SPINAL PATHWAYS SUBSERVING DEFAECATION AND SENSATION FROM THE LOWER BOWEL

BY

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The purpose of this study has been to find out the location within the human spinal cord of the following pathways: those subserving voluntary control of defaecation; those necessary for the coordination of defaecation; those conveying afferent impulses from the lower bowel, rectum, and anus.

There is almost no literature concerning the region of the spinal cord where these tracts run in man. Previous work has mainly been devoted to the effects on defaecation of total division of the spinal cord or of lesions of the sacral nerve roots.

Hertz (1911) considered the location of the spinal afferent pathway; he concluded from cases of tabes that it lay within the posterior columns. But it is now known that although in tabes the posterior columns show degeneration, this is due to the lesion at the root entry zone, and so it may be concluded that the afferent pathways from the rectum are involved here, and not necessarily in the posterior columns.

Observations on the effects of dividing the tracts of certain parts of the cord and of confirming after death the parts divided seem to have been carried out only by Foerster (1936). He stated: “After bilateral section of these tracts [the antero-lateral and the anterior columns] I have repeatedly found disturbances of the rectum, and particularly of the sphincter. But they always recover”. He concluded that the “rectal pathways” run partly in the anterior and antero-lateral columns.

The argument on which the following work is based is as follows. If division of certain limited parts of the human spinal cord causes the same abnormalities of defaecation as occur after total division of the cord, then such limited lesions must have divided the tracts that convey impulses subserving the normal functioning of defaecation. Where there is only a partial disturbance of defaecation it may be concluded that only some of the relevant tracts are divided. From such cases a more detailed analysis of the distribution of the tracts is possible.

Before considering the effects of division of pathways subserving defaecation it is desirable to consider certain aspects of the normal voluntary control of defaecation, and to relate briefly the sort of rectal and anal functioning which occurs following division of the entire spinal cord at any level between the sacral centre and the cerebrum.

Normal voluntary control of defaecation permits the subject to start defaecation, to withhold defaecation regardless of the desire to defaecate, and to stop defaecation in the middle or at the end of the act.

The mechanism of voluntarily starting defaecation is not fully understood. A reflex act is initiated by volition. The intra-abdominal pressure is increased, and the external sphincter is relaxed. If this muscle is not relaxed it tends to contract synergically whenever the intra-abdominal pressure is raised. It is obvious that defaecation cannot occur unless there is a certain minimal quantity of faeces in the rectum, and even when the rectum contains faeces, defaecation cannot always be started, even in the normal. In this respect the rectum differs from the bladder, for a normal subject is able to micturate when there are only a few drops of urine in the bladder.

The ability to withhold defaecation depends on voluntary contraction of the sphincter. This muscle can be held contracted for 30 to 60 seconds, during which time the rectum automatically dilates to accommodate itself to hold increasing contents at the same pressure.

The ability to stop the act of defaecation, once it has started, likewise depends on voluntary contraction of the external sphincter and the muscles which reinforce its action.

When the spinal cord is divided above the second sacral segment defaecation differs from the normal in four main respects.
First, voluntary control of the act is absent. The patient cannot start or stop defaecation in a normal manner.

Secondly, no afferent impulses reach consciousness. There is no urge to defaecate and no rectal pain; the patient does not know when he passes faeces. As he has no awareness of rectal events, he does not instinctively aid defaecation by increasing the intra-abdominal pressure.

Thirdly, some reflexes of the external sphincter are absent. Gaston (1948) showed in the normal that rapid distension of the rectum by a balloon causes a contraction of the external sphincter, even when the subject is asleep. This "response" normally occurs when the intra-abdominal pressure is suddenly raised. After transection of the cord the response no longer occurs, and so the patient is likely to be incontinent when he coughs or makes a sudden movement.

Fourthly, the automatic or reflex components of defaecation differ from their normal counterparts in that there is obstinate constipation (except when the faeces in the rectum happen to be in a liquid state). The reasons for this dyschezic constipation are not immediately obvious. Denny-Brown and Robertson (1935) comment:

"The defective evacuation of solids resulting from these nervous lesions appears therefore to result not from deficient reaction to distension of the rectum but from lack of sufficient propulsive power in the act. The deficiency is not an absence of peristalsis."

One of the causes is the formation of a ball-valve of hard, dry faeces blocking the anal canal, which is partly the result of the paralysis of the levator ani. But even when this hard mass of faeces is artificially removed, the rectal propulsion is incapable of emptying the rectum, unless the faeces are liquid or semi-liquid.

