Percutaneous Interruption of Spinal-Pain Tracts by Means of a Strontium\textsuperscript{90} Needle\textsuperscript{*}

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Anterolateral cordotomy for pain, first performed in Philadelphia by Martin\textsuperscript{2} in 1912, has a long established and honored position among neurosurgical operations. So undeniable are its merits that it has stood the test of time despite a mortality that has ranged between 4 and 25 per cent\textsuperscript{3} and a period of convalescence that is not inconsiderable. The lesion that is required in the anterolateral tract itself is very small, yet the operation is major. The lesion is of a magnitude that may be made accurately and discretely by the beta-emitting radioactive isotopes, and it would seem that percutaneous introduction of such an isotope should produce as effective a result as open operation with section by a knife. Such a puncture with the needle is impossible in the thoracic region because of the overlap of laminae and the posterior migration of the interarticular joints. The lack of overlap in the cervical region makes insertion lateral to the cord simple and the anterior migration of the interarticular joints on C1 and C2 allows percutaneous access to the anterior as well as to the lateral aspect of the cord (Figs. 1 and 2). The vertebral artery enters the dura mater through the atlanto-occipital space and the 2nd cervical nerve enters through the C1–C2 interval. The C1–C2 interval is, therefore, preferable (Fig. 3).

Though it is the rule that those isotopes emitting beta particles of greatest penetration have the shortest half lives, it has been possible by using a strontium-yttrium source to provide both longevity of activity and penetration of particles. A strontium-yttrium needle suitable for our purposes has been constructed by one of us (P.V.H.).\textsuperscript{4} Using the physical and biological data obtained in laboratory experiments and knowing that the average cord at this level is 10 mm. in anteroposterior diameter and almost 14 mm. in width, it is possible to plan a field of beta irradiation to any desired depth in the anterolateral cord. Fig. 4 shows such a field for a 15-min. irradiation. The needle, inserted at 45° to the sagittal plane, lies against the anterior dura mater 3 mm. from the midline. Increasing or decreasing penetrations may be provided by moving the point of the needle in relation to the midline or by altering the period of radiation. A 5-min. dose would decrease the cut by 1 mm.

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A 30-min. dose would deepen it by 0.6 mm. Thus duration provides a relatively fine adjustment. It is seen that the position at the tip of a needle provides a coarse adjustment and is a most critical factor in the precision of the operation. Larger or smaller cords than average demand appropriate adjustment of the field of radiation.

**Technic**

Under local anesthesia a thin-walled, No. 17, lumbar-puncture needle is inserted between the 1st and 2nd cervical vertebrae so as to approach the midline anterior to the cord at an angle of 45°. Local anesthesia must be *perfect*, for the
patient will jump if the 2nd cervical root is touched during insertion. We take about 10 min. to carry out this stage of the procedure, using about 20 cc. of 1 per cent procaine. The extradural space requires 1 cc. of procaine. If not, the needle, having traversed the subdural space, will come up against the anterior dura mater from within and the patient again may jump. The No. 17 needle must be guided under suitable roentgen-ray control. We prefer biplane television fluoroscopic-image intensifiers, which throw antero-posterior and lateral images on two television screens in a fully lighted room. This equipment so facilitates the insertion that this stage may take no more than 1 min. to accomplish. The patient may remain prone, lateral, or may sit up, depending upon his convenience and upon the limitations imposed by his pain. If a machine with only one plane is available, this will require several rotations of the patient at right angles and insertion may take 10 min. to accomplish. Standard radiologic equipment, using multiple Polaroid films, also is very suitable. We have only once used standard equipment with standard films and this was very tedious (because insertion must be controlled millimeter by millimeter once the dura mater is reached). When the needle penetrates the dura mater, cerebrospinal fluid will be obtained. If cerebrospinal fluid should cease to flow or if the patient experiences discomfort, the needle may be against the cord or a strong dentate ligament and it must be repositioned. Gently the needle is advanced until the anterior dura mater is reached. The sharp stylet is removed and an inactive replica of the strontium-yttrium needle is inserted. The No. 17 sheath is withdrawn to expose the terminal 6 mm. of the replica, which remains in contact with the dura mater. As the No. 17 sheath is being withdrawn the elasticity of the muscles tends to pull it back toward the anterior dura mater. There is enough friction between the sheath and the replica to transmit this pull to the replica and keep it firmly against the anterior dura mater. (When the active needle is inserted it must be certain that it does not slip posteriorly, for if posterior it will irradiate the pyramidal tract.)

