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THORACO-LUMBAR DISK PROTRUSION WITH SEVERE CORD COMPRESSION IN THE DOG

III. TREATMENT BY DECOMPRESSIVE LAMINECTOMY

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Part I of this paper was a study of the rate of development of the symptoms of motor loss in thoraco-lumbar disk protrusion with severe compression of the spinal cord. Part II dealt with the prognosis in conservative treatment of the same disease. These two investigations showed that the symptoms caused by spinal cord compression, in most cases developed slowly enough such that chances for a surgical decompression were possible before the damage to the spinal cord was irreversible. In addition, the results in conventional conservative treatment seemed to indicate trials with a more active therapy. The studies to be described in this paper were undertaken to test the therapeutic value of decompressive laminectomy in disk protrusions with severe symptoms of cord compression. The main purpose of the investigation was to study the effect of laminectomy as such; removal of disk masses which had not been exposed directly by the laminectomy was performed only in a very limited number of cases. Attempts were made to make the operation so radical that the increase of pressure which was caused by secondary changes in the epidural space and/or in the spinal cord could also be eliminated. Because of this the laminectomy was frequently of a considerable extension.

The laminectomies were performed according to two different methods which will be described as A and B. Because of circum-

stances which will be discussed later, the main part of the paper has been devoted to laminectomy according to B, while the results of the operation according to A have been treated only summarily.

MATERIAL AND METHODS

The material includes a total of 69 animals (67 dachshunds, 1 "dachsbrache", 1 cocker spaniel) with the clinical diagnosis of disk protrusion. Thirty-six of the animals were operated upon according to "A" and 33 according to "B". All animals had symptoms of motor loss to such a degree that they were unable to walk on their hind legs. The age and sex distribution of the operated animals was not significantly different from the total group (Fig. 1, Part I).

The animals were subjected to a simple neurological examination as described in Part II of this work. On the basis of the neurological examination the material was divided into three groups (I—III) according to the principles given on page 320 in Part II.

The radiological examination included plain films (lateral and frontal exposures), and myelography according to a technique described in a previous paper (*Funkquist* 1962 b). At the myelographic examinations of those animals operated upon according to B (myelography performed in 32 of the 33 cases), it was possible in 28 cases to obtain myelograms of such a quality that the posterior as well as the anterior limits of the compression of the subarachnoid space could be defined. In 2 cases the myelograms revealed only the posterior limit of the compression because of partial epidural injection. In the remaining 2 cases the main part of the contrast medium was deposited epidurally. In all cases where myelography was completely successful, a good agreement was found between the extent of the myelographic changes and the extent of the changes in the epidural space which were observed at the operation. A more detailed study concerning the reliability of the myelographic examination has been given in the previous paper mentioned above (*Funkquist* 1962b). In the 2 cases where useful myelograms were not obtained and in the case where myelography was not performed, the operation (according to B) was performed with the guidance of the findings from ordinary roentgenograms with lateral beam. The radiographic changes of the disks, which in the latter 3 ca-

ses were the basis for judging the location of the disk protrusion, were as follows:

Calcified protrusion in the spinal canal in 2 cases.
Narrowing without calcification of the disk in 1 case.

At the subsequent operation the suspected disk in all 3 cases was within the compressed area.

The time interval from the animals' loss of hind leg locomotion to the operation time varied between 2 hours and 5 days in Group A. In Group B the corresponding interval varied between 2 hours and 2 days. A more detailed presentation of this interval in the latter material is given in Diagram a. Most of the animals (31 of 33 dogs) were operated upon within 24 hours after loss of their ability to walk.

