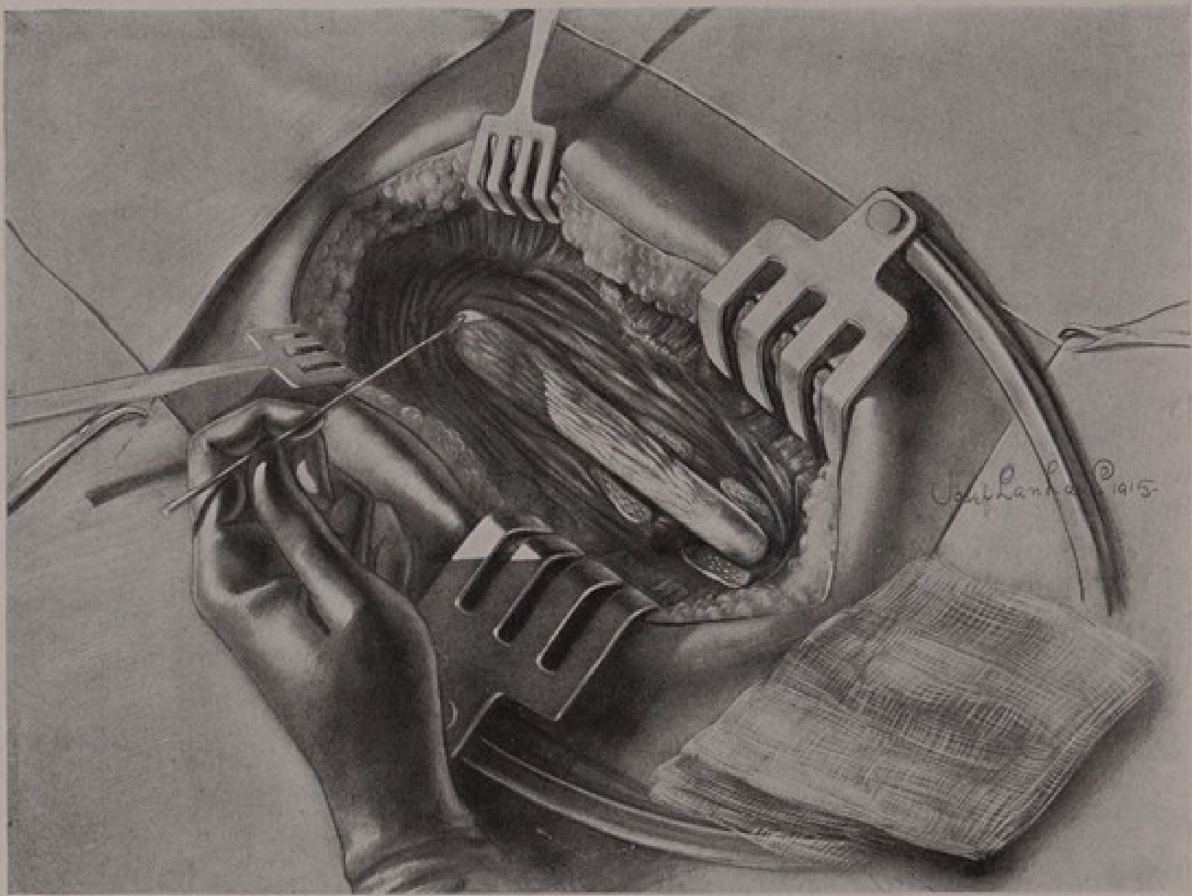


FIG. 151.—Extensive pachymeningitis. The probe points to the normal dura in the upper part of the wound.

has been penetrated. If adhesions to the pia arachnoid are found, they must be carefully divided as the edges of the incision in the dura are pulled apart. If the enlargement of the dura is circumscribed, the thickened part must be excised. This can ordinarily be accomplished without difficulty as the posterior part of the dura is most often affected (Fig. 150).

So much of the dura mater must often be excised, that closure of the dural sac by suture is impossible. In this case, the cord must be covered over by a piece of Cargile membrane or the gap left must be closed with a piece of fascia taken from the back or from the thigh. In some cases, however, after the removal of five, six, or even seven vertebral arches, the limits of the disease can not be exposed. The only procedure advisable in such extensive pachymeningitis is to leave the thickened dural sac open so that some of the pressure upon the cord and nerve roots will be relieved (Fig. 151).

The nerve roots must always be carefully examined and any thickenings around the dural openings must be excised. If severe pain over the distribution of one or more posterior roots had been complained of, it is advisable to divide the affected posterior roots. In order to avoid sensory loss, more than two successive roots should never be divided. In some cases, the roots may be freed from pressure by enlarging the dural opening. For this purpose, a small grooved director is passed through the dural opening from within outward, and a small incision running backward transversely to the long axis of the sac must be made.

The following history is a very characteristic one:

Jennie W., thirty-two years of age, admitted to the New York Neurological Institute on the service of Dr. Peterson; transferred for operation, November 20, 1913.

At ten years of age had some spinal trouble for which she was in bed for a number of weeks. Three years ago, she began to have pain in the upper part of the chest and left shoulder. She was treated for muscular rheumatism but the pain continued off and on until five weeks before admission to the hospital. Two months ago she noticed that she would stagger when walking, and that she had a girdle sensation around her body.

The patient is in excellent general condition; her gait is markedly spastic and ataxic. The cranial nerves and upper extremities are normal. Abdominal reflexes can not be obtained. There is marked spasticity of both lower limbs but movements of the limbs are difficult on account of the spasticity. The right limb is much weaker than the left. The knee jerks are exaggerated, the right more than the left; the ankle jerks are exaggerated and there is double ankle clonus and Babinski on both sides with a decided loss of deep muscle sense in the lower extremities. There is a marked diminution in tactile and pain sensations from the sixth dorsal level downward, a loss of recognition of heat and cold of the legs and feet, and a diminution of thermal sense over the thighs, abdomen and chest up to a little above the level of the sixth dorsal distribution. The sixth dorsal spine is sensitive to pressure. Wassermann and X-ray are negative. No increase of cells in cerebrospinal fluid.

The diagnosis made by Dr. Peterson was "extramedullary compression of the cord at the fifth and sixth dorsal segment, probably due to a newgrowth," and operative interference was advised.

Laminectomy was performed (Dr. Elsberg) on November 20. The spines and laminæ of the fourth, fifth, sixth and seventh dorsal vertebræ were removed. The dura was congested, very firm and hard, over the greater part of the exposed area. At the level of the sixth dorsal vertebra there was a grayish-brown thickening on the posterior surface of the dura, about 4 cm. in length, and almost calcareous in its hardness. The thickened dura was carefully incised and the cord exposed. The latter was markedly flattened by the dura which at the sixth dorsal level was over 1 cm. thick. The thickening extended laterally to the dural openings. A large piece of dura measuring 5 cm. in length and 3 cm. in width was excised, all diseased tissue being removed. The cord was then covered with a piece of Cargile membrane, and the muscles, fascia and skin were sutured in the usual manner.

The convalescence from the operation was an uncomplicated one, excepting that for a number of days the patient had to receive large doses of morphine to control her pain. She was allowed out of bed eighteen days after the operation and was discharged from the hospital much improved about three weeks later. The pathological report of the dura was "chronic inflammatory tissue."

