An Anterior Approach to Percutaneous Lower Cervical Cordotomy*

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The technique of anterolateral cordotomy has been used successfully in the treatment of intractable pain since 1912. However, this operation has not been available to many patients suffering from pain that is not relieved by the usual nonsurgical methods. The reason is that, until recently, cordotomy involved a major operation with possible mortality and morbidity, significantly greater in those debilitated patients who needed pain relief most. The procedure often caused weakness of an extremity or loss of sphincter control. If it were unsuccessful, or if pain recurred later, each successive attempt to incise the cord became more difficult.

In 1963, Mullan et al. devised an approach to the cervical spinal cord by inserting a needle through the neck under roentgenologic control. They introduced a radioactive needle (strontium) to produce a lesion interrupting the lateral spinothalamic tract. Mullan and Rosomoff et al. later simplified the procedure by using an electrical current to produce the lesion. The percutaneous methods required the insertion of a needle through the lateral aspect of the neck, between the arch of the atlas and the lamina of the second cervical vertebrae, and thus to the anterolateral surface of the cord.

Respiratory impairment associated with high surgical cervical cordotomy has been well documented, It has been shown that the fibers descending to the respiratory musculature lie exceedingly close to the lateral spinothalamic tract at the higher cervical level. Belmusto et al. reported a peculiar type of paralysis of involuntary respiration with preservation of voluntary respiratory activity occurring in patients who had undergone bilateral high cervical anterolateral surgical cordotomy. In patients who had marked limitation of pulmonary function of one lung, a unilateral cordotomy on the side of normal pulmonary function might produce a similar impairment of reflex respiration. These patients have preservation of voluntary respiration. They breathe adequately while awake but, "during a period of natural sleep, respiratory efforts become ineffective and require assistance." In his series of percutaneous high cervical cordotomies, Mullan reported a similar respiratory complication, but Rosomoff et al. did not.

We have done percutaneous radiofrequency high cervical cordotomy by a modification of the Rosomoff technique and had deaths due to paralysis of involuntary reflex mediated respiration. In an attempt to avoid the respiratory complications associated with high cervical percutaneous cordotomy, we devised an anterior approach to the lower cervical cord. The needle electrode is inserted through an intervertebral disc in the lower cervical area, below the emergence of the phrenic nerve fibers that control diaphragmatic respiratory movement (Fig. 1). With this approach we are not only able to protect involuntary respiratory function but also to reduce the risk of postoperative motor and sphincter paralysis. Moreover, by this method we can do a selective segmental cordotomy.

**Method**

The electrode is a modified version of that used by Rosomoff et al. It consists of a standard uninsulated three inch, 18 gauge, thin walled, lumbar puncture needle through which is inserted a steel wire stylet .016 inch in diameter. The stylet protrudes 4 mm. beyond the point of the needle and is insulated with Teflon, except for the last 2 mm. Two different types of stylets can be used interchangeably. One is straight, and the other has a curve at the end so that the lesion can be made at a point 1 to 2 mm. from the alignment of the needle (Fig. 2).
Fig. 1. Schematic drawing of the anterior approach for low cervical percutaneous cordotomy. The needle is inserted from the opposite side of the neck between the carotid sheath and the trachea-esophagus complex. It enters the disc space obliquely to avoid the anterior spinal artery or corticospinal tract.

The 500,000 cycle radiofrequency generator is commercially available (Radionics, Model RFG-2A). Its output is continuously variable between 0 and 12 watts. The current is monitored on an incorporated milliamperemeter.

The patient is placed supine on a stretcher with the head resting on a Franklin head unit and immobilized by a standard head clamp. The anterior portion of the neck is prepared and draped. The skin, subcutaneous tissues and prevertebral fascia are infiltrated with a local anesthetic. The needle is inserted medial to the carotid sheath and lateral to the trachea and esophagus, about 2.5 to 5 cm. above the sternoclavicular joint on the side opposite to the intended lesion. By palpation with the needle tip, either C 5-6, or C 6-7 disc space is identified and entered. The needle is directed diagonally through the disc, aiming toward the target point in the opposite anterolateral quadrant of the cord. This oblique angle is desirable in order to avoid injury to the corticospinal tract and anterior spinal artery in case of overpenetration. The placement of the needle is determined by repeated antero-posterior and lateral Polaroid roentgenograms, and appropriate corrections are made. Antero-posterior films are taken with the Franklin x-ray tube and lateral x-rays are taken with an overhead or portable unit, so that the patient's head need not be moved during the entire procedure.