The decompressive laminectomy was performed in all cases in direct connection with the myelography, as mentioned earlier. The two different operative methods according to which the operation was performed have been described in detail in an earlier publication (*Funkquist* and *Schantz* 1962). In the operation according to technique A, the dorsal surface of the dura was exposed by excising the vertebral arch including the articular processes down to a level below the dorsal tangent of the spinal cord's cross-section (Fig. 1). In 14 of the animals operated upon according to technique A, attempts were made to reconstruct the roof of the vertebral canal by transplantation of autogenous bone chips (*Funkquist* and *Schantz* 1962). The lumbo-dorsal fascia was sutured in 29 of the 36 cases (in 10 cases after transplantation of bone chips) while in 7 cases the fascial defect was left open. In the latter cases the wound cavity was filled with fibrin foam (Spongostan ®). In operations according to technique B the dorso-lateral portions of the vertebral arch were hollowed out from above (Fig. 2). By this method it was possible to expose the dorsal surface of the dura while sparing the outer compact bone of the dorso-lateral portion of the arch and the outer (and parts of the inner) articular processes. (In 2 cases, to be described in detail below, the laminectomy opening performed initially according to B was widened laterally within a limited region to make the ventral epidural space more accessible). The lumbo-dorsal fascia was not sutured in the operations according to technique B and attempts were not made to reconstruct the roof of the spinal canal.

"Fenestration" (*Olsson* 1951) and evacuation of 1—2 calcified disks situated *within* the laminectomized region was performed in 5 dogs immediately after laminectomy (according to B). Further, evacuation of one disk situated *outside* the region of laminectomy was performed in one of these 5 animals and, in addition, in another animal showing no disk calcification within the laminectomized region.

In the laminectomies attempts were made to remove the roof of the spinal canal to such an extent that normal conditions existed in the epidural space at both cranial and caudal limits of the laminectomy opening. The condition in the epidural space was judged as normal if no disk masses were observed and if epidural fat could be observed between the dorsal surface of the dura and the roof of the vertebral canal. The extent of the laminectomy in the operations performed according to technique A varied between 2 and 6½ vertebrae, and in the operations according to technique B between 2 and 6 vertebrae. In the animals operated according to the latter technique, the laminectomy extended over 2 vertebrae in 9 cases, 3—4 vertebrae in 20 cases, and 5—6 vertebrae in 4 cases.

Only the animals operated upon according to B will be described with respect to the findings at operation. In 11 cases the changes had the character of a limited dorsal elevation of the spinal cord (presumably disk protrusion of type 1 according to the nomenclature in Part I). The elevation of the spinal cord was located over disk T9/T10 in 1 case, T12/T13 in 3 cases, T13/L1 in 4 cases, L1/L2 in 2 cases,and over L4/L5 in 1 case. In 22 cases disk masses were observed which were spread out diffusely, some of these animals showing, in addition, a distinct elevation of the spinal cord (disk protrusion of type 2 and 3). The disk masses in the latter cases extended over a region of the epidural space comprising one or more vertebrae (maximally 5 vertebrae). In 4 cases the disk masses were located in the posterior thoracic region, in 13 cases in the posterior thoracic and anterior lumbar region, and in 5 cases in the lumbar region.

The protruded disk masses were as a rule removed only when easily accessible through the laminectomy opening, that is, if they were located laterally or dorsally to the spinal cord. However, in 3 animals, that showed a pronounced dorsal elevation of the spinal cord, after removal of the roof of the spinal canal according to B, attempts were additionally made to remove the

disk protrusion by extradural approach after lateral displacement of the cord and the spinal meninges. In 2 of these cases the laminectomy opening in the region of the protruded disk was enlarged, as mentioned above, in a lateral and ventral direction towards the side where the main part of the disk protrusion was located. The laminectomy opening was thus made confluent with the intervertebral foramen over the current disk.

The postoperative treatment of the animals (Groups A and B) was in accordance with the routine treatment at the clinic. During periods when the animals refused to eat, this treatment usually included intravenous or subcutaneous injections of Aminosol-Glucose ® (Vitrum) and/or Ringer's solution in such doses that the total volume of fluid amounted to about 20 ml per kg body weight and day. The degree of filling of the urinary bladder was controlled daily. The bladder was emptied by manual compression when necessary. If hemorrhagic cystitis occurred, it was treated with antibiotics. The neurological status of the animals was as a rule controlled daily during their stay at the clinic (2—3 weeks after the operation as a rule). Special attention was paid to the occurrence of voluntary motor activity and pain sensitivity.

The follow-up of the animals operated upon according to technique A usually consisted of a telephone interview with the owner; only in 6 cases were the animals subjected to professional examination.

The follow-up examination of the animals operated upon according to technique B was performed at the clinic in 16 cases and by the veterinary surgeon in the owner's place of residence in 2 cases. In the remaining 9 cases the follow-up was restricted to questioning the owner by telephone. The follow-up was performed for the most part in the way described in Part II, attention being paid mainly to the motor functions of the animals.