The first improvement in the patient's condition was observed a few days after the operation. The sensory disturbances gradually improved so that by December 8, the pain and temperature senses were normal, and the tactile disturbance was much less marked. When she was discharged from the hospital, no sensory disturbance of any kind could be found. Deep muscle sensation in the lower extremities was normal. The spasticity in the lower extremities was much less marked. On the right side an exhaustible ankle clonus persisted. The power in both lower limbs was almost normal.

Five months after the operation, she was free from all pain, but some spasticity in the lower limbs remained. This gradually improved. When the patient was last seen (December, 1914) she was free from all symptoms, considered herself perfectly well, and had been back at her work for a number of months.

## LOCALIZED SEROUS MENINGITIS

Attention was first called to this affection by Oppenheim; since his first paper, numerous cases have been reported by Horsley, Krause, Borchard, and others. The pathological condition is often secondary to inflammatory processes in the pia arachnoid. I have seen it as a complication of syphilis of the cord, of pachymeningitis, of meningo-myelitis of unknown origin. Horsley believed that in many of the patients, the disease is due to gonorrhea. It is easy to understand that any inflammatory process which causes adhesions between the inner layer of the dura and the arachnoid or between the arachnoid and the pia mater, may result in the formation of a walled-off space filled with fluid, which compresses the nerve roots and the cord. The instances are rare, I believe, where a localized adhesive or serous meningitis occurs as a distinct disease without pathological changes in the cord or outside of the membranes. The mechanical effects of a localized collection of fluid or band of adhesions may be very similar to those of an extramedullary tumor—a gradual onset with root symptoms, and a slow progress with level cord symptoms.

If the process is more diffuse, there may be no distinct level of motor or sensory disturbances, and in these cases, it is often possible to recognize the nature of the disease from the multiplicity of regions affected. The spasticity of the lower extremities is apt to be very marked, so that the limbs are flexed on the trunk and upon each other. The sensory disturbances are often poorly marked and very irregular in their distribution, and no distinct level of sensory disturbance can be determined.

I shall speak of the conditions found at operation, and the non-operative and operative treatment after I have considered

### CHRONIC SYPHILITIC MENINGITIS

In most instances syphilitic disease of the cord begins in the pia arachnoid and results in thickening of the membranes and the formation of adhesions between them. The process is usually a diffuse one although it is very often met with in the lower part of the membranes around the nerves of the cauda equina. The diffuseness of the process is, however, characteristic. The nerve roots are swollen and congested, there is a grayish-yellow exudate in the arachnoid, the membranes are bound together by numerous fine adhesions, the surface of the cord is covered by abnormally prominent blood vessels. Syphilitic meningitis is soon followed by changes in the cord which may either consist of degeneration with cyst formation or of softening. In some cases, the affection of the meninges is slight while the disease of the cord is very marked, and in others the meningeal changes are very marked and the cord is but little affected. The latter class of cases is most amenable to surgical treatment.

The patients usually suffer from root pains over extensive areas, and the symptoms have a great tendency to fluctuate. At times, the symptoms of a cord lesion are very marked, at other time, much less so. Thus the tendon reflexes may vary from day to day and the motor and sensory symptoms may be subject to the greatest variations.

If the anterior nerve roots are markedly affected in the cervical or lumbar regions, degenerative atrophy of single muscles or of groups of muscles occurs. The most important symptoms are those referable to the cord. These, sooner or later, dominate the clinical picture of the disease and cause all the symptoms of an incomplete transverse lesion with paraplegia and bladder and rectal disturbances.

At times, it is impossible to localize the disease at any cord level and one can only explain the symptoms on the basis of multiple foci of disease. Sometimes the disease causes a marked thickening of the meninges at one point, or fluid collects between adhesions. Gummata of the cord may rarely occur, and hypertrophic pachymeningitis is not infrequent. The disease is often localized in the lumbosacral part of the membranes. Adhesions may form between the nerve roots of the cauda equina and between the nerves and the membranes. The symptoms are characteristic of cauda lesions—pain and sensory disturbances in the distribution of the nerves, paralysis of the bladder and rectum, and impotence. The frequency of other evidences of syphilis of the central nervous system—brain symptoms, immobile pupils, etc.—more especially the history of syphilitic infection, and a positive result from the Wassermann test, make a correct diagnosis possible.

The question will often arise whether local symptoms are due to a disease of the cord substance or to meningitis. In the majority of instances, a distinct dissociation of the sensory disturbances indicates intramedullary disease.

**The Surgical Treatment of Primary or Secondary Localized Adhesive and Serous Meningitis.**—My experience in the operative treatment of spinal disease has led me to the conclusion that meningeal diseases with definite level symptoms should always be subjected to a laminectomy, and I have seen very satisfactory results in a large number of patients. In some cases, localized adhesions between the membranes were found and divided; in others, cystic collections of fluid were evacuated; in still others, the great improvement that followed the operation must have been due to the spinal decompression.

The spines and laminæ should always be widely removed so that the dural sac is well exposed on its posterior and lateral aspects. If little cerebrospinal fluid escapes after the incision of the dura, the operator must search for the cause of the obstruction. If a cystic collection of fluid is found between the dura and arachnoid, the fluid from the cavity must be evacuated, and the affected portion of the arachnoid carefully excised. This can usually be done without bleeding, as the vessels of the arachnoid are of insignificant size. Adhesions between the membranes must be separated and the dura freed from the pia arachnoid. This can usually be accomplished with the aid of a fine probe or a strabismus hook. Every effort must be made to avoid injury to the pial vessels, for the ensuing bleeding may be very disturbing. When the dural sac is first incised and the edges drawn apart, special care must be taken that adhesions between the membranes are not torn and enlarged pial vessels not injured. A small probe should be carefully passed upward and downward behind and in front of the cord. Very often the probe will be arrested by a pocket in the arachnoid, which can be exposed and the adhesions which caused it divided.

The cord itself must always be examined. Aside from a marked enlargement of the pial vessels, an intramedullary cyst may be found and an incision be made into it.

When the adhesions between the membranes are very extensive, it is impossible to divide them all or to expose the entire area of the disease.

If the inflammatory process is not well localized, it is advisable to leave the dura open, so as to obtain the maximum amount of decompression. The operator should not hesitate to divide several posterior roots, if well localized root pains have been complained of.

In syphilitic meningo-myelitis, a thorough course of antisyphilitic treatment must, of course, precede any surgical operation. If distinct sensory and motor level symptoms have been found and the disease is progressively growing worse, a laminectomy should be performed, adhesions between the membranes and around the nerve roots separated, and the affected nerve roots divided.

In these patients careful and repeated examinations should be made, for a laminectomy is justifiable only when a definite sensory level can be found. I have seen a number of patients in whom a level of sensory disturbance was found only after repeated examinations. Several of these patients were subjected to operation, and great improvement followed. The following case is given as an illustration of what can be accomplished:

A man, fifty years of age, single, a patient of Dr. James Pedersen, was seen by me on November 18, 1914.

The patient contracted syphilis in 1896, and was thoroughly treated for two years. In November, 1898, he began to notice a numbness in both lower extremities, and began to have difficulty in walking. Intensive antispecific treatment was again begun, and the numbness and weakness in the lower limbs disappeared gradually during the course of three months.

In 1911, he developed diplopia and had some difficulty in walking. The diplopia cleared up after antispecific treatment but some weakness in the lower extremities persisted. In September, 1914, the left lower extremity became rapidly worse. Two months later, both lower limbs were completely paralyzed, and the patient had lost all control of the bladder and rectum.