This syndrome, however, is not always as complete as has just been described. Sometimes the rectum is able to discharge its contents automatically, and to do so regularly at the same time every day. Foerster (1936) reported that one of his patients with a complete transection of the cord could always begin on defaecation by rubbing the inner side of the thigh.

**CLINICAL EVIDENCE**

**Material and Methods of Investigation**

The material of this study consists of patients with cancer on whom the operation of antero-lateral cordotomy has been performed for the relief of pain. Only those cases in which histological examination of the spinal cord has been carried out are used as evidence. In the section on the clinical syndrome resulting from unilateral antero-lateral cordotomy, cases in which no necropsy has been performed will also be considered.

Routine clinical observations were made in all cases before and after the operations on the spinal cord. A rectal examination was carried out, and the postural tone and voluntary contraction of the sphincter and levatores ani were investigated digitally; the cutaneous-muscular anal reflex was elicited by dragging a pin over the peri-anal skin. Two forms of balloon were passed per anum into the rectum. The one form consisted of a condom surrounded by a silk bag connected by a t-tube to a mercury manometer and to an inflating bulb. Notes were made before and after operation at what pressure in millimetres of mercury a desire to defaecate was experienced and at what pressure this sensation became painful. With such an apparatus part of the pressure is certainly dissipated against the silken case surrounding the condom, but as this factor is constant, the same silk bag being used before and after operation, the readings on each patient are comparable. The pressures at which most patients had a desire to defaecate varied between 40 mm. and 100 mm. of mercury. The other form of apparatus consisted of a rather thick toy balloon connected to a very narrow tube. The balloon was passed into the rectum while the tube, passing through the anal canal, was connected to a syringe. The amount of air injected to cause the sensations was noted. To cause a desire to defaecate, usually 100–400 ml of air had to be injected. The patients were also asked to comment on the sensation when the balloons were extruded through the anus.

**Cases with Bilateral Spinal Lesions**

The cases with bilateral lesions are considered under the headings Groups Ia, Ib, and II. They are listed in Table I. To facilitate reference to the same cases in our previous paper (Nathan and Smith, 1950), the same case numbers are used throughout.

**Group Ia:** Defaecation Similar to that of Total Cord Transection.—Before their operations these 14 patients had normal rectal and anal functioning and normal sensation. After their operations they had a syndrome most similar to that described above as occurring in complete cord transection.

In these patients, after the operation the pressure in the rectal balloon could be raised as high as 280 mm. of Hg (the upper limit of the apparatus) without there being a desire to defaecate or pain.
Although it is believed that the pathway conducting pain from the rectum had been divided in all these cases this could obviously be shown in only those cases in which there was rectal pain cured by the cordotomy, namely Cases 2, 5, and 6. It should be noted, however, that none of the patients of Group I had any discomfort even though the recta were filled with faecal blocks.

That the dyschezic constipation which occurred in all the cases in Group I is due to disturbance of the nervous arrangements controlling the rectum and not those of the colon above, was shown by three further patients (not included in Table 1). These patients had satisfactorily working colostomies in the descending colon. The bilateral antero-lateral cordotomy was performed as on the patients in Group I; this caused no disturbance of bowel behaviour, no change in the daily evacuation rhythm, and no change in the consistency of the faeces.

Thus the cases of Group Ia show that the lesions made by bilateral antero-lateral cordotomy may cut all those tracts subserving normal, voluntarily controlled defaecation. In these cases the lesions in the cord were made between the third and the twelfth thoracic segments.

These cases of Group Ia differ, however, in three respects from cases of cord transection.

Most of these patients regained some degree of anal sensation: sensations of warmth, cold, and pain remained lost to them, but sensations of touch and stretch recovered or were never lost. Such sensation was adequate to enable them to feel faeces passing through or in the anal canal, or to feel them at the internal entrance of the canal. Accordingly, many of these patients knew when they were about to pass or were passing something per anum. This anal sensation, however, is not the same as that underlying the normal desire to defaecate, although, unless the matter is gone into carefully, some patients state that they have the normal desire to defaecate. It may be held that it is hardly correct to consider the sensation experienced when faeces or an instrument dilate the anal canal as not being the sensation underlying the desire to defaecate, especially when this sensation is interpreted by the patient as an urgent desire. Yet it is known that the true desire to defaecate normally arises in the rectum and not in the anus. Anal sensation, from which the elements of thermal sense have been removed, was found to be inadequate to permit its possessor to distinguish wind from faeces.

The second respect in which these cases differed from cases of complete transection is that there was a tendency for the levatores ani to recover from the original paralysis.