The observation period varied between 7 and 39 days for those animals which were sacrificed because of an unsatisfactory postoperative course of the disease. In the majority of the cases the time of observation was longer than 2 weeks. In all these animals there was complete absence of voluntary movements and pain sensitivity of the hind legs. The length of the observation time for the improved or completely recovered animals is given under the heading of "Results".

The animals that died in connection with the operation or that died or were sacrificed for various reasons at a later time (a total of 16 in Group A and 7 in Group B) were subjected to patho-anatomic examination as follows. Complete autopsy was performed in 2 animals belonging to Group B. In addition, patho-anatomic examination restricted to the vertebral column and the spinal cord and its meninges was performed in all the 16 A animals and in 5 of the B animals. The patho-anatomic examination in part of the animals (10 belonging to Group A and 2 belonging to Group B) consisted of removal of the vertebral arches, inspection of the epidural space, and macroscopic and histologic examination of the spinal cord and its meninges. The remaining animals (6 belonging to Group A and 5 belonging to Group B) were fixed by intra-arterial injection of 10 per cent formalin, after which transverse sections of the frozen vertebral column with the spinal cord *in situ* were made in the way described in a previous paper (*Funkquist* and *Schantz* 1962).

RESULTS

Operation according to technique A.

Two of the 36 animals died 9 and 11 days respectively after operation, showing signs of hemorrhagic cystitis. A third animal died after 25 days, the main clinical sign being cachexia of uncertain origin.

The results of the laminectomies according to technique A are given in Table 1. As is shown by the table, 9 of the animals in Group I (11 animals in the group) regained their ability to walk while a complete restitution was observed in 6 of these animals. The corresponding figures for Group II are 7/20 and 3/20 and for Group III 3/5 and 1/5.

For the 9 animals which regained their ability to walk, but at the time of the follow-up still showed some disturbances in their movements, the time of observation varied between 1 and 28 months. For 2 of these animals this period was more than 1 year. The 10 animals that completely recovered were observed for 16—33 months.

Following a temporary postoperative improvement aggravation of the symptoms of motor loss was observed in 7 animals. According to the clinical course and/or the results of the X-ray investigation the aggravation in these cases was probably not

Table 1.
Results of operation according to "A".

Degree of motor loss at the time of operation (for definition see text page 345)	Total number of animals	Final outcome of the current attack			Occurrence of impairment of motor function probably not referable to recurrence		Recurrence
		Normal movements	Ability to walk but remaining disturbance of movements	Dead or killed because of impairment of motor function or absence of improvement	Within 1 week	After 2—4 weeks	
Group I	11	6	3	2	3	1	2
Group II	20	3	4	13	1	2	2
Group III	5	1	2	2			2
Total	36	10	9	17	4	3	6

caused by recurrence of the disk protrusion. The distribution of this complication within the time of observation is given in Table 1. In 2 of the 7 animals, which had shown signs of impairment during the first week after operation, the wound was opened down to the dura, after which the skin only was resutured. In both these animals a considerable improvement was observed with respect to the voluntary motor activity 1 and 2 days respectively after reoperation. One of these animals recovered completely. The other regained the ability to walk but showed remaining unsteadiness. The remaining 5 dogs were destroyed 10—39 days after operation because of lasting impairment.

Impairment that was presumably caused by recurrence of disk protrusion (according to the clinical course and/or the findings at the X-ray investigation) was observed in 6 of the "A" animals; in 4 cases the recurrences had the character of weak pain attacks while in 2 cases paralysis occurred 10 weeks and 12 months respectively after the operation. The last-mentioned 2 animals were sacrificed because of the recurrence.

Patho-anatomic examination. That part of the material which was subjected to patho-anatomic examination comprises, *inter alia,* 11 animals that were destroyed because of absence of improvement and occurrence of post-operative impairment that was probably not caused by recurrence (*cf.* above). Further patho-anatomic examination was performed in 3 animals that had regained the ability to walk but were destroyed because of remaining disturbance of movements and finally in 2 animals that were

destroyed because of recurrence. In 8 of the 11 animals in the group first mentioned, the examination revealed a sharply limited disk protrusion (type 1 according to the definition in Part I) while in the other 3 cases of this group there were only small amounts of disk substance that did not encroach considerably on the space of the spinal canal (disk substance situated dorsally or laterally to the spinal cord has been removed at the operation). The last-mentioned type of changes was found also in those 3 animals which were killed after having regained the ability to walk. In the both animals with recurrence, finally, there was a new disk protrusion situated within the region of laminectomy.

