THE TECHNIQUE OF ANTEROLATERAL CORDOTOMY*

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In 1933, 78 cases of anterolateral cordotomy were reported from the University of Michigan Hospital. At the time of this report the results in over 20 per cent of the cases were known to have been unsatisfactory either because the level of analgesia reached at operation was not sufficiently high or because a level which was adequate at first was not maintained. That we were not alone in these failures is attested by the variety of methods advocated for the relief of pain, only to be abandoned after ample trial. The failures in this series led us to modify the technique in many cases by carrying the cordotomy incision farther anterior in the cord substance.

In our report of 1937 on 12 cases of tabetic crises in which it was urged that the incision be carried "at least 2 mm. beyond the emergence of the anterior nerve root," the results were better, 10 being satisfactory, with 1 failure and 1 death 10 days postoperative.

A review just completed shows that we are still having a surprising number of failures. It can be generally stated, however, that when an incision 4 mm. in depth is carried well anterior to the emergence of the anterior nerve root under direct vision, high levels of analgesia are obtained and it is a rarity for such a level to fail.

Though the more anterior incision was arrived at empirically, the rationale of the procedure has since been demonstrated by Hyndman and Van Epps and by Walker on the human; and by Weaver and Walker on the monkey. This will be elaborated upon, following discussion of the selection of cases and the actual technique of operation, based upon an experience of over 300 cases.

SELECTION OF CASES

It was formerly our belief that morphine addiction, though not a contra-indication to cordotomy, played an important role in its failure as it apparently does in many procedures advocated for the relief of pain. Frazier stated that he had never seen morphine addiction in trigeminal neuralgia, and this has been our experience. It has even been suggested that the occurrence of morphine addiction was evidence against the pain being of organic nature. True drug addiction is probably caused by a psychogenic need which is ordinarily lacking in patients with an organic basis for pain. The latter, as a rule, are genuinely honest in their protestations that they wish to "get away from morphine." We now believe that most of the failures that were attributed to morphinism were in fact due to an imperfect cordotomy.

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In the selection of patients for cordotomy the greatest difficulty is met with in those individuals who seemingly have severe pain for which no satisfactory organic basis can be found. Such a patient is told that his pain cannot be evaluated objectively by the examiner but that if his pain is real it will be relieved by a properly performed cordotomy. He is also warned of the risk of permanent bladder disturbance, the loss of voluptuous sensation, and the possibility of paralysis. If this patient then elects operation, one can be more than reasonably certain that his pain is organic in nature. It is at least not malingered.

It is difficult to evaluate the pain of transverse myelitis when it is not purely radicular. In an Army paraplegia service of 136 patients for which one of us was neurosurgeon, approximately 10 per cent complained of severe pain. After several cordotomies had been performed, word passed rapidly around the wards as to the value of the procedure. Soon a dozen patients had been operated upon with excellent results in the 5-month period in which they were followed. One patient, however, of low intelligence with a marked depression was not improved in spite of a high level of analgesia.

An officer was recently seen by us who claimed to have had continuous pain from the onset of his paraplegia, which had occurred 2 years previously. He had at one time become a morphine addict but was relieved of addiction by his medical officer, who believed that the patient was actually not having pain and that cordotomy would be a mistake. We were of the opinion that the patient was suffering pain and accordingly a cordotomy was performed, with complete relief. A report just received 16 months postoperatively states that he has had no pain since operation. We still cannot be certain that the pain was not of psychogenic origin, but the psychiatrist had failed to relieve it, and with a complete paraplegia, the patient had so little to lose that operation seemed justified. The same may be said for the 12 patients operated upon in the Army hospital, though the fact that the first good results precipitated the others into operation, may mean that the element of suggestion entered. However, it may also mean that these men did not wish to submit to a purely destructive operation until they were reasonably certain of relief from pain. It should be remembered that when pain is a conversion mechanism, it is a crutch for a man to lean upon and he has the need to keep this crutch until he has a better one with which to support himself.