Careful measurements are made of the angle of insertion and of the position of the tip of the needle, which should lie just inside the shadow cast by the dens at 3 mm. from the midline. The optimum duration of radiation then is calculated. It usually lies between 15 and 30 min., though 40 min. have been employed. Long periods of irradiation are undesirable to deepen the field because they also lengthen it, extending it into the territory of the pyramidal tract. Central hemorrhages which resulted from lesions of greater than 30 min. in the laboratory experiments need not be a factor in cordotomy as the highest dose is expended in the cerebrospinal fluid lateral to the cord. When one is confident that the inactive needle is in optimum position it is withdrawn and the active needle is inserted. Protection of the operator from beta particles is provided by two small pieces of brass, which may be clamped onto the active point of the needle and to that part of the sheath that is held by hand. It is advisable to check the position of the active tip because sometimes a change of direction occurs during transference. When the needle has been withdrawn after the calculated period of exposure, the patient, if ambulatory, may walk off the table unaided. He is advised to lie flat for the next 24 hours, lest post "limbus-puncture" headache develop. One patient who went home the same day had such a headache develop.

**Results**

In all, we have performed 60 cordotomies upon 42 patients. The youngest was 3 years old; the oldest was 71. Thirty-seven suffered from malignant disease. Five had benign conditions (Table 1). In 27 instances the operation was single unilateral; in 5, 2 operations were done upon the same side. In 8 the procedure was bilateral; 1 patient had 3 procedures, 2 being on the same side; 1 had 4, 3 being on the same side. The type of results obtained might be understood best by giving several examples:

**Case 1.** A woman, 41 years old, had known carcinoma of the uterine cervix for 2 years. She had severe pain in her left leg and there was motor and sensory impairment of the anterior thigh.
It is of interest that relief from pain was experienced before sensory loss could be determined by pin prick. The interval of time may be much longer.

Case 2. A 58-year-old man was admitted to the Neurosurgical Clinic with "sciatica." It was obvious that he had lost weight and that his chronic cough had increased. He had carcinoma of the lung with multiple metastases. On Aug. 21, 1962 a strontium-yttrium cordotomy, 25 min. in duration, was performed, the needle lying 4 mm. from the midline. During the next week his sciatica gradually disappeared. Six weeks later relief from pain persisted and there was no abnormal neurological sign. Ten weeks after the procedure there was partial loss of sensation on pin prick to T4 and at the end of 15 weeks there was complete loss on pin prick up to C4. He was ambulatory during most of his remaining 6 months of life.

Sometimes relief from pain, though very useful, is not complete in those patients who do not have a sensory loss develop.

Case 3. A 51-year-old man had multiple myelomatosis for 2 years. There were multiple deposits in his thoracic spine and he had severe left-sided pain in the chest for several months. On Nov. 1, 1962 a strontium-yttrium cordotomy was performed, the tip of the needle being 5 mm. from the midline and the duration of the cordotomy being 45 min. The next day he had considerable relief from pain and by the 4th postoperative day he stated that it had all disap-

**TABLE 1**

<table>
<thead>
<tr>
<th>Carcinoms of:</th>
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<tr>
<td>Uterus</td>
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<tr>
<td>Lung</td>
<td>9</td>
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<td>Prostate</td>
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<td>Thyroid</td>
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<td>Rectum</td>
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<td>Neuroblastoma</td>
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<tr>
<td>Multiple myeloma</td>
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<td>Hodgkin's disease</td>
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<td>Diabetic gangrene</td>
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<td>Diabetic neuropathy</td>
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<td>Tubes</td>
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<td>Herpes</td>
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<td>Painful paraplegia</td>
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On Aug. 1, 1962 she had a 30-min. cordotomy performed, the tip of the needle lying 3 mm. from the midline. Next day there was some improvement in her pain and toward evening of that day it disappeared completely. On the morning of Aug. 3 some sensory loss to pin prick was noted in all areas below L1 and later on that day the level was observed to ascend to T8. Next morning it was at T6. On August 11 it reached C3, where it remained for the ensuing 5 months of her life. No further neurological deficit developed. Postmortem appearances of the cord are shown in Fig. 5.