Physical examination, November 18, 1914: General condition good. Cranial nerves and upper extremities normal. Abdominal reflexes can not be obtained. Cremasteric reflexes absent. The left lower limb is completely paralyzed; on the right side, the patient is able to move his toes slightly. Knee jerks and ankle jerks absent. No Babinski or other pathological reflex. There is a very slight disturbance of all three sensations up to the level of the sixth dorsal segment. The sensory loss is more distinct on the right side than on the left, and the pain and temperature are more affected than the tactile sense. Deep muscle sense is normal. The diagnosis of a localized degenerative process on a syphilitic basis was made, and a decompressive laminectomy advised by Dr. Bailey.

Decompressive laminectomy (Dr. Elsberg), November 28, 1914. Removal of spines and laminæ of dorsal fourth, fifth, sixth and seventh in the usual manner. Upon incision of the dura, a moderate amount of clear fluid escaped. The vessels on the posterior surface of the cord were markedly enlarged, giving to the cord a pinkish color. No thickening of the arachnoid or pia mater; no adhesions. Closure of wound in the usual manner.

Convalescence from the operation was uneventful; the wound healed by primary union.

December 21 (four weeks after the operation): Both knee jerks are now present, the right more marked than the left; the ankle jerks are present; there is Babinski on the right side. There has been a considerable return of power in the lower limbs. The patient can flex both lower limbs at the knee, the left much less than the right.

The power of the right lower extremity is much better than that of the left. The abdominal reflexes are present, but weak.

Eight weeks after the operation, the patient had improved so much that he could raise both limbs from the bed, but the left limb was still weaker than the right one.

Four months after the operation, the improvement had advanced sufficiently that the patient was able to walk with assistance. The left limb was still weak at the knee and the patient was given an appropriate brace for support. The power in the right lower extremity was amost normal. The patient now had some control of his vesical and rectal functions.

In syphilitic meningitis which has not yielded to specific treatment pain in the distribution of one or more posterior nerve roots is often the main symptom, and these patients may be much benefited or entirely relieved by a laminectomy with division of the affected posterior roots. If, however, the degeneration in the cord itself is far advanced, the result of the operation may not be a satisfactory one. For this reason, a guarded prognosis as to improvement should be given to the patient's family.

The experiences of a single operator cannot be large. In my cases about every other patient was greatly benefited by the operation, and Horsley and Krause have had a similar experience.

### NEURITIS OF THE CAUDA EQUINA (Fig. 152)

About two years ago Foster Kennedy and I described a non-syphilitic inflammatory process which affected the nerves of the cauda equina and was followed by ascending degeneration in the spinal cord (American Journal of the Medical Sciences, May, 1914). Previous to our publication a similar case had been described and published by Oppenheim.

The disease usually began with sharp shooting pain in the backs of the thighs and calves. The pain was unilateral at first, and gradually affected the other limb. The leg first involved remained throughout the illness more affected than the other leg. Tingling and numbness in the legs, knees, or in the entire extremity were regularly complained of. The progress of the disease was usually a very slow one, and most of the patients had a history dating back two to three years. Atrophy of the anterior tibial muscles with loss of power of dorsiflexion at the ankle was always a prominent feature.

The objective sensory changes showed an astonishing uniformity; in all, the main incidence of the disease had fallen on the lowest roots of the cauda, the sacral roots being always affected with the utmost severity. In one patient all the lumbar roots were also involved though to a somewhat lesser degree than were their more lowly placed fellows.

As would be expected, the more markedly the lower sacral roots were involved the more complete was the sphincter disturbance. The disorganization of the functions of the bladder and rectum was complete in all but one case, in which precipitancy and frequency of micturition prevailed.

The abdominal reflexes were present in all of the patients. In but one were the ankle jerks obtained in the affected limbs. The knee jerks became lost, coincident with the upward progress of the disease.

None of the patients gave either a history or indication of luetic infection. In all, the Wassermann test was carried out in both the blood and cerebrospinal fluid, with completely negative results in every instance.

The conditions found at operation were the following: In two patients a large number of the caudal roots and in three all the roots were swollen, congested, and of a bluish-red color. The difference between the color of these nerves and the color of the normal nerve roots was striking and easily recognizable. The changes seemed to be due to an intense hyperemia on the surface of the nerves, and extended into the nerves themselves. In one patient in whom a piece of posterior root was excised for histological examination, the entire nerve on cross section looked discolored. Fine blood vessels hardly visible to the naked eye could sometimes be traced upward on the nerve roots to the conus, where they formed a fine network in the pia mater.

Adhesions between the nerve roots were present in only one case; in the others the only changes were swelling and discoloration.

In all of the patients the inner surface of the dura was smooth and glistening and without signs of inflammatory change. The cerebrospinal fluid was normal in appearance and on chemical and microscopic examination.

While the symptoms of neuritis of the caudal roots are very similar to those of a spinal tumor, the differential diagnosis should be made in