In the 6 cases of postherpetic neuralgia for which cordotomy was performed the results were not completely satisfactory in a single case. Three patients with analgesic levels above the postherpetic lesions had had their pain at least 3 years. Two of these showed definite evidence of cerebral arteriosclerosis and were thought to have an obsessive type of pain. The level in the third was only two segments above his chest lesions. Though the level persisted he was free of pain less than 2 weeks. In one case the level was not checked and in another the level fell. The most satisfactory case will be given in more detail:
A man aged 76 was seen 3 months after onset of a herpes zoster of the sacral segments on the right. The pain was severe enough to resemble that of trigeminal neuralgia. A unilateral cordotomy was performed at the 2nd or 3rd dorsal segment, with resulting analgesia and thermanaesthesia to the 5th dorsal segment. He was entirely free of pain for 3 months, when a mild burning was noted at the site of the old pain. This continued to increase until his return 22 months postoperative. There was still none of the old pain but the burning was now sufficient to disturb sleep. The level of analgesia and thermanaesthesia was exactly the same as it was immediately postoperative.

The operation for postherpetic neuralgia is always a unilateral one, and the gradual return of pain may be due to an assumption of more important function by homolateral fibers. We believe, however, that there is a better explanation. Walker, using the Marchi technique, has shown that after anterolateral cordotomy the number of degenerated fibers that reach the thalamus is much less than the number of degenerated fibers in the spinal cord just above the lesion. He believes this disparity to be the result of terminations of many fibers of the lateral spinothalamic tract in the medulla, pons and midbrain. The inflammatory process in herpes zoster is known to ascend in the cord and medulla. Persistence of pain after cordotomy may be accounted for by action of a chronic "burned out" inflammatory process on cell bodies of fibers of the spinothalamic tract which synapse in this tract above the cordotomy incision but below the thalamus and can still initiate impulses to the thalamus which are interpreted as pain.

ANAESTHESIA

The laminectomy itself can be carried out under the kind of anaesthesia the surgeon believes to be best for that particular patient. The patient should be unconscious, however, while the incision into the cord is being made. We prefer endotracheal anaesthesia for the entire procedure, but if the laminectomy has been carried out under local anaesthesia, enough pentothal should be given at the last minute to prevent any movement of the patient when the cord is rotated. A cordotomy can be accurately performed only on a quiet patient, and if it is properly planned and accurately performed, the level is bound to be satisfactory. Before we made the more anterior incision, many of these operations were carried out under local anaesthesia, the sensory level being tested immediately after the cord incision. The level of analgesia was just as apt to fall as it was when the procedure was carried out under general anaesthesia, the more anteromedial fibers of the tract having been only grazed by the knife and temporarily put out of action.

TECHNIQUE

For high cervical cordotomy the 2nd and 3rd cervical laminae are removed. For the usual cordotomy the 1st and 2nd, or 2nd and 3rd dorsal laminae are removed, depending on which are more accessible. Grant, who has had an experience with cordotomy comparable with ours, routinely cuts bilaterally at C5 or C6 segment. He does this to avoid "some of the residual burning pain which sometimes is not relieved by section at D3 or D4." Grant
attributes this residual burning pain to sensory fibers that run from the lower extremities along the sympathetic chain entering the posterior roots above D4 but below C7 or C8.

We have not seen much of this residual burning pain and would be inclined to do the higher cordotomy only if the usual section at D3 failed and the burning became severe. In tabetic crises or postzoster states with high radiation of the chest pain, C5 or C6 segments would be a logical place for the incision. One should never perform cordotomy at C5 or C6 unless he has had extensive experience with this procedure, as technical errors or postoperative hemorrhage could lead to a tetraplegia.

One should avoid laminectomy below the 3rd dorsal lamina, as the pull of the shoulders causes greater pain and tends to force the incision apart in these debilitated patients. The laminectomy should be a wide one in the dorsal region but can be a hemilaminectomy in the wider cervical canal, where one rarely attempts a bilateral cord incision.

The dura should always be opened if possible without injury to the underlying arachnoid. This can be done almost invariably unless the dura is adherent to the arachnoid. It is best to use a small round bivalled knife blade. The procedure may be likened to that of the Rammstedt operation, where one divides the hypertrophied pyloric muscle without opening the mucoa. If on opening the dura a small hole is made in the arachnoid through which fluid escapes, one can still usually prevent further opening of the arachnoid by pushing it away from the overlying dura with cotton pledgets.

There are two reasons for not opening the arachnoid in the midline. First, with the sudden release in pressure due to the rapid escape of subarachnoid fluid, the epidural veins may dilate and burst, causing annoying hemorrhage. If the dura is opened, leaving the arachnoid intact, traction sutures can be taken through the dura, which is pulled against the cut laminal edges, thus preventing a loss of support to the epidural veins, which do not suddenly "let go" when the arachnoid is opened. The second reason for wishing to preserve the arachnoid in the midline is that when the dura is closed at the end of the operation, the intact arachnoid will herniate up against the dural suture line and prevent any leak of spinal fluid, should the dural closure not be a watertight one.