![Fig. 5. Case 1. Section of cord at level of cordotomy.](image-url)
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Fig. 6. Case 5. Section of cord at level of cordotomy. Note that swelling and degeneration extend beyond the area of necrosis.

peared. Moderately vigorous turning in bed could still hurt him, but though relief was incomplete it made life much more comfortable for this bedridden patient. Six weeks later he expired without development of any sensory loss.

In addition to those patients for whom standard surgical cordotomy might be advised, this percutaneous procedure has been offered to several patients whose pain was insufficient to justify a major surgical operation, but enough to incapacitate them in their daily work.

Case 4. A 48-year-old woman, who had initial treatment for carcinoma of the cervix 1 year previously, had pain in her left leg for 3 months and limped considerably. A 29½-min. cordotomy was performed, the needle lying 2 mm. from the midline. Next day all her pain was gone. One month later when she returned for check-up, a sensory level to pin prick was present at T5. She had not been aware of this change. Six months later she remains free from pain, and the sensory level is at C4.

Percutaneous cordotomy also may be offered to patients too ill for consideration of a major surgical operation.

Case 5. A 48-year-old woman with terminal carcinoma of the cervix had known occlusion of one ureter. Oliguria developed with obstruction of the second ureter and her left-sided pain increased in severity. A 40-min. cordotomy was performed, the tip of the needle being in the midline. The next day all pain had disappeared. As she became increasingly drowsy, it became difficult to follow the exact development of her sensory loss and she expired 21 days later (Fig. 6).

We have been slow to use this new type of operation for patients who did not have malignant disease, but have used it on 5 occasions.

Case 6. A 58-year-old diabetic had pain in the leg unrelieved by removal of his left L5-S1 disc 1 year previously, in another hospital. His diabetes was under good control. There was bilateral stocking anesthesia but sense of vibration still was detectable at the ankles. He had not worked for 1 year because of this pain. A 15-min. cordotomy with the tip of the needle 5 mm. from the midline appeared at first ineffective. Two weeks after the procedure he reported a 5 to 10 per cent improvement in the pain in the left leg. After 4 weeks he reported a 60 per cent improvement. Seventy days later he reported that the pain in his foot had disappeared gradually and a sensory level to pin prick was present at T8. At 100 days it stands at T5.

Complications

Complications of insertion were less than we had expected. One nervous patient jumped in such a manner during insertion
that the needle must have bruised or penetrated the cord. During the remainder of that day he had some weakness of fine movements in the corresponding arm and leg, but next day this weakness had disappeared entirely. The experience caused him to decline any further attempt and it emphasized to us that we simply must anesthetize the 2nd cervical nerve adequately. (As cordotomy was not performed, he is not included in results.)

Another patient during insertion complained of an "atomic explosion, a ball of fire". He saw it like a red flash and felt it hot on the right side of his head. Subsequently he had a proprioceptive loss in his right hand and a mild diminution in perception of pin prick on his right face and right arm. It was supposed that the needle may have dislodged an embolus from a tortuous vertebral artery and that this embolus lodged in his thalamus.

Perhaps most patients will complain slightly of a discomfort in the back of the neck during the following 2 or 3 days, but 5 have complained of severe pain in the back of the neck, which radiated up to the back of the head, and this has come on usually after several days and has persisted for 10 to 14 days. It is apparently caused by irradiation in the occipital nerve and occurs even when there has been an absolutely painless insertion of the needle. A course of one to three injections of procaine at daily intervals or on alternate days has ended, or has coincided with the termination of, this discomfort. As the 2nd nerve lies close to the 1st vertebra, the needle should keep close to the 2nd.

Weakness. Weakness occurred in 6 instances, and was severe in 1. Four patients were bedridden and in 3 the overdosage was quite deliberate, to ensure early relief of pain. Two were ambulatory and recognized significant weakness in one leg. They were not incapacitated by this weakness. It is possible that other patients who were bedridden did have weakness develop, but of a degree that could not be detected by routine neurological examination. One had a positive Babinski's response develop without gross weakness.

Sphincters. As many of these patients had pelvic disease, they were already wearing an indwelling catheter. One of 2 patients who had bilateral cordotomy and who did not already have an indwelling catheter did have paralysis of the sphincters develop on the 5th day after the second procedure. He had extensive Hodgkin's disease of the spine. No study has been made of the effects upon libido in any instance.