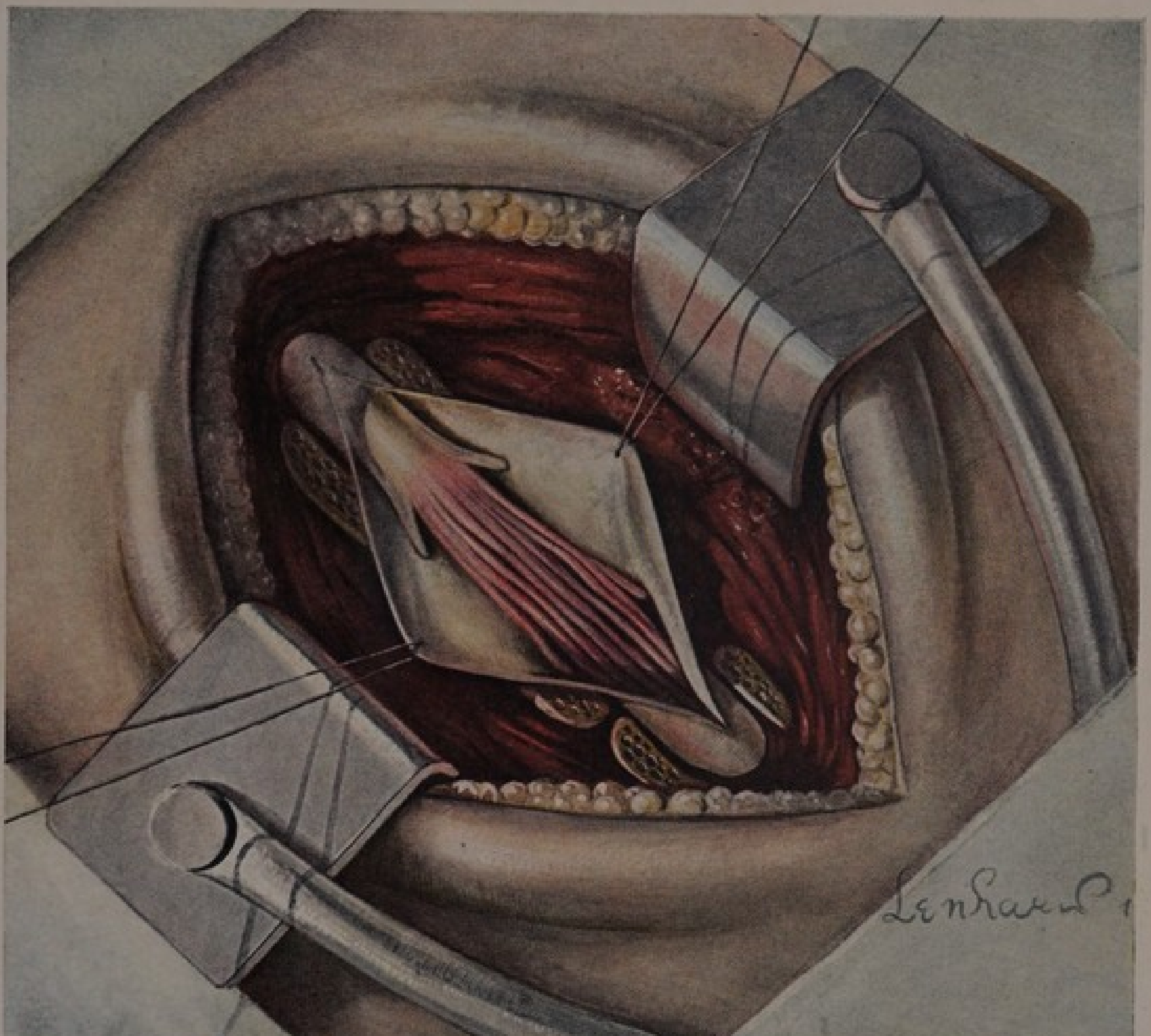



FIG. 152.—Neuritis of the cauda equina.

many of the patients. The only condition in which difficulties of diagnosis might arise, is endothelioma of the conus and cauda equina. In these growths which fill up the lower part of the spinal canal and surround the nerves of the cauda equina, the sensory loss is generally slight and no fluid is obtained by lumbar puncture. When a tumor of the cauda equina is suspected, the possibility of a neuritis should be kept in mind.

It is still an open question whether these cases of caudal neuritis should be subjected to operation. All of my patients improved to a very great extent after the operation, but in most of them the improvement was a slow one—requiring several years. At the operation the caudal roots were rubbed with sponges dipped in 1–500 bichloride of mercury solution. In each case the disease had been steadily progressive up to the time of the operation, but all of the patients began to improve from the time that the laminectomy was performed. I have seen one patient, however, who was not operated on and whose symptoms finally became stationary and then began to improve.

A typical history of neuritis of the nerves of the cauda equina follows:

Mrs. St. J., aged thirty-seven years, married, no children.

First seen on May 21, 1913. Two years before the patient had an attack of pain in the right thigh, shooting from the hip and lasting nine weeks. About one month later she had another slight attack of pain, and thereafter had some pain off and on up to the time of coming under observation. About eight months before, she began to have pain in the small of her back and in her rectum. Later she was more than usually constipated. In January she had noticed that both lower limbs felt weak; had considerable pain in the left leg and numbness in both knees.

In April an abdominal hysterectomy was done, on account of difficulty with her bladder and rectum. She recovered satisfactorily from the operation, but her symptoms were unrelieved and steadily became worse. After operation she had retention of urine for three days, then she regained control of her bladder for two weeks; from that time on she lost all control of that organ and had to be catheterized. From May 14, she had severe shooting pain in the right leg and in the back, and noticed that her right leg felt stiff when she attempted to move it, and that she did not feel the catheter when the urine was withdrawn. Her bowels were constipated, excepting after a cathartic, when incontinence prevailed. She was confined to bed for several weeks before our seeing her, on account of the pain and weakness of her lower limbs.

On examination the patient was a woman of small stature and slight build. Cranial nerves and upper extremities were normal.

Abdominal reflexes were present and equal.

Flexion of the right thigh at the hip and dorsiflexion of the right foot was weak. Knee jerks were present and equal; ankle jerks were present on the left, could not be obtained on the right side. The muscles of the right thigh were flabby. No loss of deep muscle sense in lower limbs.

At a second examination several days later, ankle jerks on both sides could not be obtained; there was (Fig. 153) a loss of all sensation over the second, third, fourth and fifth sacral areas on both sides. Wassermann test was negative; fluid obtained

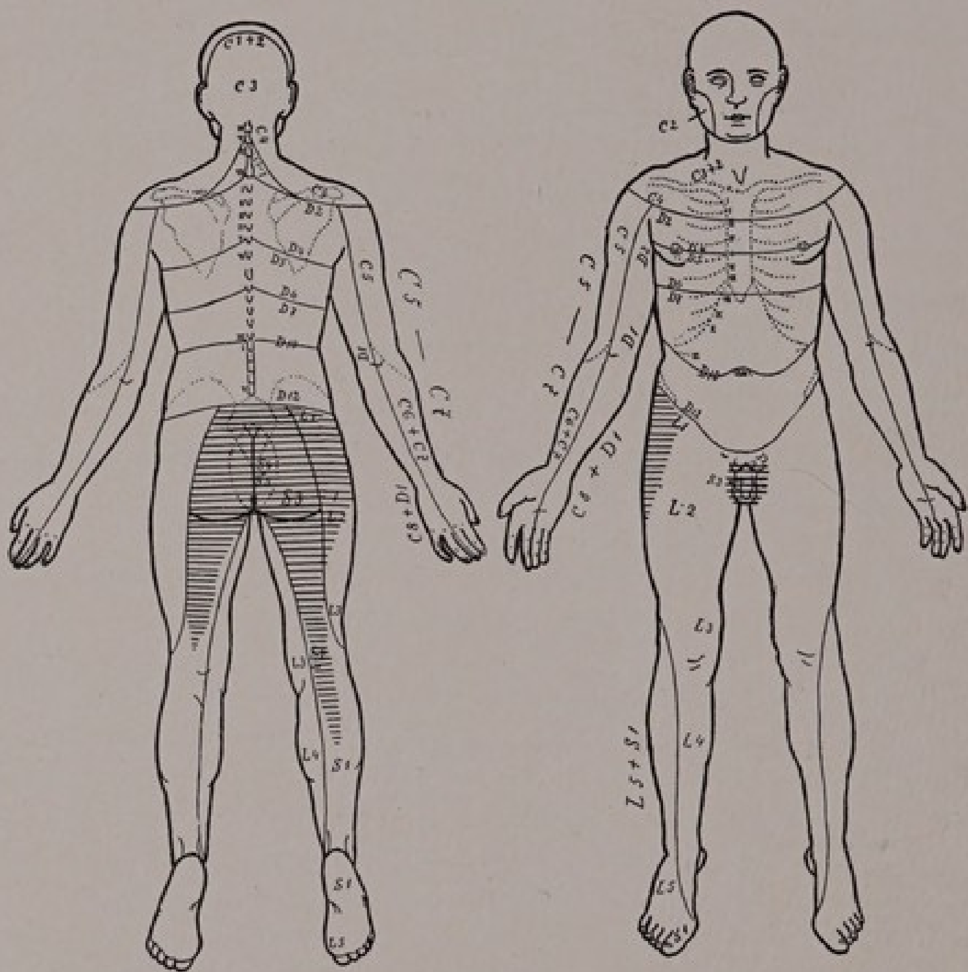



Fig. 153.—Sensory disturbances in the case of a patient with neuritis of the cauda equina. Horizontals: complete loss of all sensation.

by lumbar puncture was of a light yellow color; globulin increased, twenty cells to the cubic millimeter; X-ray examination was negative.