After the dura has been opened, it is necessary to divide the dural attachments of the dentate ligaments. This can be best done extra-arachnoidally. One follows the arachnoid laterally until 1, 2, or 3 attachments of the dentate ligament to the dura are seen and divided with scissors. There should be less trauma to the cord structures with an extra-arachnoid approach. Regardless of whether the cordotomy is to be unilateral or bilateral, the dentate attachments should be divided on both sides; otherwise the cord cannot be rotated sufficiently to insure an accurately placed anterior incision.

The arachnoid is now incised anterior to the dentate ligament. This may be done by pricking the arachnoid with a sharp pointed right-angled instrument. The nerve roots must be completely freed to gain maximum rotation.
Even more important, the arachnoid must be freed from the surface of the cord where the knife is to be inserted or the incision cannot be made into the cord substance. The dentate ligament is then grasped, the cord gently rotated and a straight hemostat is placed on the dentate ligament directly down to where it attaches onto the pia. The cord is then rotated almost to a right angle by traction on this hemostat, supporting and rotating the opposite side of the spinal cord with the handle of a knife. The anterior nerve roots of the side on which the cordotomy is to be done will then come into view. A dull right-angled instrument should be placed under an anterior nerve root, to free it entirely from any remaining arachnoid and to develop it clearly. One is then ready to make the incision into the cord substance.

The incision is best made with a sharp, pointed blade on a long handle. A distance of 4 to 5 mm. is measured with a steel rule on the blade and this is marked on the blade with wax. Before the knife is inserted the exact attachment of the dentate ligament to the cord must be re-established, as by this time it might have been pulled loose from the cord substance. This is done by placing an instrument, such as a ganglion knife, along the dorsal aspect of the dentate ligament until it encounters its attachment to the cord substance. One then establishes this point exactly by looking at the instrument bulging through the anterior aspect of the dentate ligament. The point of the knife is to be entered just in front of this point. As avascular an area as is possible over the anterolateral column should be selected for the incision. The anterior nerve root should be held away from the cord substance as another landmark. The blade is entered almost parallel to what is visualized as the transverse diameter of the cord. Paralysis will result if the blade is passed posterior to this axis, so that it is safest to enter the knife so that an angle of about 30° is made anteriorly with the transverse diameter. It is usually best to incise the pia first before plunging the knife into the full depth of 4 to 5 mm., as this membrane is extremely tough and in attempting to make the incision the dentate ligament may be avulsed from the cord, thus losing not only a landmark but the means of holding the cord rotated as well. This constitutes an unpleasant technical complication, for the cord can then be rotated and held only by the anterior nerve root. In a small percentage of cases the dentate ligament is not even or only loosely attached to the spinal cord, and this makes the operation very difficult. One then rotates the cord by means of the anterior nerve root and enters the knife 3 mm. posterior to the emergence of the anterior nerve root.

To resume the technical part of the incision—the knife is inserted into the pial opening until the desired depth is reached when it is brought out 2 mm. anteromedial to the anterior nerve root. The only possible danger of carrying the incision too far forward is that the anterior spinal artery might be encountered. The latter lies, however, 4.5 mm. in front of the center of the anterior nerve root. We have never had this catastrophe happen, though we have heard of its arising in 3 cases.

It is probable that the depth of the incision need never be over 3½ mm.,
provided it is carried sufficiently far anterior. As a rule, however, a depth of $4\frac{1}{2}$ mm. is used, and in high cervical cordotomy in a large man 5 mm. and even 5.5 mm. has been used. We believe that the greater the depth of the incision in bilateral cordotomy, the greater will be the percentage of permanent bladder complications.

When bilateral cordotomy is to be carried out, the two incisions should not be placed opposite each other. This has not been established experi-

![Diagram of Thoracic II Spinal Cord Segment](image)

**Fig. 1.** Thoracic II spinal cord segment from Henry A. Riley's *Atlas of the basal ganglia, brain stem and spinal cord* (Baltimore: The Williams & Wilkins Co., 1943), with diagrammatic representation on it of cordotomy incision.

mentally, but it would seem as if there would be less disturbance to the blood supply of the cord, which has so rich an anastomosis, if the incisions were staggered.