Unpleasant Sensations. One patient with carcinoma of the prostate, who had pain down the back of his left leg, complained of a burning sensation in the same area 45 days after the procedure. Soon after, his objective sensory level began to appear. At the moment of writing (60 days after the cordotomy) he has dense analgesia below his knee, subtotal analgesia to the groin and a very slightly hypalgescic level at T4. It is too early to say whether this is a temporary or permanent complication, as the level is still ascending. One other patient complained of occasional shock-like sensations down his spine during the period of development of analgesia.

Failures

Addiction. Three patients, who were taking massive doses of narcotics, continued to demand narcotics in spite of clinical and postmortem evidence of adequate destruction of the anterolateral tracts.

Case 7. A man, aged 51, had known carcinoma of the bladder for 2 years. For several months he had complained of pain in his back, sides and right shoulder. There was very extensive metastatic disease. On May 23, 1962 he had a cordotomy performed for his right-sided pain. This gave dramatic relief, but very soon he complained of equal pain on the other side. On August 23 he had cordotomy for this pain and it was repeated on September 6. In spite of the development of adequate clinical and pathological evidence of impairment of the anterolateral tract, he continued to demand morphine every 3 hours.

Inadequate Dosage. Of the 5 patients with benign disease, 2 (1 with diabetic gangrene, and Case 6 with diabetic neuritis), who had adequate dosage at cordotomy got good results. Two (tubes, herpes) must be regarded as failures. In both the dose delivered was deliberately less than our theoretical calcu-
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lations demanded. No sensory loss occurred and the failure could be either the result of inadequate dosage or resistance on the part of the disease. The patient with herpes had pain along the 7th intercostal segment on the right and complained of intolerance to touch as well as of deep, burning pain. She had relief of intolerance to touch only. It is difficult to evaluate the patient with painful paraplegia. The initial cordotomies of all 7 patients who had 2 or more cordotomies on the same side must be regarded as failures because of inadequate dosage. All were corrected by the final procedure.

Anatomical Abnormality. The patient who had 4 cordotomies falls into this category. Two cordotomies for right-sided pain (30 min. at 3 mm. from the midline) brought the sensory level to T10 only. An identical cordotomy (30 min. at 3 mm. from the midline) on the other side produced a C4 sensory level within 3 days (which we would expect if the needle had been 1 mm. from the midline). A third cordotomy (identical dose) for his right-sided pain produced a partial sensory loss up to T2 within 3 days. Later it ascended to C2 and he ceased to complain of pain though some islands of sensation remained towards the upper limit. It is postulated that his cord lies 2 mm. to the right of the midline of his vertebrae. This may be ascribable to his widespread metastasis from carcinoma of the kidney. (He seems too ill to advise myelography for confirmation.)

In short, effective cordotomies with relief from pain have been achieved in 34 of our 42 patients. Good objective sensory loss was obtained in 3 other patients who had become addicted to narcotics, but they still complained of pain. Two patients who had inadequate dosage did not obtain relief. In 1 a burning sensation developed and the patient feels no better. One is too difficult to evaluate and 1 is too early to evaluate.

Discussion

This cordotomy, which attempts basically to duplicate the effects of a surgical cordotomy, differs in several essential ways. A most interesting one is the early development of relief from pain before sensory loss becomes evident. This perhaps suggests that C fibers carrying dull pain are more susceptible to the radiation than are the myelinated fibers carrying perception of pin prick. Neither sensation of temperature nor tendo-achillis pain was lost at this early stage.

The disassociation of loss of pain and sensory loss seemed to be more evident in the case of infiltration of the pelvic nerve than in cases of destructive lesions in bone, though it was present in those patients also (Case 3). The delay of 2 or even 3 months in the full evolution of the lesion was anticipated from our experimental studies and it may be followed out in Cases 2 and 7. This delay must be explained to those patients for whom minimal doses are employed. When maximal dosage is used, loss of pain and sensation is complete within a few days, but motor loss may be expected in some of those patients whose survival exceeds 3 months. It is impossible to provide early relief of pain in the upper limb without risking this late motor loss, but a slower relief may be provided safely. Later models of the needle will have the isotope in the terminal 4 instead of the terminal 6 mm. and this shortened field should eliminate damage to the pyramidal area. Up to the moment we have not inserted the needle at an angle greater than 45° to the sagittal plane because of increased likelihood of irritation to the 2nd cervical nerve, but it may be that a greater angle would be advisable in those patients in whom an early deep “cut” is desired.