The third respect in which the cases of Group I differed from cases with complete cord transection was that the cases of this group had lost the anal reflex. After the cord has been divided in man this reflex emerges early from spinal shock. But all cases of Group I showed permanent absence of this reflex. Müller (1901) stated that the absence of the anal reflex has no pathological significance, as he found it absent in a half of normal women and three-quarters of normal men. But the fact that the reflex was always present in these patients before the operation and always absent after it has pathological significance.

Group Ib: Slight Recovery of Voluntary Control of Defaecation.—In this group there are two patients. They both had at first the same syndrome as that shown by the patients in Group Ia, but in their case there was more return of voluntary power in the levatores ani than in the patients in Group Ia, and there was some recovery of voluntary control of the external sphincter. They could contract these muscles and keep them contracted only by using much effort, and they could do so only when they contracted other related muscles. Thus they were able to close the anal canal by performing a large movement, consisting of indrawing of the pelvic floor and adduction of the thighs. This return

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**TABLE 1**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Sex</th>
<th>Survival* (Days after Operation)</th>
<th>Dermatome below which Analgesia is Present</th>
<th>Pain in Rectum before Operation</th>
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<td></td>
<td></td>
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<td>M</td>
<td>53</td>
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<td>M</td>
<td>154</td>
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</table>

*When there were two operations there are two numbers under the heading of survival. Right or left in this column indicates the side of the cord incised. In the next column, it refers to the side of the body.
of some voluntary control of the anal sphincter and levatores ani occurred in the one case about three weeks after the operation, and in the other about two months after it. It is possible that had some of the patients in Group Ia lived longer, or had they regained better general health and more agility, they might also have shown similar recovery in this voluntary control. One is therefore unwilling to lay much stress on this recovery in these two patients or the lack of it in the others.

**Group II: Partial Lesions.**—This group contains two heterogeneous cases. In Case 21, the incision was purposely made superficial on one side of the cord. The disturbances of defaecation that were present immediately after operation eventually passed off. In Case 22, a colostomy had previously been performed, and so the rectum was no longer in use as an organ concerned with defaecation or the retaining of faeces. But as the operation caused effects on the pain arising in the rectum, the case is of use in throwing light on the afferent pathway of impulses subserving pain from the rectum.

In Case 21, the incision on the left side of the cord was made 4 mm. deep and in an oblique direction latero-anteriorly, the knife being inserted 2 mm. anterior to the denticulate ligament; on the right side of the cord, the usual 5 mm. incision was made, starting just anterior to the denticulate ligament. At first after the operation the patient had urgency of defaecation. He knew when something was about to pass, but he could not tell wind from faeces; if he thought it was wind, and decided to pass it, and then found that it was faeces, he could not stop the act. Twenty-five days after the operation he still had much difficulty in defaecating; the act did not occur spontaneously and was performed only with difficulty when he tried to induce it; he could defaecate only after taking aperients. When he was about to defaecate, however, he could not delay the act for long, still having urgency of defaecation. He had by this time recovered the ability to discriminate between wind and faeces, being able to tell which he wanted to pass, and being able to distinguish them as he passed them. He had the normal sensation underlying the desire to defaecate. Fifty-two days after the operation he considered that all aspects of defaecation had returned to normal; he defaecated daily or every other day. The tone and grip of the sphincter were normal and the levatores ani were under normal voluntary control. The anal reflex was present on the side of the body opposite the superficial cord incision, and absent on the side of the body opposite the usual incision. Before the operation, when the pressure in the inserted balloon was 30 mm. of Hg, he got a desire to defaecate, and when it was 50 mm. he had pain. After operation a pressure of 40 mm. gave him the sensation that he was defaecating; at a pressure of 100 mm. he got this sensation more strongly, but no urge to defaecate. Thus, from the beginning, this patient never had the syndrome seen in Group Ia. He had only urgency of defaecation, and the inability to distinguish wind from faeces. These conditions recovered, so that the patient said that defaecation was normal; in fact it was so, except that some disturbance of function was shown by the absence of the anal reflex, and it was open to doubt whether the pathway conducting impulses subserving the sensation underlying the desire to defaecate was in fact normal.

In Case 22, there was a carcinoma of the rectum, which protruded at the anus, involving the sphincter. The patient had a constant, severe, aching pain within the rectum, and, intermittently, a sharp shoot of pain, which felt as though a knife were being dug into the anus. A bilateral cordotomy was performed at the fifth thoracic segment (in another hospital); it caused no complete analgesia in any part of the body. It did, however, ameliorate the pain, although it did not entirely remove it; a feeling of soreness at the anus remained. The operation did not interfere with the functioning of the colostomy.