When pelvic malignancy is present, cordotomy should always be bilateral even if the pain is sharply localized to one side. We have too often in the past cut the spinothalamic tract on one side in such cases, only to have the pain appear on the opposite side before the patient has left the hospital. It is surprising how soon after a unilateral cordotomy the pain appears in the side allegedly free of pain before operation. It leads one to believe that either the threshold for pain has been lowered on the uninvolved side by a unilateral cordotomy or that pain already present has been prevented from reaching consciousness by the preponderance of pain on the one side.

In high cervical cordotomy when the 2nd and 3rd cervical laminae are removed, it is always best to divide the 2nd and 3rd posterior nerve roots bilaterally. This is done to prevent postoperative pain and is a most gratifying procedure to patient and doctor. This, of course, aids rotation of the cord,
though section of one nerve root would be all that is necessary for that. The rhizotomy also raises the level of analgesia without producing noticeable anaesthesia.

If a second cordotomy operation must be performed, it is certainly better to carry out the procedure through virgin territory. During the 1st week postoperative the cord is somewhat swollen and the surrounding structures are edematous. Re-operation can still be carried out but with more difficulty. It is later, however, after meningeal adhesions have formed, that re-operation is not only difficult but dangerous. It is far simpler, certainly for the inexperienced, to carry out an entirely new procedure either above or below the previous laminectomy incision.

**RATIONALE OF THE MORE ANTERIOR INCISION**

Though Martin performed the first cordotomy at Spiller’s request in 1911 it was Frazier and Spiller who really put the operation on a solid foundation.\(^1\)\(^2\) The incision recommended by them extended \(2\frac{1}{2}\) mm. in depth, starting just in front of the dentate ligament and extending to the anterior nerve root. In 1926 Peet\(^3\) reported: “It is the depth of the incision, particularly in the anterior portion of the antero-lateral tract, which determines how closely the level of analgesia approaches the level of sensory distribution of the segment operated on. The highest level of lost pain and temperature sensation was obtained when the incision of the cord extended directly forward through the anterior root.”

Weaver and Walker showed in the monkey and Walker postulated in man that the pain fibers from the sacral segments are displaced posteriorly as they ascend in the lateral spinothalamic tracts of the cord, the fibers of the thoracic segments coming to lie more anteromedial, while those of the cervical segments lie most anteromedial. Hyndman and Van Epps in an interesting anatomico-clinical study came to a similar conclusion. Thus, in the upper thoracic region of the cord, those fibers that have just entered the spinothalamic tracts from the upper thoracic segments, lie as far medial as the downward prolongation of the medial surface of the anterior horn. Hyndman and Van Epps point out, on the other hand, that the line of emergence of the anterior nerve roots from the cord does not correspond to the downward prolongation of the anterior horn but is considerably more lateral. We do not believe that this is quite true of the lowermost cervical segments, but it is certainly true of the upper cervical and thoracic segments. At C2 or 3 segments the distance from the ventral median fissure to the center of the emergence of the anterior nerve roots circumferentially is from 4 to 5 mm. and averages 4.5 mm.; from the anterior nerve root to the dentate ligament the distance is almost exactly the same. These distances at T2 segment, as measured circumferentially in a number of fresh autopsy spinal cords in both men and women, are almost invariably identical with those of the upper cervical segments. The downward prolongation of the medial surface of the anterior horn at T2 is 2 mm. or less from the ventral median fissure. If then
pain fibers of the spinothalamic tract reach this medial point, the cordotomy incision must be carried not just to or through the emergence of an anterior nerve root but 2 mm. anterior to it, in order to reach the highest possible level of analgesia or even a high level of analgesia which will not fall.

**SUMMARY**

A. When incisions into the spinothalamic tracts 4 to 5 mm. in depth are made, starting just in front of the dentate ligament and emerging 2 mm. anterior to the anterior nerve root, high levels of analgesia are obtained and these levels rarely fall significantly.

B. The causes of failure, in order of importance, are:

1) Level falls or was too low to start because cordotomy incision was not carried sufficiently far anteriorly.

2) Improper selection of cases.

3) Performing unilateral cordotomy for unilateral pain that is due to abdominal malignancy.

4) Where the pain is low in the pelvis, making the incision too far in front of the dentate ligaments, thus sparing the sacral segments.

C. The rationale of the more anterior incision in the light of the experimental work of Hyndman and Van Epps and of Walker and Weaver is discussed.

**REFERENCES**


2. Grant, F. C. Personal communication.