June 18: Laminectomy (Dr. Elsberg). Removal of spinous processes and laminæ of the eleventh and twelfth dorsal, and the first, second, and third lumbar vertebræ in the usual manner; when the dura was incised, considerable fluid escaped, and the roots of the cauda equina were found deeply congested and of a reddish-blue color. Numerous tortuous vessels ran between the nerve roots. The inner surface of the dura showed a few small spots of congestion, but everywhere it was smooth and glistening. All sides of the nerves of the cauda, of the conus, and of the lumbosacral cord were examined, but no evidence of a tumor, of a bony abnormality, or other lesion could be found. A probe was passed upward and downward without meeting any obstruction. After the toilet of the wound, bichloride of mercury solution, 1–500 was rubbed on the nerve roots, and the dura, muscles, fascia, and skin closed in the usual manner. Duration of the operation, forty minutes.

Convalescence from the operation was uneventful; the wound healed by primary union.

June 26: For the past few days the patient has been able to feel when her bladder is distended. She once passed several drams of urine voluntarily. After taking a cathartic she still has incontinence of feces. Has not had any pain in her lower limbs since operation.

September 1: Has gained almost complete control of her rectum, and at times can pass urine voluntarily. Is free from all pain. Both ankle jerks present, but weak.

February, 1913: General condition excellent; has gained much flesh and strength. Passes urine without trouble, but had 4 to 6 oz. of residual urine, and has to be catheterized occasionally. She has considerable sensation when her bladder is distended and some urethral sensation has returned. Bowels moved well after small doses of cascara, and she was conscious of the desire to go to stool. Had occasional pain in her right leg. Knee jerks lively and equal; left ankle jerk lively; right, weak but distinct. There are irregular areas of diminished sensation over the third, fourth, and fifth sacral areas, but they are indefinite, and their limits can not be mapped out. In some parts of these areas sensation was good, while in others it was poor. Vulva sensitive to touch and pain. Patient said she felt the catheter plainly when it was inserted and withdrawn. Could recognize the temperature of an enema, and declared that she was much better than when last seen.

# CHAPTER XX

## THE SPINAL COMPLICATIONS OF POTT'S DISEASE

Tuberculosis may occur as a primary disease in the arches of the vertebræ, in the spinal dura mater or in the substance of the cord, but its usual origin is in the bodies of the vertebræ. Compression of the spinal cord and the nerve roots may be due to the sinking together of the bodies of one or more vertebræ with angulation of the cord, or to projecting fragments of bone, extradural collections of pus, granulation tissue, sequestra or secondary pachymeningitis. As has been mentioned in another chapter, a localized serous meningitis may complicate tubercular bone disease.

A chronic edema of the cord over a localized area frequently accompanies tubercular disease of the vertebræ and dura, and is often followed by a toxic softening of the cord at the affected level and by secondary ascending and descending degenerations in the fiber tracts.

Sometimes there are marked cord symptoms without any demonstrable macroscopic cord lesion, and a number of cases of this character have been reported in the literature. I have seen one patient with a complete paraplegia in whom the post-mortem examination failed to show any evidence that the cord had been compressed or diseased.

Tubercular disease of the vertebræ is most often met with in the lower dorsal and lumbar regions; it occurs somewhat less often in the upper dorsal and in the cervical regions. The symptoms may appear at any time of life from childhood to old age. Over 40 per cent. of the cases occur in children before the fifth year, about 70 per cent. before the tenth year, and over 90 per cent. before the twenty-fourth year of life.

The disease usually begins in the bodies, but it may originate in the arches of the vertebræ and cause early cord symptoms. The progress of the affection is generally a slow one. The patients first complain of fatigue on slight exertion, or of pain in the back or in the distribution of one of the nerve roots. If the upper cervical vertebræ are affected, the first sign may be a rigidity or stiffness of the neck or, in children, a retropharyngeal abscess. Some patients first consult the physician on account of a swelling in the back to one or other side of the spinous processes, while the occurrence of a girdle sensation or of root pains leads others to seek medical advice.

Tenderness of the spinous processes is very frequent. Unless the progress of the disease is interrupted by the treatment, a kyphosis with marked angular deformity occurs in more than one-half of the patients, followed by cold abscesses (retropharyngeal, retroperitoneal, psoas, etc.). Under appropriate treatment all of the symptoms may disappear and complete recovery occur. No patient can be considered cured, however, until two to four years have elapsed. Deformities of the spine remain in many instances.

If the disease involves the nerve structures within the spinal canal, the first symptoms are caused by root irritation or compression, although root and cord symptoms may appear at the same time. The distribution of the cord symptoms will depend upon the level of the cord lesion, and at different levels the symptoms will vary. When the uppermost cervical vertebræ are affected (malum suboccipitale), there may be symptoms referable to cranial nerves, with respiratory and cardiac difficulties, and all the signs of a high cervical cord lesion.

If the disease affects the lower cervical vertebræ, there may be all the symptoms and signs characteristic of that part of the spinal cord. In the lower dorsal region, the most frequent location of tubercular disease of the spine, the signs of a transverse lesion of the cord—spastic paraplegia of the lower limbs, anesthesia up to the affected segment and disturbances of the vesical and rectal functions, are of frequent, occurrence.

1. *Root pains* may exist for years as the only symptom of Pott's disease. The roots are pressed upon either by bony deposits around the intervertebral foramina, by abscesses or masses of tubercular granulations, or by sequestra. The root pains may begin very suddenly with the sudden collapse of a vertebral body and the appearance of kyphosis, or they may begin insidiously, due to gradually increasing pressure upon the affected

nerve roots. It is not rare for the symptoms to appear very suddenly after a trauma to the back. In one of my patients root pain appeared suddenly after the lifting of a heavy weight, and in another, pain in the abdomen appeared a few hours after a fall upon the back. Pain is rarely absent in Pott's disease, and is generally referred to the peripheral distribution of the nerve roots. In the cervical region occipital neuralgias are frequent; in the dorsal region intercostal nerve symptoms are complained of. Abdominal pain, as a result of root pressure in the lower dorsal and upper lumbar regions, has often been the cause of a mistake in diagnosis. Thus a patient was once referred to my service in Mount Sinai Hospital, with fever and acute pain in the lower part of the right side of the abdomen, as a case of acute appendicitis. Careful examination showed that the pain in the right side was a skin and muscle tenderness due to posterior spinal root irritation, and the X-ray confirmed the diagnosis of tubercular disease of the lower dorsal vertebræ.

Another patient had for years a girdle sensation around the middle of the trunk as the only symptom of caries of the dorsal vertebræ. In still other patients a root hyperesthesia around one-half of or around the entire body may be, for a long time, the only symptom of vertebral disease. Intercostal neuralgia is rarely a primary affection, but is usually secondary to intrathoracic or to spinal disease. If a patient complains of intercostal pain and no signs of an intrathoracic disease can be discovered, a careful examination of the spine by the X-rays and a thorough neurological examination must be made. If an individual who has been losing flesh and who has slight evening temperatures develops an intercostal neuralgia without any other evidences of disease, the physician must be very suspicious that he has to deal with the early symptoms of a tuberculosis of the vertebræ.

As recovery occurs by the substitution of new-formed bone for the tuberculous tissue, this bone may encroach upon the intervertebral foramina and cause root symptoms. In several instances I have seen patients who suffered from severe root pain due to this cause.

With marked kyphosis, the nerve roots may be stretched or pressed upon and severe root pains may result.