**Cases with Unilateral Lesions**

The possible criticism that a unilateral lesion may not divide all the relevant pathways on the one side of the cord is met by showing histologically that the unilateral lesion is in the same place as one of the bilateral lesions which together cause the clinical picture described of the cases of Group Ia. The effects of unilateral division of the spinal pathways subserving defaecation will be considered under motor aspects and sensory aspects.

Twenty patients with a unilateral antero-lateral or lateral cordotomy were studied, and the cords of three of them have been examined histologically. Photographs from two (Cases 20 and 35) are shown in the histological section.

After unilateral division of the pathways voluntary control of the anus is normal; the subject is normally continent of faeces, is able to hold them at the entrance of the anal canal, and can interrupt the act of defaecation. One patient out of the 20 had slight urgency of defaecation. She described this as an anxiety lest she might have an accident when the bowels were at all loose, but as far as was ascertained, she was always continent. All
patients had normal voluntary power in the levatores ani and external sphincter. Thus these muscles must be bilaterally supplied from each side of the cord.

Unilateral division of the pathways may cause dyschezic constipation. It was not present in 15 of the patients; in one, it was fairly severe; and in the other four it was just as severe as that which occurs following division of the tracts on both sides of the cord, defaecation being impossible without an enema or manual removal. As voluntary control of the anus and perineal musculature was normal in these cases, and there was no disturbance before operation, it seems that it should be concluded that this disorder of defaecation results from a division of the pathways mediating the more automatic functioning of the rectum. It is surprising to find that division of these pathways on only one side of the cord should so completely upset the function of the rectum as a whole, and to find it occurring only in some cases, instead of in all, or in none. This derangement of automatic function might be due to interruption of afferent or efferent pathways. It would seem unlikely that it is due to interruption of afferent fibres on one side of the cord, for it would be imagined that the impulses from the rectum making use of one pathway in the cord would be sufficient to supply information to medullary or higher centres to enable them to function adequately.

Following unilateral division of the tracts, the anal reflex is nearly always absent unilaterally on that side of the anus that is analgesic. In one case it was present.

When the afferent pathway from the rectum is divided unilaterally, pain is not felt on the side opposite to the incision. This is shown by the following two cases.

Mrs. S. (Case 25) had, due to a carcinoma of the cervix, a recto-vaginal fistula on the left side of the rectum. It caused most severe pain felt "just inside the rectum on the left side"; it was worse on defaecation. Unilateral lateral cordotomy caused complete analgesia on the left below the ninth thoracic dermatome. There was complete relief of this pain, and defaecation occurred painlessly. Permission to carry out a necropsy was refused by this patient's relatives, and so histological confirmation of the extent of the lesion and of degeneration of fibres could not be obtained.

Mrs. Ald. (Case 36) had, due to carcinoma of the cervix, a pain in the rectum. It consisted of a shoot of painful pins and needles, and it was so severe that she could not prevent herself crying; it was made worse by straining to defaecate or by passing motions. The rectum was found to be deformed and drawn over to the left; it was surrounded by hard, craggy growth about 3 to 4 inches above the anal canal; this had reduced the lumen so that it just admitted a finger. A cordotomy on the right side of the cord caused complete analgesia throughout the left side of the body below the tenth thoracic dermatome. All the pain was relieved, and instead of defaecating once a fortnight, she defaecated twice a day. Necropsy was also not obtained in this case.

With regard to the impulses giving rise to the desire to defaecate, a pathway on one side of the cord is usually adequate; after unilateral cordotomy the patient notices no loss or change in this sensation. In the following two patients, however, this was not so.

Mr. St. (Case 23) before the unilateral operation had a desire to defaecate when the pressure of the balloon reached 180 mm. Hg. After the operation he got the desire at the same pressure, but he noticed that he felt this sensation only on the side which was normally innervated. He was able to distinguish wind from faeces, and he felt and got discomfort from the fact that the rectum was constantly full of hard faeces.

Mr. Pe. (Case 33) before the unilateral operation had a desire to defaecate when the pressure of the balloon reached 180 mm. Hg. Three weeks after the operation he had no desire at a pressure of 200 mm. He felt, however, a pricking and a throbbing on the normally innervated side of the rectum.

This was confirmed on many later occasions.