The histopathology of the spinal cord (studied in 10 cases) did not diverge principally from the changes that may be found in animals that have been treated conservatively (*cf. Funkquist* 1962b).

In those (6 of the above-mentioned 16 cases) cases, where the patho-anatomic examination included preparing of frozen transverse sections with the spinal cord *in situ*, a varying degree of dorso-ventral flattening of the spinal cord was always seen. The changes were in good agreement with those which have been described in a previous experimental study (Fig. 5). In one of the cases investigated, (showing postoperative impairment that was probably not caused by a new prolapse of disk substance) the spinal cord was elevated by a large disk protrusion. The flattening of the spinal cord was here so strong that the cross-section of the cord appeared like a thin plate situated dorsally to the disk protrusion (Fig. 3).

Operation according to technique B.

Of the 33 animals operated upon according to technique B, 2 animals died during or immediately after the operation (presumably due to a technical misadventure in connection with the anaesthesia). Three animals died in the postoperative period after 1, 2 and 5 days respectively. The last-mentioned animal had shown a rapid recovery of the motor functions during the first 4 days after operation. In 2 of the above-mentioned 3 animals that died during the first part of the postoperative period, autopsy was not allowed, the dominating clinical symptom were respiratory embarrassment and signs of wound infection, respectively; in the third dog showing clinically indeterminate systemic disturbance, autopsy disclosed signs of diabetes melli-

Table 2.

Results of operation according to "B", related to the degree of motor loss at the time of operation and to the time of development of these symptoms.

Degree of motor loss at the time of operation (for definition see text page 345)	Time of development of symptoms of motor loss (until inability to walk)	Total number of animals	Final outcome of the current attack				Remaining kyphosis	Recurrence
			Normal movements	Ability to walk but remaining disturbance of movements	Dead in connection with operation	Killed because of absence of improvement		
Group I	Unknown but < 12 hours	1	1					1
	Instantaneous or < 15 min	3	2	1				
	90 min— 12 hours	2	1		1			
	12—24 hours	3	1	1	1			
	2—5 days	4	4					
	> 7 days	3	3					2
Total		16	12	2	2			3
Group II	Unknown but < 12 hours	3	2		1			
	Instantaneous or < 15 min	1		1				
	90 min— 12 hours	3	2			1		1
	12—24 hours	2	2					1
	2—5 days	4	3		1[1]		1	1
	> 7 days	1	1					
Total		14	10	1	2	1	1	3
Group III	Unknown but < 12 hours	2	1	1				
	Instantaneous or < 15 min							
	90 min							
	12 hours	1			1			
	12—24 hours							
	2—5 days							
	> 7 days							
Total		3	1	1	1			

[1]) Died on the 5th postoperative day having previously regained voluntary movements of the hindlegs.

tus. Of the surviving 28 animals 1 was sacrificed 17 days after operation without signs of motor or sensory recovery. The remaining 27 animals regained their ability to walk and 23 of the animals regained normal movements during the time of observation. In the other 4 animals, slight disturbances of movements were still present at the follow-up examinations held 3, 7, 9 and 11 months respectively after operation.

A detailed description of the results of the treatment related to the animals' status immediately before the operation and to the speed of development of the symptoms is given in Table 2. The postoperative course and the length of the observation time for the animals that survived the operation and the first postoperative period are given in Diagram a. In this diagram the animals have been arranged firstly according to their preoperative status and secondly according to the length of the interval between the onset of paralysis and the time of operation. Table 3 is a separate account of the animals operated upon within 12 hours after the onset of paralysis. The same table includes for comparison the results of the conservative treatment of animals admitted for examination within 12 hours after the onset of paralysis. Concerning the two groups it should be pointed out, that 10 of the operated animals showed progression of the symptoms of cord compression during the 6 to 12 hours during which the animals were observed at the clinic before operation; the animals treated conservatively did not show any aggravation of the symptoms during the first 12 hours of their stay at the clinic.