Although the intervertebral disc affords adequate immobilization of the needle, some fine adjustment is possible by maintaining firm manual pressure on the hub of the needle. Adjustments of more than 2 mm. may require complete withdrawal of the needle from the disc and reinsertion in a more appropriate direction.

When the tip of the needle emerges from the posterior portion of the intervertebral disc, the dura is encountered. It is advisable to use a sharp needle because, in this area, the dura may be more difficult to penetrate than in its lateral or posterior portion. Sometimes it is necessary to perforate the dura first with a stylet from a slightly longer lumbar puncture needle.

When the tip of the needle is in the subarachnoid space, free flow of spinal fluid occurs. Ten cc. of air are then injected through a 2-way stopcock and the anterior surface of the spinal cord is visualized by lateral Polaroid roentgenograms, as in an air myelogram (Fig. 3).

The target point is determined by the intended area of analgesia. To produce a segmental area of analgesia in the low cervical and upper thoracic dermatomes, the tip of the electrode should enter the cord 4–6 mm. from the midline, as determined by bisecting the interpedicular line. In order to produce lumbar-sacral analgesia, the tip of the electrode should be positioned more laterally, 8 to 9 mm. from the midline (Fig 4).

Only the most anterior border of the cord is seen in the lateral projection, and this represents that portion of the cord nearest the midline. When the target is near the midline, the tip of the electrode

Fig. 2. The needle and electrodes used for the anterior cervical percutaneous cordotomy. Note the curved electrode described in the text.
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should lie about 5 mm. below the projected anterior surface. When the target is more lateral, the actual anterior surface of the cord is more posterior than the apparent surface on the lateral projection. Indeed, when the sacral fibers are interrupted, the target is just anterior to the dentate ligament, which lies midway between the projected anterior surface of the cord and the anterior border of the lamina. Our initial experiences have suggested that within the anterolateral fasciculus the pain fibers are dorsally located.

The needle-electrode is used in a bipolar system, with one lead of the radiofrequency generator attached to the needle and the other attached to the protruding stylet wire. The lesion is produced by repeated application of small amounts of current, testing for areas of analgesia and for motor function between each current application. A satisfactory level is usually obtained by the use of 4.8 watts (40% setting of the 12 watt maximum output of this generator), which produces 60–110 ma. The current is first applied for 15 seconds and then for successively longer periods, depending on the response to each application. The analgesic effect of the current is immediate or appears within a few minutes.

In order to enlarge or alter the area of analgesia being produced, the depth of the electrode or the

Fig. 3. Lateral roentgenogram showing air in the subarachnoid space outlining the anterior surface of the spinal cord. The tip of the electrode is 5 mm. below the apparent surface of the cord.

Fig. 4. Anteroposterior roentgenograms with needle in position showing the curved tip pointing medially (a) and laterally (b). The mid-point is measured by bisecting the interpedicular line.
position of the electrode tip should be changed, rather than depending solely on changing the intensity or duration of the current.

The discomfort experienced by the patient during production of the lesion is less than in radiofrequency percutaneous cervical cordotomy done through the lateral approach at C-1-2 interspace. This is probably because the heated electrode is not near the emerging posterior nerve root. The post operative morbidity from the procedure itself is negligible, except for mild headache from air in the subarachnoid space. Pain secondary to penetration through the disc space is usually surprisingly minimal but occasionally annoying pain in the ipsilateral extremity lasts for a few days. This procedure is usually done on one side during one sitting and, if necessary, the opposite lesion is made a week later, although we have produced bilateral lesions during the same session with no untoward effect.

Results

Since June, 1965, we have performed 60 radiofrequency cervical percutaneous cordotomies on 42 patients. Twenty-one procedures on 17 patients were done at the C-1-2 level, using a technique similar to that described by Rosomoff. Thirty-nine procedures on 25 patients were done by the anterior approach in the lower cervical level. There were 12 bilateral procedures, 3 done at the C-1-2 level, 10 done in the lower cervical level; 1 patient had a lesion at the low cervical level on one side combined with a lesion at the C-1-2 level on the contralateral side.