There can be no question of the character of this sensation having been suggested to these patients, for the information which they spontaneously supplied was a greater surprise to the examiner than it was to the patients. A surgical colleague, who four years previously had had a unilateral cordotomy, was so kind as to give us the notes he made on his state and to allow us to examine him. He found that for the first few weeks after operation "the sensation of rectal fullness was dulled but not absent"; it eventually became normal.

One further disturbance of sensation sometimes occurs after the unilateral cordotomy, the sensation underlying the ability to distinguish wind from faeces. In four of these 20 patients, information on this subject was not available; of the other 16 three had lost this ability. As this symptom is liable to disappear eventually, it may be that with the sensory apparatus available to them, some patients relearn this skill. It may be that other patients had also had this symptom originally, and as they had regained the skill early, they had forgotten about it. The loss of this ability caused many accidents, even though these patients had voluntary control of the external sphincter and levatores ani.
Anal sensation after unilateral division of the relevant part of the spino-thalamic tract was as would have been expected: there was loss of pain and thermal sensation, with retention of the sensations of touch and tension.

It remains to consider the effect of unilateral spino-thalamic division on the sensation of the lower bowel above the rectum. Most patients having a unilateral lesion of the spino-thalamic tract have had no colic of the bowel following the operation; they have never mentioned any pain due to visceral events. Two excellent witnesses, however, provided evidence on the conduction of the pain of colic. Our surgical colleague mentioned above was emphatic that when he had colic associated with wind he felt this pain only on the right, that is to say that he felt nothing of it on the side opposite the incision made into the cord. Similarly the other patient (Case 25) who had a left-side cordotomy told us that she always noticed that after she took an aperient, when she got gripping pain, she felt it only on the left.

One is thus led to believe that the visceral pain of colic from the lower bowel is due to impulses passing in both spino-thalamic tracts, and that section of one tract causes this visceral pain to be felt unilaterally.

**HISTOLOGICAL EVIDENCE**

**Material and Methods of Investigation**

All 18 cases of bilateral and three cases of unilateral cordotomy were examined histologically.

Fixation of the spinal cord was initiated as soon after death as possible. In the majority of cases the cord was fixed in situ, 20% formol saline being injected into the cisterna magna; after a few hours the brain and the cord were removed and the necropsy was completed. Fixation of the brain and cord in 20% formol saline was continued for 10 to 18 days in the majority of cases, and up to four weeks in a few cases. The cord was then divided into anatomical segments and these were subdivided into a number of thin slices. Most of the slices were embedded in celloidin, and a few were used for frozen sections. The techniques mainly used were the Swank-Davenport modification of the Marchi method, the Kulchitsky modification of the Weigert Pal method, and the Gros silver method. Sections were also stained with thionin, haematoxylin and eosin, haematoxylin and van Gieson's stain, Mallory's phosphotungstic acid haematoxylin, Anderson's Victoria blue, and by Holzer's and Loyez' stains. Sections were taken at several levels of each segment; serial sections were cut throughout the area of operation and in any zone of special interest.

The possible criticism that the appearances of the area destroyed may be very different according to the various lengths of time between the making of the lesion and the patient's death has been considered. In early cases the lesion may be somewhat more extensive and less clearly delimited than in later cases; there are a few degenerating fibres scattered near the region, which, as far as can be assessed, have not been actually severed by the knife. These fibres run among normal fibres; they are far too few to have much functional significance. In these early cases in which survival was less than two months, the area of maximum, and presumably total, destruction can be determined by excluding the scattered fibres around the periphery of the degenerating area. In the later cases, it was thought at first that owing to the disappearance of degenerated myelin the area of destruction might appear unduly small, and that the appearance in a Marchi preparation would minimize the actual area of destruction. But comparison of the outlines of the degenerated area shown in Marchi, Weigert Pal, and Gros silver preparations, and sections stained by the other methods enumerated above, showed such consistent limits in all cases that it was obvious that the Marchi method was reliable also in later cases.

A further criticism could be that the tracts investigated might be composed entirely of small, thinly myelinated or unmyelinated fibres, and that such fibres would not be shown up by myelin stains. But the total area of destruction demonstrated in myelin preparations has been shown to have the same extent as that shown in preparations stained to demonstrate axis cylinders. It may be concluded that such small fibres, if they are relevant to the tracts under consideration, are intimately mingled with larger myelinated fibres, and so the picture of myelin degeneration due to staining of the large degenerating fibres covers the area of degeneration, whether the relevant fibres are large or small.