The return of voluntary motor activity generally occurred in the operated animals in the same manner as has been described for those treated conservatively (Diagram a). In the animals completely paralysed before operation, the latest time for the appearance of the first signs of voluntary motor activity was the 3rd postoperative day. In 6 of the animals, 4 of which showed a complete motor paralysis and 2 of which showed complete motor and sensory paralysis before the operation, improvement occurred immediately after the awakening from anaesthesia. This improvement was manifested by returning voluntary motor activity and pain sensitivity.

Aggravation of the symptoms of motor loss (after a temporary improvement) after operation was observed in 3 animals (nos. 1, 11, and 18 in Diagram a). In these cases the operation included removal of a sharply limited disk protrusion (type 1)

Table 3.

Comparison between surgical (operation according to "B") and conservative treatment in animals operated upon and brought to the clinic respectively within 12 hours after onset of paralysis (loss of ability to walk).

Degree of motor loss at the beginning of treatment (for definition see text page 345)		Total number of animals	Final outcome of the current attack				Occurrence of signs of ascending paralysis in the animals recorded in the previous column	Occurrence of impairment of motor function later than 12 hours after admission
			Normal movements	Ability to walk but remaining disturbance of movements	Dead during operation or during the first postoperative period	Dead as a result of the cord injury or killed because of impairment of motor function or absence of improvement		
Group I	Surgery	12	9	2	1			
	Conservative treatment	10	4	4		2		5
Group II	Surgery	4	3		1[1])			
	Conservative treatment	9	3	3		3	2	2
Group III	Surgery	2	1	1				
	Conservative treatment	5				5	5	5

[1]) Died on the 5th postoperative day having previously regained voluntary movements of the hind legs.

located ventrally to the cord. In one of these animals (no. 11, where attempts were made to remove the disk protrusion without widening of the laminectomy opening) the wound was opened 5 days after the first operation. In this case it was evident that disk substance had been forced into the epidural space subsequent to the first operation. The condition improved immediately after reoperation; pain sensitivity returned after 1 day and voluntary motor activity after still another day. The animal regained the ability to walk but at the end of the time of observation (11 months after the operation) it still retained a slight unsteadiness of movement. The remaining 2 animals (where the disk protrusion was removed at operation after widening of the laminectomy opening) recovered completely.

Four of the animals (nos. 1, 10, 14 and 18) had developed

their preoperative symptoms of motor loss over an exceptionally long time, (more than 1 week before they were unable to walk). Two of these animals (nos. 1 and 18) belonged to the above-mentioned group where attempts were made at the operation to remove the disk protrusion (resulting in recovery). The 2 other animals (nos. 10 and 14) in the group with the slow progression also recovered completely. According to the findings at operation, three of the animals with slow development may have belonged to type 1 and the 4th to type 2.

Symptoms of recurrence were observed in 6 dogs that previously had regained their normal ability to walk (Table 2). Five of the 6 recurrences occurred in the period between 3 and 6 months after the operation (Diagram a). Three of the recurrences, all at about 4½ months after the operation, had the character of an acute paraplegia which in 2 cases (nos. 1 and 21) warranted the sacrificing of the animals. The third animal (no. 10) regained the ability to walk but still retained unsteadiness of movements 14 weeks after the onset of recurrence. In the remaining 3 cases the recurrence had the character of pain attacks combined with slight paresis. One of these dogs (no. 23) recovered after fenestration and evacuation of the disk which was suspected of causing the symptoms. The 2 remaining dogs (nos. 6 and 24) recovered after conservative treatment.

In the 6 animals with recurrence, the extent of laminectomy was as follows: 8th—13th thoracic vertebrae in 1 case, 13th thoracic and 1st lumbar (including partial laminectomy on the 12th thoracic and 2nd lumbar) vertebrae in 4 cases, and finally, the 13th thoracic — 3rd lumbar vertebrae in 1 case.