Relief of pain was classified as follows: excellent—complete relief of pain; good—slight residual pain requiring only occasional non-narcotic oral medication; fair—diminished pain that still requires either oral or parenteral analgesic; poor—no improvement.

The average age in this series was 56 years. All but 4 patients had their intractable pain from metastatic carcinoma. The follow-up of these patients has been from 2 weeks to 7 months.

Of the 21 procedures performed at the C-1-2 level, 14 (67%) patients had excellent results and 4 (19%) good, giving a total of 18 or 86% with satisfactory pain relief. In 2 patients (9%) the results were fair; in only 1 patient (5%) was there a poor result.

Of 39 procedures at the lower cervical level, 16 (41%) results were excellent and 13 (33%) were good, giving a total of 29 (74%) with satisfactory alleviation of pain. Seven procedures (18%) gave fair relief and 3 (7%) were classified as poor. Since percutaneous cervical cordotomy at the lower cervical levels is admittedly a more difficult procedure than that done at the C-1-2 level, it is not surprising that most of the unsatisfactory results were found in the first cases. Indeed, if only the last 10 lower cervical cordotomies are considered, 8 had satisfactory results, 2 were fair and all had at least some pain relief. The somewhat less satisfactory pain relief obtained in the lower cervical approach, as compared to the upper cervical approach, can easily be justified when one considers the relative lack of untoward side effects.

Paresis of the contralateral extremities was encountered after cordotomy in 5 cases at the C-1-2 level. In the group done through the anterior cervical approach there was only 1 case of transient weakness of the contralateral leg and 1 case of contralateral weakness of the arm and the leg. All cases of motor weakness improved with physiotherapy.

The occurrence of bladder retention in patients who had no sphincter difficulty prior to the procedure occurred in 5 cases done at the C-1-2 level (26%). Only one out of a total of 39 cases operated on through the anterior lower cervical approach had transient urinary incontinence.

There were 4 cases where the anterior lower cervical approach was first attempted but was unsuccessful because of an anatomical variant at the operative site. One was due to the displacement of the cord from epidural metastasis. The second was due to the presence of marked spondylolisthesis of the cervical vertebrae, preventing an accurate interpretation of the mid-point of the spinal cord. The remaining 2 failures were due to the presence of advanced degenerative osteoarthritis of the cervical spine through which the needle could not penetrate.

In the entire series there were 4 deaths. They all occurred in the group done at the C-1-2 level.

Discussion

Mullan7,8,9,10 and Rosomoff et al.15 are correct in their contention that percutaneous cervical cordotomy is extremely advantageous in relieving intractable pain in patients who are debilitated with terminal disease and can-
not undergo open cordotomy. In addition, in many other patients it affords satisfactory relief of intractable pain without the necessity of a surgical operation. The need for such a procedure is evidenced by the large number of such patients who have been referred to us since we adopted this technique one year ago, despite an effort to remain objectively selective in the choice of patients.*

Anterior percutaneous cervical cordotomy at the lower cervical level has a distinct advantage over the high cervical technique in that the possible complication of paralysis of involuntary respiration can be avoided. In our series of bilateral cordotomies done by the anterior approach, there has been no respiratory difficulty or mortality. Four of the 21 patients with lesions at the C-1-2 level of the spinal cord died. This respiratory insufficiency has been of a peculiar type as revealed by the following case reports.

**Case Reports**

**Case 1.** F.B., a 38-year-old woman, had a right pneumonecetomy in 1964 for a bronchogenic carcinoma. In February, 1965, increasingly severe right chest pain from local invasion of the tumor occurred. She became debilitated and had weight loss, dysphagia, and dyspnea. On June 18, 1965, a left-sided C-1-2 percutaneous cervical cordotomy was performed using the Rosomoff technique. The patient was rendered analgesic to and including the C-1-2 level on the right. For several minutes following the procedure some weakness of the left leg was noted but this improved very rapidly. The patient had immediate and total relief of her chest pain. She later enjoyed a good night's sleep without sedation. The day after the procedure she had slight unsteadiness on walking, and, because of urinary retention, she required an indwelling catheter. She remained comfortable and in good spirits. At midnight on the 3rd night after the cordotomy the vital signs were stable. At 4:40 a.m. the patient was found dead. No autopsy was done.