By comparison of the areas of degeneration at equivalent levels in all cases in group Ia the smallest common area of degeneration was determined. At the level of operation, where destruction is maximal, this common area contains all the relevant tracts. Confirmation of the boundaries of this common area is provided by the evidence of the other cases; they also permit one to make a tentative subdivision of this area. At levels other than that of the operation, the same method was applied for the determination of the position of the long tracts. It is possible that some of the tracts are in the form of intersegmental fibres; these would not necessarily be degenerated at a distance from the lesion, and would therefore be seen only at the operation level and at short distances from it.


Results

Photographs from representative cases are shown in Figs. 1 to 17. Of the 14 cases of Group Ia, only two showed any significant degeneration in the posterior columns. It is then clear that the tracts must lie within that area of degeneration common to all the cases. That means that they run somewhere in the lateral or antero-lateral columns, and not in the posterior columns or the grey matter.

Operation Level.—The operation area is the most important region for showing the position of the tracts, because any rectal function which persisted or recovered must have been subserved by fibres lying outside this large area of destruction.

The area of operation on the left side of the cord of Case 13 (Fig. 3) shows that the common area of degeneration cannot extend more posteriorly than the posterior boundary of this area. This is confirmed in Case 10 (Fig. 2), which actually suggests an even more anteriorly lying, posterior border to the common area but, owing to the involvement of peripheral nerves in this case, it cannot be accepted as incontrovertible evidence.

Case 7 (Fig. 1) shows on the left side that the pathways do not lie in the anterior column, as this is entirely free from degeneration, and the area of operation on the right side of Case 6 (Fig. 4) shows that the common area of degeneration cannot extend further anteriorly than in this case. The pathways must then lie somewhere in the area enclosed by these two boundaries. This area has the form of a narrow band extending from the periphery of the cord to approximately the lateral horn of the grey matter. A line joining this area on the one side of the cord to the same area on the other side passes through the central canal, dividing the cord antero-posteriorly (Fig. 18).

Further evidence confirming the location of the common area of degeneration containing all the fibres comes from Case 21 of Group II. In this case there was originally evidence of a partial lesion of the pathways, and a considerable amount of recovery later ensued. This suggests that fibres in the region adjacent to the degenerated area were temporarily rendered non-functioning, but that they later recovered. Thus, at least on one side of the cord, no permanent involvement of the tracts occurred. From the photograph (Fig. 5) it can be seen that on the left, at least, the common area escaped permanent damage.

In Cases 3 and 19, which form Group Ib, there was more recovery of voluntary control of the levatores ani muscles and the anal sphincter. The photographs of the operation area show a clearly marked and extensive destruction of the outer zone of the common area, with sparing of the more medial fibres (Figs. 7 and 8). It may be that the recovery of some slight degree of control over the external sphincter and levatores ani is due to the survival of some fibres in the neighbourhood of the operation.

In Case 22, no evidence on the function of defaecation could be obtained, as this patient had had a colostomy, but there was some relief of pain in the rectum and anus. The areas of operation are shown in Fig. 6. On the left side it is improbable that the common area of degeneration was damaged, but on the right side the outer zone of the common area was involved in the operation lesion.

Afferent and Efferent Fibres.—The photographs of upper cervical segments (Fig. 11–13) show the distribution of the afferent degenerating fibres at some distance cranial to the lesion. The photographs show a band of degeneration on the periphery of the cord, the most anterior part being common to all the cases. This common area extends approximately from the antero-lateral fissure to just posterior to the dorso-lateral process of the anterior horn. This area is large, as it includes many ascending fibres of different systems. In the thoracic level it has been determined that the tracts lie approximately opposite the central canal. As it is most probable that the tracts do not markedly change their position at different levels of the cord, it may then be deduced that the tracts lie approximately opposite the dorso-lateral process of the anterior horn at the cervical level. This zone is in the most posterior part of the common area of degeneration (Fig. 19).

Photographs of the upper lumbar segments (Figs. 14 to 17) show the distribution of the efferent degenerating fibres at some distance caudal to the lesion. In Figs. 14, 15, and 16, slight degeneration can be seen in the anterior columns. This may be ignored, for it has been shown that throughout the thoracic region the tracts lie in the lateral columns, and it is this region of degeneration which continues down the cord into the lumbar segments. In addition, the anterior degeneration is not found in all the cases bilaterally; there is, for example, no degeneration in the left anterior column of Fig. 14. In all the cases there is a band-like area of degeneration on each side of the cord, which is shown most clearly in Fig. 16, although in this case the degeneration is more extensive than in most of the others. The appearance on the right side of Fig. 15 probably indicates more accurately the zone of degeneration containing the long descending fibres.
All photographs are of transverse sections of the spinal cord (× 7). In all figures, except Figs. 8 and 16, the photographs are of Marchi preparations, in which the degenerating fibres are stained black. Figs. 8 and 16 are from Weigert Pal preparations, in which the degenerating fibres are unstained.