2. *The spinal cord* is involved in the disease, according to different authors, in anywhere from 3 to 18 per cent. of the patients. The cord symptoms are due to a variety of causes. Actual tubercular disease of the cord is rare, although a few cases of solitary or conglomerate tubercle of the cord have been described, and I have once removed a tuberculoma from the substance of the lower dorsal cord (Figs. 144–146, page 277). Tubercular disease of the arachnoid and inner surface of the dura is rare, while tubercular abscesses and masses of granulation tissue on the outer surface of the dura are frequently met with. There is often a thick mass of granulation tissue adherent to the outer surface of the dura. Not so rarely the dura itself is the seat of a tubercular pachymeningitis which results in marked thickening, so that the cord is markedly compressed, with symptoms much like those of spinal tumor. The spinal cord symptoms may, on the other hand, be due to compression of the cord through the dura by dislocated bone, encapsulated masses of cheesy material or by new-formed bone which causes a marked narrowing of the spinal canal. There may, however, be a great deformity of the spinal canal without any compression of the cord, and many patients in whom the disease has healed are left with a marked gibbus but without any spinal cord symptoms.

Ordinarily the cord symptoms appear very gradually. The patients begin to tire easily, there is a slowly increasing weakness and spasticity of the lower extremities with exaggeration of the muscle and tendon reflexes, girdle sensation, and root pains. The weakness in the limbs increases and well marked signs of interference with the pyramidal tracts are soon observed. A double Babinski reflex may appear very early and may persist for a long time before ankle clonus can be obtained. Root pains may be as severe in Pott's disease as in metastatic malignant disease of the vertebræ, so that the patient holds the affected portion of the spine rigid. The pain is increased by movement, by coughing, sneezing, or other jars to the spine. Hence stiffness of the neck in cervical Pott's disease, and rigidity of the back in dorsal or lumbar caries, is often a protective phenomenon. Aside from root pains and root hyperesthesias, sensory symptoms may not be observed for many years. If, however, the collapse of several vertebræ causes marked deformity of the spinal canal, the spinal cord may be compressed to such a degree that all of the symptoms and signs of a complete transverse cord lesion—complete motor and sensory loss, disappearance of all reflexes, paralysis of bladder and rectum—may appear, followed by trophic ulcers and decubitus. In the upper cervical region occipital neuralgia, anesthesia or hyperesthesia in the areas of distribution of the upper cervical nerves, bulbar disturbances (respiratory and cardiac difficulties), and paralysis of the upper extremities with rapidly advancing muscular atrophies are frequent. There may be paraplegia of all four extremities with sudden respiratory failure and death.

In the lower cervical, in the dorsal and lumbar regions the characteristic symptoms of lesions of the spinal cord at the different levels (see Chapter V) are met with.

The compression of the cord is often an incomplete one and the motor are often much more prominent than the sensory disturbances. The Brown-Séquard symptom complex rarely occurs, although cases of this kind have been reported by Oppenheim and others. Transverse lesions of the cord most often occur in the advanced stages of tubercular disease, and the death of the patient is not long delayed.

**Diagnosis.**—It is outside the scope of this volume to consider all of the symptoms of Pott's disease which are referable to the process in the bony structures—the fever and loss of flesh, the presence of tubercular lesions in other parts of the body, the formation of paravertebral abscesses, of psoas abscesses behind the peritoneum or in the groin, etc. The X-ray examination will often show marked changes in the vertebral column, but in some cases the X-ray picture will give no evidence of the vertebral disease. In very young children the von Pirquet test may be useful, but in adults its presence or its absence means nothing. The symptoms referable to the spinal cord and nerve roots are often so similar to those of other spinal diseases that the differential diagnosis may be very difficult.

Malignant disease of the spine may present symptoms almost identical with those of Pott's disease. The stiffness of the back, the tenderness of one or more spinous processes, the root pains and the cord symptoms may be alike in both diseases. Tubercular affections of the lungs, bones, joints, etc., and irregular fever occur rather in tuberculosis, although irregular rises in temperature are not so rarely observed in metastatic malignant disease of the vertebræ. Very severe root pains may occur in either affection, but they are more frequent in metastatic malignant disease. The history of previous malignant disease in other parts of the body is of value, but metastatic malignant disease is met with where the location of the primary newgrowth can not be determined before death.

The differentiation between tubercular disease and primary sarcoma of the arches of the vertebræ is sometimes impossible before the operation. The X-ray pictures show similar lesions; irregular fever is very frequent. In several patients whom I have had under observation the diagnosis was uncertain for a considerable period of time.

Many patients with spinal symptoms are treated for Pott's disease, and I know of a number of cases of vertebral or intradural tumors in which the spine had been immobilized in a plaster cast in the belief that the patient had a tuberculous disease of the vertebræ. The patients with spinal tumors are rarely improved by the immobilization; in several cases that I have later operated upon, the symptoms were distinctly aggravated.

The differentiation between tubercular disease and osteoarthritis deformans, and other spondylitic changes of the spine, is sometimes not easy, but the X-ray picture will often make the diagnosis possible.

It may be very difficult to differentiate the X-ray pictures of arthritis deformans from those of old tubercular disease of the vertebræ in which there has been an extensive new bone formation. From the therapeutic standpoint, however, the differential diagnosis is not important. When cord and nerve roots are markedly compressed by the new-formed bone, a decompressive operation is indicated, no matter what the nature of the disease.

In rare instances, Kümmel's disease (*q.v.*), typhoid spondylitis, chronic non-tubercular osteomyelitis of the vertebræ may have to be excluded.

The differences between caries of the spine and extradural and intradural newgrowths have been considered in the chapter on spinal tumors (see Chapter XVII). In several instances the differential diagnosis between Pott's disease, aneurism of the aorta with bone absorption, and syringomyelia has presented some difficulties.

**Treatment.**—The surgical treatment of the spinal complications of Pott's disease is called for only after conservative methods have had a long and thorough trial. Hygienic treatment, a high amount of nourishment, sufficient fresh air, etc., are more important than drugs. The problem of local treatment is to hold the spine at rest, and this is accomplished by various orthopedic measures—rest in bed, plaster-of-Paris jackets, extension, braces, etc. The abscesses are treated conservatively by aspiration and injections of iodoform emulsions. A number of methods have been described whose object is to cause a bony union between a number of the spinous processes, and thus to permanently immobilize the affected part of the spine.

Hibbs aims to accomplish the fixation of the affected part of the spine by sawing through and fracturing downward one-half of a number of the spinous processes. Albee splits the spines and implants between the split ends a long wedge-shaped piece of bone removed from the tibia of the patient. In both of these methods the patient is kept on the back in a plaster-of-Paris splint for about three months until bony union has occurred.

Other procedures that have been suggested for accomplishing the immobilization of the spine are: wiring the spines or the laminæ together (Hadra, Chipault, etc.), the uniting together of the laninæ by means of flaps of periosteum (Calot, Vulpius, etc.).

By all of these methods a more or less satisfactory local immobilization is obtained, and the healing of the tubercular disease favored.

The attempt to expose and directly treat the disease of the bodies of the vertebræ has given few good results.

The removal of the arches of several vertebræ for the direct local treatment of the disease in the vertebral bodies should never be advised, because the already weakened spinal column may be thereby deprived of its last support. The exposure of the bodies of the vertebræ by costo-transversectomy described by Menard, for the removal of foci of disease and the drainage of cavities in the bodies of the vertebræ, is a difficult and seldom justifiable operation. The bone disease can not be eradicated by surgical means, for if the disease is extensive it is impossible to remove the entire bodies of one or more vertebræ.