At no time did this patient experience any noticeable increase in the mild respiratory impairment which attended her primary disease. She was comfortable and apparently breathing normally following her percutaneous cervical cordotomy. The night of her death she went to sleep normally and experienced no feeling of dyspnea or apprehension.

**Case 2.** A.T., a 54-year-old woman, had an abdominoperineal resection for a carcinoma of the rectum in 1962. In July, 1964, she developed local recurrence of the tumor and progressively severe bilateral sacral and rectal pain. On July 19, 1965, the patient had a left-sided percutaneous cervical cordotomy at the C-1-2 level. Analgesia was produced to and including the C-1-2 level on the right. She had a transient episode of hypotension following the production of the lesion, but her blood pressure stabilized at the preoperative level by the following day. The patient had relief of 80 to 90% of pain on the right side of the body. She had no weakness and was doing well, and 12 days later a percutaneous cordotomy was performed on the other side at the C-1-2 level. Analgesia was produced to and including the C-1-2 level on the left half of the body. During the production of the lesion the patient complained of some shortness of breath, but when the current was discontinued the patient once again breathed normally. She had complete relief of pain, but was somewhat nervous and complained of being "conscious of my breathing." Because of urinary retention it was necessary to insert a Foley catheter. The following day she complained again of a "consciousness of my breathing" and became more apprehensive. The sensory level on the left had dropped to T-4 and mild pain returned in the left gluteal area. However, the patient required no narcotics and was able to get out of bed. Because of poor respiratory excursions, intermittent positive pressure breathing was prescribed. On the 3rd day the respiratory effort became labored and she was placed in a Monahan respirator. Although she was able to tolerate being out of the respirator for 2 hours that afternoon she was still maintained in the respirator for most of the day. About 8:30 p.m. she got out of bed, and stood without help, apparently somewhat better. She went back to bed and fell asleep and was found dead at 11:30 p.m. An autopsy was done, but a specimen of the cervical portion of the spinal cord was not obtained. No other immediate cause of death was apparent.

The apprehension this patient displayed was not directed toward anything in particular, and, when asked, the patient denied any specific cause for her anxiety. The respiratory embarrassment was of a particular type. While awake, she was able to breathe apparently normally. She appeared to have satisfactory pulmonary exchange and was not cyanotic or obviously anoxic. When asked to take a deep breath, she was able to do so with no difficulty. However, upon going to sleep, ventilation decreased and required assistance.

* Since submission of this report to the present date (July 15, 1966), additional procedures have brought the total to 81 procedures in 50 patients, with 23 at the C-1-2 level and 58 by the anterior approach. By each technique, 82% of procedures have resulted in satisfactory relief of pain.
Case 3. N.M., a 67-year-old woman, who had a history of endometrial carcinoma, developed severe back and bilateral leg pain from local extension to the sacral plexus over one year previously. On July 7, 1965, she had a left-sided high percutaneous cervical cordotomy at the C-1-2 level. During the current application the patient became extremely apprehensive and moved because of the neck pain associated with the production of the lesion. The needle became displaced across the midline to the opposite anterior quadrant so that analgesia on both sides up to the C-2 level was produced. This inadvertent bilateral lesion relieved her rectal and leg pain completely. There was no motor weakness. On the night of the procedure she was noted to complain, "I'm having difficulty catching my breath." The next morning her respiration was obviously quite labored and required voluntary effort. She was placed in a respirator at 10:20 a.m., and remained alert and had good motor functions throughout the next 3 days. On the 4th day after the procedure she developed mild weakness in the left arm and the left leg. The 5th and 6th days after the procedure she seemed to be doing better. She was out of the respirator several times. On the 7th day after the procedure she was seen at 5:30 a.m. and her condition appeared satisfactory. However, 1 hour later she was found dead. An autopsy was done, but the cervical portion of the spinal cord was not obtained. No other immediate cause for death was apparent.

The respiratory difficulty experienced by this patient was easily compensated by voluntary respiratory efforts, which were apparently not impaired. However, when the patient did not think of consciously controlling her breathing, she became drowsy and cyanotic. She, as all other patients in this group, died during her sleep when she was not able to employ conscious voluntary respiration.