Another point of interest relative to surgical cordotomy was that the sensory level has not been observed to fall in any patient, which is in striking contrast to our previous experience. Sometimes islands of sensation persist in the upper limits, but these have not been observed to develop after analgesia had become complete. It is realized that the follow-up period is as yet very short.

One other observation was that in 1 instance pain did not disappear in spite of a good unilateral sensory level, but did disappear when a contralateral cordotomy was performed, suggesting that in some instances
pain may ascend bilaterally. This suggestion may not be valid because since the cordotomy produces progressive destruction, it may be that this fortuitously became adequate at the period when the second cordotomy was carried out.

The advantages offered by this type of cordotomy are fairly clear. The elimination of mortality and of the uncomfortable convalescent period are the most important. The technical simplicity is another. While it is true that the procedure initially was about as difficult as a myelogram for both patient and surgeon, it was soon evident that further experience on the part of the surgeon reduced this difficulty toward the magnitude of a lumbar puncture. It is now performed almost entirely by Dr. Hekmatpanah who is our second-year resident. This technical simplicity and safety allow the surgeon to offer relief from pain to a much greater number of patients than was possible with standard surgical cordotomy. It is possible to offer it to those who are too ill to survive surgical cordotomy and to those whose life span is too short to make its inconveniences worth while. It is also applicable to those whose pain is too severe to be relieved by simple analgesics but not severe enough to demand a major operation. Lastly, those patients who have had a series of futile operative procedures for cancer and who, though otherwise suitable are simply scared of another operation, usually are very willing to accept the help offered by the simplicity of an injection of a nerve. It is certain that in any hospital population there are very many more patients who are suitable for this percutaneous method than for a surgical one. Allowing for the inevitable enthusiasm of a new procedure, it is significant that in a previous period 1 year ago, we performed less than 10 surgical cordotomies. It is our feeling that this method bears about the same relationship to standard surgical cordotomy that percutaneous carotid arteriography bears to cut-down carotid arteriography. Modifications of the present needle and the use of other isotopes such as thulium remain to be explored.

Summary

1. Percutaneous anterolateral cordotomy was performed on 42 patients, using a strontium-yttrium (54 mc.) needle introduced between the laminae of C1 and C2.
2. Of these patients, 37 had terminal malignant disease.
3. Of the 42 patients, 34 had satisfactory relief from pain.
4. Three patients who were taking large doses of narcotics had adequate sensory loss, but retained their addiction and continued to complain.
5. One patient with herpes and 1 with tabes experienced no relief. The dose used may have been inadequate.
6. One had burning sensation in the area of analgesia.
7. Two have not yet been evaluated.
8. Weakness of mild degree developed in 5 instances and was severe in 1. This weakness in all cases was related to overdosage. There was no evidence of damage to the cord by puncture with the needle or intraspinal hemorrhage.
9. There was no mortality and no period of convalescence.

References


Discussion

Dr. R. F. HEINBURGER: Dr. Sean Mullan’s Irish ancestry has led him to many bold and imaginative endeavors. This is one of them.

Close association between surgeons and engineers is becoming increasingly frequent. The engineers have many devices that can help the surgeon who has the imagination to take advantage of their knowledge. Dr. Mullan obviously has this imaginativeness.
The boldness to follow through with such an endeavor also is needed, and in this instance also is obviously present.

I am sure that many patients are not offered the benefit of relief from pain because of the major surgery that it requires. Most patients and many physicians will accept the needle where they would reject a scalpel.

Dr. Mullan's ability to work this into a relatively easy routine procedure is interesting and probably indicates that the measurements of the cervical spinal canal are much more uniform from individual to individual than are measurements of the basal ganglia. I suspect that this technique will stimulate further investigation of these measurements.

We all worry about the late effects of radiation. I am sure Dr. Mullan has considerable information about this for his combination of radioactive strontium and yttrium. Although most people subjected to the procedure will not survive the 7 years or so for long-term effects to take place, I wonder if there is any information yet regarding the possible increase in size of the spinal-cord lesion for those who survive a long time.

Dr. Sean Mullan: I have nothing much to add, but I would like to pay tribute to my colleague, Dr. Harper, who is not only a general surgeon but an atomic physicist and an engineer of outstanding ability, and to whose very organic couch I must say I take my problems in the nuclear field. Without the availability of his skills, this type of work could not be done.