The only hope for cure of the bone disease in the bodies of the vertebræ is by hygienic and orthopedic means, aided in special cases by the operative immobilization of the spinous processes and laminæ. As far as I can see, our only hope for a real treatment of the bone disease will be the discovery of a specific treatment for tuberculosis.

If the tubercular process affects only the arches of the vertebræ, all of the diseased bone can be removed by laminectomy. Such cases are, however, very rare.

The early cord and root symptoms demand careful immobilization of the spine by one of the methods that I have mentioned, and operative interference is demanded only in those patients in whom the disease is at a standstill or is improving, if they develop increasing signs of compression of the cord. Root symptoms are often entirely relieved by repeated aspiration of a lumbar abscess with injections of 10 per cent. iodoform emulsion. The abscess should not be incised unless there are already evidences of secondary infection with pyogenic organisms. It is almost impossible to prevent a secondary infection of a tubercular abscess if an incision into it is made.

If, in spite of immobilization of the spine the symptoms of compression of the cord have grown rapidly worse, and if the cord compression is not due to dislocation or collapse of the bodies of the diseased vertebræ, the opening of the spinal canal by the removal of the spinous processes and laminæ should be done without delay. The laminectomy is done in the usual manner, but no more spines and laminæ than are absolutely necessary should be taken away.

As soon as the laminectomy has been performed, the operator may find one of several conditions. If a collection of fluid is found on the side or in front of the dural sac, it must be opened by a small incision, the tubercular pus evacuated, and the cavity filled with iodoform emulsion which is injected by means of a syringe. The opening in the sac may then be closed by suture, or the edges of the incision may be sewn to the fascia of the back so that the cavity can be drained and be treated regularly after the laminectomy wound has healed.

If a probe can be passed into the abscess cavity and through it into the body of a vertebra, it is allowable to curette out the bone cavity with a small sharp spoon. During all the manipulations, the operator must be very careful that the dural sac is not opened.

If the outer surface of the dura is covered by granulation tissue, this may be carefully scraped off with a sharp spoon. Whenever this granulation tissue is found, the neighboring laminæ must be carefully examined for foci of tubercular disease.

Sequestra are sometimes found in the spinal canal and must be removed; they most frequently lie on the anterolateral aspect of the dura. The unopened dural sac must therefore always be drawn to one side, so that the anterolateral wall of the spinal canal can be examined. If the palpating finger discovers a sharp projection of bone on the posterior surface of one of the vertebral bodies, this prominence must be removed with rongeurs. For this purpose the dural sac may have to be lifted up from the body of one or several vertebræ, and it is occasionally necessary to divide one nerve root before this can be satisfactorily accomplished. The nerve root must be cut as far away from the dura as possible, so that no opening into the dural sac is made.

There may be very lively oozing from the venous plexus between the anterior surface of the dural sac and the posterior surface of the body of the vertebra, but this is always easily controlled by packing the oozing cavity with gauze and waiting until all bleeding has stopped. After the prominence of bone has been removed, the dural sac is allowed to slip back into place, and the laminectomy wound is closed in the usual manner.

The dura should never be incised, if tubercular disease has been found outside of it in the spinal canal. If, however, there is no evidence of disease on the outside of the dura to explain the cord symptoms, then a small exploratory incision is made and the arachnoid and cord examined. Should a localized serous meningitis (adhesive arachnitis) be found, the fluid is evacuated and the dural sac again closed.

The results of operation for the spinal cord complications of Pott's disease have, in the main, been very unsatisfactory. Decompressive laminectomy has, in a few patients, prevented an irremediable transverse lesion of the spinal cord from pressure of a pachymeningitis or from cold abscesses or sequestra in the spinal canal. In most of the patients, however, the benefit derived from the operation has been a questionable one. Unless there are special indications, a laminectomy for the spinal symptoms of tubercular spondylitis should be done only when all other methods have failed to afford relief.

There are some patients who, years after the tubercular process has healed, develop signs of gradually increasing compression of the cord. The X-ray picture generally shows that the spinal canal has been narrowed by a newgrowth of bone. In these patients a decompressive laminectomy with the removal of the new-formed bone, wherever it presses upon the dural sac, will be followed by great improvement, but operative interference should not be too long delayed.

## CHAPTER XXI

### OSTEOMYELITIS OF THE SPINE. OSTEOARTHRITIS OF THE SPINE. SPONDYLOSE RHIZOMÉLIQUE. KÜMMEL'S DISEASE. TYPHOID SPINE. RAILWAY SPINE

The bones and joints of the vertebral column are frequently affected by acute and chronic diseases, and spinal cord and nerve root symptoms are occasionally observed.

1. **Acute osteomyelitis of the vertebræ** is comparatively rare. It is most often due to trauma, to metastases from other parts of the body or to direct infection from wounds of the back. It may occur secondary to deep bedsores over the sacrum. The inflammatory exudate around the diseased bone may exert pressure upon the nerve roots in the intervertebral foramina, or extradural collections of pus may cause cord symptoms. Pachymeningitis—affecting the outer layers of the dura—is frequent. The infection usually remains localized to the dura, but it may invade the pia arachnoid and cause purulent meningitis with acute softening of the cord.

Acute osteomyelitis may occur in the bodies, the arches, or the transverse processes; it is met with most often in the lower dorsal and lumbar regions. The symptoms are those typical of an acute bone inflammation in any other part of the body, to which are added signs due to the peculiar structure of the spine and to the spinal cord and nerve roots within the spinal canal.

The onset is usually ushered in by a chill, high fever and delirium, and in its early stages it may be difficult or impossible to recognize the location of the trouble. Or the symptoms develop gradually so that the pain, edema, and localized tenderness of the back point to the affected part of the spine. If the arches of the vertebræ are diseased, a red tender swelling may form in the back, but if the bodies are affected, there may be no evidence of an abscess in the back, but the infection may travel in an anterior direction into the mediastinum or the pleural cavities. While marked spinal symptoms are rare, slight changes in the reflexes are often observed. I have seen a patient with high fever and delirium, with a small tender swelling over the lower dorsal spines, who had exaggeration of both knee jerks and double ankle clonus. The operation disclosed an osteomyelitis of the arches of two vertebræ with an abscess partly outside and partly inside the spinal canal.

In these patients early operation is, of course, indicated. If the osteomyelitis is in the arches or the transverse processes, the bone can be opened and drained without difficulty; if the bodies are diseased, the approach to them by costo-transversectomy is much more difficult.

2. **Infectious Spondylitis.**—Aside from acute suppurative bone disease, there are affections included under the name "infectious spondylitis," which may complicate the infectious diseases, articular rheumatism (Oppenheim, Jaksch), gonorrhea, etc. They occur relatively often after typhoid fever—beginning several weeks after the temperature has reached normal. The condition, commonly known as "typhoid spine," ordinarily runs a benign course, and seldom, if ever, goes on to suppuration. The patients may not show any cord symptoms. Some, however, have the signs of a lesion in the lower part of the cord and the cauda equina—root pains, muscular weakness in the lower limbs, exaggeration of reflexes, paresthesias, bladder and rectal disturbances. The cord and nerve root symptoms usually disappear within a few weeks. Treatment must be directed toward immobilization of the affected part of the spine. In some cases it has been difficult at first to distinguish the affection from an infectious myelitis, but the absence of marked cord symptoms or their rapid disappearnace makes the differentiation possible.