Figs. 1 to 10 show the maximum area destroyed by operation on one or on both sides; Figs. 11, 12, and 13 show the ascending, and Figs. 14 to 17 show the descending, degeneration.
SPINAL PATHWAYS SUBSERVING DEFAECATION

**Fig. 9.** (Case 35) C. 3

**Fig. 10.** (Case 20) C. 3

**Fig. 11.** (Case 6) C. 4

**Fig. 12.** (Case 1) C. 4

**Fig. 13.** (Case 10) C. 4

**Fig. 14.** (Case 7) L. 3

**Fig. 15.** (Case 13) L. 3

**Fig. 16.** (Case 5) L. 2

**Fig. 17.** (Case 35) L. 2–3
The area within which these fibres runs is in the form of a narrow band lying on a line passing through the central canal, bisecting the cord in an antero-posterior direction (Fig. 20).

It is of interest to note that the operations performed fairly anteriorly in the cervical region, as in Cases 35 and 20 (Figs. 9 and 10) caused the same zone of degeneration in the lumbar region (Fig. 17).

In view of the findings in Cases 3 and 19, in which clinically there was some recovery of voluntary control of the levatores ani and anal sphincter but no recovery of rectal sensation, and in which histologically there was a sparing of some medially lying fibres in the common area, it is tentatively suggested that the efferent fibres lie medial to the afferent.

Conclusions

In the thoracic region, the afferent pathway from the rectum, including the pathways conducting impulses subserving pain from the rectum and anus, the efferent pathway used in controlling defaecation, and the pathways concerned in coordinating the reflex function of defaecation, run within a narrow band extending from the periphery of the cord to approximately the lateral horn of the grey matter. A line joining this area on one side of the cord to the same area on the other side passes through the central canal. Evidence suggests that the lateral part of this band is mainly afferent, and the more medial part mainly efferent (Fig. 18).

In the cervical region the afferent pathways lie near the surface of the cord, approximately opposite the dorso-lateral process of the anterior horn (Fig. 19). It is probable that the efferent fibres lie medial to the afferent in the same plane.

In the lumbar region the efferent pathway lies somewhere in a narrow band on a line passing through the central canal, bisecting the cord in an antero-posterior direction (Fig. 20).

DISCUSSION

The question whether the efferent tract mediating the voluntary control of defaecation forms a part of the classical cortico-spinal tract obviously needs to be answered. We have not yet been able to provide an answer. It is our intention to consider this question together with the similar question related to the voluntary control of micturition in a later communication.

With regard to the disturbance of defaecation following the unilateral operation, it should perhaps have been expected that it would occur following division of the tracts subserving the automatic functioning and voluntary control of defaecation on one side of the cord. For, whether the descending tracts activate motor cells of one or both sides of the cord, and whether the efferent nerves supply one side or both sides of the viscus, the behaviour of the viscus is controlled by the impulses it receives from all its nerves; being a tube, it behaves as a whole in response to the totality of impulses received. It might therefore be expected that when half of its normal supply of impulses is cut off, the rectum might not function normally. It is likely to be immaterial whether the quantity of these impulses to the whole of the tube has been diminished, or whether the impulses have been cut off totally from one side of the tube.
From the unilateral cases, it was learnt that the levatores ani and the external sphincter are bilaterally supplied from each side of the cord. When one considers the great importance of the levator ani—in forming the inferior wall of the abdominal cavity, in keeping the bladder and uterus in position, and in aiding micturition and defaecation—one understands how useful this bilateral supply must be.

The permanent absence of the anal reflex following lateral cordotomy may be associated with the depression or abolition of other superficial reflexes which usually follows this operation, for in the syndrome of total cord transection this reflex is among the first to return.

The alegic pathway from the large bowel has been shown to lie in the lateral column of the cord. Thus in man this pathway runs within the region where it was found in the cat by Spiegel and Bernis (1925). Thus, combining this work with that reported previously, we have shown that the alegic pathway for the lower ends of the ureters, for the bladder, for the urethra, for the rectum and the large bowel, is in the lateral columns in the spino-thalamic tract.