Case 4. M.K., a 48-year-old woman, had a radical mastectomy for carcinoma of the right breast in May, 1962. Thereafter, she developed pain from local tumor invasion of the right chest and from a pathological fracture of the left femur. She had chemotherapy, radiotherapy, oophorectomy, and hormonal therapy with no relief. A right-sided percutaneous cervical cordotomy at the C-1-2 level was done on July 19, 1965. Complete analgesia was produced below the T-6 area on the left side of the body with immediate pain relief. In addition, an area of hypesthesia was noted from the C-2 to T-6 level on the right side. The following day it was necessary to catheterize the patient for urinary retention. The patient had no weakness of her extremities and was free from pain over the entire left side of her body, but the pain on the right side of her body increased. Twelve days later a percutaneous cervical cordotomy was done on the left side of the cord by the lateral approach to the C-1-2 level. This procedure produced a complete analgesia up to and including the C-2 level on the right side of the body. The same evening the patient experienced some difficulty with breathing and intermittent positive pressure breathing was prescribed. The following morning she was free of pain and seemed better. Examination showed no weakness of her extremities and no evidence of pulmonary failure or infection. A catheter was inserted because of urinary retention. On the second day she complained of a sensation of being "smothered" when she tried to sleep. She was placed in an Emerson respirator. She did well but she seemed apprehensive. She went to sleep that evening, apparently comfortable, and at 1 a.m., was found dead in bed. An autopsy was done, but the cervical portion of the spinal cord was damaged during removal. No other immediate cause of death was apparent.

The sensation of being smothered occurred only when this patient attempted to sleep. During the day, the patient was active and in good spirits.

The clinical picture shown by the preceding 4 patients is similar to that described by other authors\(^1,3,4,5,13,14\) after surgical anterolateral cordotomy in the upper cervical levels and after percutaneous cervical cordotomy at the C-1-2 level.\(^10\) The patients have satisfactory voluntary respiration. However, this becomes inadequate when they fall asleep, and they die of respiratory failure. This fatal complication led us to develop the anterior lower cervical approach and is the reason why we prefer it to the high cervical level for percutaneous cordotomy.

Although our procedure is somewhat more difficult than the approach to the upper cervical cord, it is still technically simple and does not require elaborate apparatus. The intervertebral disc itself affords excellent immobilization to the needle. The time required for the procedure varies between 30 and 60 minutes.

The occurrence of weakness of the contralateral side of the body following the procedure is much less in the patients who had the anterior approach than in those who had the high cervical procedure.

Another advantage of the lower anterior cervical approach is that segmental analgesia can be obtained. Stimulating the cord before the production of a lesion has facilitated pre-
cise placement of the needle in the spinothalamic tract. The stimulation produces a sensation of pain or throbbing in a specific somatic area, which can then be made analgesic by application of the radiofrequency current. Correlation of the areas of segmental analgesia with postmortem specimens promises invaluable information to our present inadequate knowledge of dermatomal organization within the spinothalamic tract (Fig. 5).

The lower cervical anterior approach has made it possible to produce segmental thoracic or lumbar analgesia in the area of pain while sparing the sacral dermatomes. We believe this is the reason for the low incidence of postoperative urinary retention in our cases.

The lower cervical approach is preferable when bilateral lesions are needed, except when the pain is in the shoulders or neck. A lower cervical lesion can be produced in conjunction with a contralateral high cervical approach so as to insure normal diaphragmatic respiration on at least one side. Moreover, as we have become more experienced the efficacy of this procedure in the relief of pain approaches that of upper cervical percutaneous cordotomy.8,15

Summary

1. We have verified the usefulness of percutaneous cervical cordotomy for the relief of intractable pain, especially in debilitated patients.
2. The complication of respiratory embarrassment after high cervical percutaneous cordotomy stimulated us to find a new percutaneous approach to the lateral spinothalamic tract at a lower cervical level. We have described this technique.
3. We have compared the results of percutaneous cordotomy at the upper and lower levels. The upper cervical approach offers a slightly better chance for relief of pain, but the lower cervical approach has proved to be safer and less likely to be complicated by undesirable side effects.

References

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