3. **Chronic osteomyelitis of the vertebræ** may result in bone necrosis and the formation of discharging sinuses. Aside from tuberculosis (Chapter XX), the disease may be due to syphilis or actinomycosis, or it may follow an acute osteomyelitis.

The symptoms referable to the spinal cord are usually vague, and marked fluctuations are often observed. Root pains may at times be complained of; on some days the patient is free from pain. Spasticity of one or both lower extremities may constitute the only evidence of a neurological lesion. This spasticity may also be subject to great variations in its intensity. One one day the lower limbs may be so stiff that the knee jerks and ankle jerks can not be elicited, while, perhaps, on the following day the limbs may be relaxed and the reflexes normal. There may be well-marked root hyperesthesias, but more often the most careful examination will fail to show any sensory disturbances.

In these chronic bone conditions a laminectomy may be necessary for the removal of diseased bone or sequestra or for the control of the pachymeningitis.

4. A variety of names have been given to chronic inflammatory processes which affect the vertebral column—arthritis deformans, spondylose rhizomélique, osteoarthritis, spondylitis deformans, etc. In these diseases there are changes in the bodies and arches of the vertebræ. The edges of the bodies may become irregular, the transverse processes may be much thickened, the bodies of several vertebræ may become united by processes of new bone, or an anchylosis of a number of vertebræ may occur. The disease may affect only a few vertebræ, or the greater part of the spinal column is gradually invaded (see Figs. 34–40, pages 84–90). The main symptoms of all these conditions are pain and stiffness of the back; cord symptoms are rare.

The pain is usually due to the bone disease, although root pains may occur. The new-formed bone may cause a narrowing of the intervertebral foramina and compression of nerve roots. Hence muscle atrophies and localized hyperesthesias are often observed. Bailey and Casamajor have described a number of cases of localized osteoarthritis of the spine which caused more or less well-marked spinal symptoms and which were cured by the removal of the affected spines and laminæ. In these cases there was always a slight pachymeningitis externa. The outer surface of the dura was found to be congested and roughened or thickened over an area which corresponded to that of the disease of the laminæ. The beneficial effects of the surgical interference were probably due, to a considerable extent, to the decompressive effect of the operation. The following case (reported by Bailey and Casamajor) is a characteristic one.

M. S., forty years of age, admitted to the New York Neurological Institute on the service of Dr. Pearce Bailey on March 29, 1910.

The patient's symptoms date back three years, having begun with pain in the lower part of the back. The pain was severe enough to keep him awake at night and was worse in wet and damp weather.

During the last year the pain has become much worse and he has had pain in the left lower extremity, which has become weaker. No bladder or rectal symptoms. The pain in the back has become so severe that he can only walk with difficulty.

The patient is a well-nourished, healthy looking man. There are scars of old tubercular bone disease over the sternum. The dorsal spine is held very rigid, and there is distinct tenderness over the second lumbar spine. The patient has great difficulty in moving his limbs on account of the pain in the small of the back. The abdominal and cremasteric reflexes are normal. The knee jerk is diminished on the left, the ankle jerk greater on the right side. There is some diminution of sensibility below the twelfth dorsal level. Wassermann test and X-ray negative.

A spinal cord tumor was suspected and a laminectomy performed (Dr. Elsberg) on April 2, 1910. The spinous process and laminæ of the twelfth dorsal vertebra were found to be abnormally soft and somewhat gray in color. The inner surface of the dura at the twelfth dorsal and first lumbar level was slightly congested. Otherwise nothing pathological could be discovered. The pathologist's report of the bone removed was "osteochondritis with new bone formation."

Recovery from the operation was uneventful. The pain in the back disappeared after the operation and within two weeks, excepting for a very small area of hyperesthesia on the posterior aspect of the right thigh, sensation and motor power in the trunk and extremities was normal.

About one year later the patient reported that he had remained well, that his work demanded his riding horseback thirty to forty miles each day.

*Spondylose rhizomélique* is the name given by Pierre Marie to a disease which occurs almost exclusively in male adults and whose main characteristic is a progressive anchylosis of the vertebræ and their articulations.

The disease usually begins with pain in the lumbar part of the spine and in the lower extremities. After a few months this part of the back becomes stiff, the pain ceases, and the patient is left with a more or less marked stiffness of the lumbar spines and of the hip joints. After the expiration of a few months or years, similar pain is felt in the cervical region and in the upper extremities, soon followed by stiffness of this part of the spine. The disease may begin in the cervical and later involve the lumbar vertebræ. The process then gradually extends over the dorsal vertebral column, and the patient is finally left with a stiff back, so that walking is interfered with. The patient is finally able to get about with great difficulty by the aid of canes and crutches. The heredito-traumatic kyphosis described by Bechterew is very similar to spondylose rhizomélique of Marie and Strümpell, excepting that the larger joints (hip and shoulder) remain unaffected.

The nature of the pathological process is unknown; it may follow gonorrhea or other infections, and has been observed in patients who have been frequently exposed to cold and wet. The lesion most often found is a marked proliferation of bone and calcification of the ligaments of the vertebræ, so that a firm bony anchylosis occurs. With this anchylosis there is usually an atrophy of the vertebral bodies.

Root pains, due to the compression of the nerves in the intervertebral foramina, may occur in the early stages of the disease. When, however, firm anchylosis has occurred, the patients are usually free from pain. Exaggeration of the knee jerks, with ankle clonus, was observed in one of my patients, and may occur as a result of angulation of the vertebral column and the spinal cord. There is not, however, any tendency for the disease to cause a narrowing of the spinal canal, and there are, therefore, few, if any, spinal cord symptoms. In some cases it may be difficult to distinguish spondylose rhizomélique from chronic vertebral rheumatism, but in the latter, changes in the small joints of the extremities are of frequent occurrence. There is no satisfactory treatment for the condition.

5. **Kümmel's Disease.**—Kümmel first called particular attention to a disease which is characterized by atrophic changes in the vertebræ and which has been observed after slight or severe injuries to the spine. Months or even years after a slight or a severe traumatism to the back, the patient begins to complain of pain in the location of the former injury, and soon afterward a kyphosis or gibbus develops. The gibbus is due to the atrophy and softening of the body of one or more vertebræ and the sinking together of a part of the spinal column. The resulting angulation of the spinal canal may be followed by root pains or by more or less well-marked cord symptoms. Extension and immobilization of the spine will usually free the patients from their subjective symptoms, but the compression of the cord may require a laminectomy. Since the advent of the X-ray, Kümmel's disease has become rare. The X-ray has shown

us that fractures of the vertebræ often occur after very slight trauma and with very slight symptoms. Injuries to the bones of the spinal column are, therefore, more often recognized and more correctly treated.

**6. Railway Spine.**—For the sake of completeness, the condition once described as railway spine—a pure traumatic neurosis—must be mentioned. After a slight injury to the back, in which there has been no reason to suspect a gross injury to the spinal cord, the patient begins to complain of a host of nervous disturbances—headache, weakness, cardiac palpitation, loss of memory, etc. To these symptoms are added great liability to fatigue, exaggeration of the reflexes of the lower limbs, pain in the back and inability to walk. There is no organic basis for the symptoms.

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