It can be concluded from the evidence provided by the two intelligent observers mentioned above that division of this pathway from the lower bowel results in the pain of colic being felt unilaterally. This is surprising, seeing that the gut is a midline structure. It is known, however, since the work of Bentley and Smithwick (1940) that the pain due to distending the jejunum in man is felt unilaterally after the peripheral pathway of one side has been divided. Although one might not have expected that the division of one spino-thalamic tract would have resulted in visceral pain being felt unilaterally, this is nevertheless analogous to that which Woodworth and Sherrington (1904) found in the cat. From their observations on cats in which they had performed hemisections of the cord, they concluded that the pathway for the conduction of impulses subserving pain from the soma was both crossed and uncrossed, but mainly crossed, and they found that the pathway from the viscera had the same arrangement. In man, as the pathway for conduction of pain from the soma is entirely crossed, it would be analogous to find the pathway from the viscera to be entirely crossed also.

In our previous paper (Nathan and Smith, 1950) on the afferent pathways from the bladder, five cases were reported in which the sensation underlying the desire to micturate was felt only on one side after unilateral division of the lateral column. In one case (Case 23) this was a permanent state, in the others it was transient. It will be noted that the subject of Case 23 had also a unilateral sensation underlying the desire to defaecate. Another patient (Case 35) following the unilateral division of the lateral column had an abnormal sensation underlying the desire to defaecate, and this was felt only unilaterally, yet he experienced a normal sensation underlying the desire to micturate. In the case of our surgical colleague, Case 26, there was, as mentioned, a dulling of the sensation of rectal fullness, and definite loss of sensation on one side when the bladder was over-distended.

It is perhaps possible that the afferent pathway from the rectum and the bladder passes up both sides of the cord, and that the extent to which this occurs varies not only from person to person, but also from viscus to viscus. In the unusual cases mentioned in this and our previous paper, it could be that the amount of bilateral conduction is minimal, and so division of one lateral column may in some cases result in division of the total afferent pathway from the opposite half of the viscus.

From the fact that the patients who had a bilateral lesion of the spino-thalamic tract and who are left with anal but not rectal sensation are nearly always unable to distinguish wind from faeces, it may be concluded that the ability to distinguish these substances depends on rectal sensation. Indeed this is obvious, for the normal person does not usually allow these substances to penetrate the anal sphincter before he decides with which substance he has to deal.

**SOME CLINICAL APPLICATIONS**

The knowledge of the location within the human spinal cord of the tracts concerned with defaecation has implications for clinical medicine. Certain selected implications are considered here.

**Defaecation with Spinal Pathways Bilaterally**

**Interrupted**

Although the rectum may be found by the examiner to be full of hard faeces, the patient may be unaware of this. The patient is likely to complain of severe constipation, and if he has an attack of diarrhoea, he will then report that he has no or very little control over the sphincter. He will know when faeces are passing and he knows when they are just about to pass, but he will be unable to distinguish wind from faeces. The examiner will find the sphincter closed, and its tone will be within the limits of the normal. The anal reflex will be absent.

A bilateral cordotomy which renders the sacral segments of the body permanently analgesic
divides the tracts to and from the higher rectal centre. Thus a part of the price that the patient has to pay to get relief of pain in these segments is to be left with the kind of defaecation described above.

A Unilateral Lesion of the Lateral Column

From the foregoing, it will be gathered that a unilateral lesion of the lateral column may cause no symptoms of lower bowel dysfunction; the only abnormal sign may be the absence of the anal reflex on the side opposite to the lesion. This sign of a lesion of the lateral column, however, is of little value, for, on the one hand this reflex may be absent bilaterally without pathological significance, and on the other hand its pathological absence is associated with marked diminution or absence of the sensation of pain in the lowest sacral segments, a more obvious sign of equal localizing value.

When a patient complains of severe constipation of the dyschezic type, and/or an inability to distinguish wind from faeces, and/or some urgency of defaecation when he has diarrhoea, one requires the answer to the question whether (assuming that the lesion is in the spinal cord) the lesion is bilateral or unilateral. The answer is that the lesion is likely to be bilateral, but that it may well be unilateral. If the patient has good voluntary power in the external sphincter and levatores ani, the lesion is unilateral; if he cannot contract these muscles without adducting his thighs and straining, it is bilateral.

SUMMARY

The location within the human spinal cord of the tracts subserving defaecation is determined. The tracts run within a narrow band extending from the periphery of the cord to approximately the lateral horn of the grey matter. The evidence suggests that the lateral part of this band is mainly afferent, and the more medial part is mainly efferent.

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Patients 6, 11, 13, 19, 24, 25, 27, 31, 32, 33, 34, and 36 were in the National Hospital; their case numbers were respectively 18299, 23011, 12166, 12168, 30790, 26668, 16148, 28848, 29786, 30036, 32673, and 31747.

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