In all 6 animals the radiograms taken after appearance of the relapse, when compared with the radiograms taken at the first attack, gave certain criteria (narrowing of the intervertebral space and/or disappearing of calcified material from the disk) for localization of the disk responsible for the new symptoms. The suspected disk was situated in 1 case within the laminectomized region; in 4 cases it was situated just outside this region at the cranial (3) or caudal (1) end. Finally, in 1 case the suspected disk was situated 2 vertebrae behind the caudal end of the laminectomy region. (In 2 of the animals where the X-ray examination suggested one of the disks at the end of the laminectomized region was responsible for the relapse, autopsy was performed with confirmation of the X-ray findings).

Patho-anatomic examination of the spinal canal was performed in 4 animals which died at or within 5 days after operation and in 3 animals sacrificed after 17 days (1 animal without signs of improvement) and 18 weeks (2 animals with recurrence) respectively. In the first mentioned 4 animals the macroscopic examination did not reveal any important facts beyond the changes observed at the X-ray examination and at the operation. In the unimproved animal sacrificed after 17 days the patho-anatomic investigation showed small amounts of disk substance spread out diffusely in the ventral epidural space of the laminectomized region. In the two animals that had shown signs of recurrence the examination confirmed the suspicion based on the findings at the X-ray investigation (*cf.* above) that disks situated at the ends of the laminectomized region were responsible for the recurrence (disk herniation of type 1 and 3 respectively). In none of these cases were there signs of dorso-ventral cord compression that could be ascribed to the process of healing of the operation wound (Fig. 4) (*cf. Funkquist* and *Schantz* 1962).

DISCUSSION

Operation according to A.

Both of the operative techniques (A and B) employed in the clinical studies were also used contemporaneously in an experimental study concerning the effect of the healing process on the space in the spinal canal. These experimental studies showed that an extensive laminectomy comprising several vertebrae at the junction between the thoracic and lumbar region involves a considerable risk of compressing the spinal cord when performed according to technique A. This compression seems to be brought about by shrinkage of the granulation tissue which fills out the laminectomy defect during the first phase of healing. The clinical trials with laminectomies performed according to technique A have shown good agreement with the experimental studies. Firstly, several animals have shown symptoms of spinal cord compression during the healing process that were probably not caused by recurrences. Secondly, the patho-anatomic control of the clinical cases with postoperative impairment of motor functions has shown the same type of dorso-ventral compression of the spinal cord as has been observed in the experimental stu-

dies (Figs. 3 and 5). Thus it appears that laminectomy performed according to technique A is not a suitable method to test the therapeutic value of decompression in disk protrusion.

Operation according to B.

Subsequent to laminectomy performed according to technique B (which as is shown in the experimental work mentioned above involves less risk of secondary compression of the spinal cord, Fig. 6) 27/33 (81.8 per cent) of the operated animals regained their ability to walk (with or without remaining disturbance of movements). The corresponding percentages for the animals treated conservatively at the clinics in Hälsingborg, Skara and Stockholm (Part II) have been 45.7, 47.2 and 36.9 per cent. Further it seems worthy of mentioning that of the animals operated according to technique B, 23/33 (69.7 per cent) regained complete normal movements; the corresponding percentage for the animals treated conservatively in the Stockholm clinic was 14.2 per cent. It cannot be precluded, however, that the last-mentioned figure may have increased if the time of observation had been prolonged. With a sufficient observation time the figure might thus be raised to 30 per cent at the best according to discussion in part II of this paper.

There is reason to believe that a faulty technique of anaesthesia contributed greatly to the outcome for at least 3 of the 5 animals that died during or after operation; the main part of the anaesthesias was performed without the cooperation of a trained anaesthetist. With regard to a possible future reduction of the operation mortality, it seems worth while to point out that of the 28 animals surviving the operation and first 5 postoperative days, 27 regained their ability to walk. In this connection it should be mentioned too, that the remaining animal (killed after 17 days of observation without signs of recovering) was operated upon as late as 24 hours after the onset of a complete motor and sensory paralysis that had developed very rapidly.

For the most part, the animals operated upon belonged to Groups I and II. If one compares these groups of animals with corresponding groups of Stockholm animals treated conservatively, one will find the following: The percentage of operated animals which regained the ability to walk with or without disturbance of movements) is 87.5 per cent (14/16 animals) in Group I, and 78.6 per cent (11/14 animals) in Group II. The

corresponding figures for the conservatively treated animals are 81.8 per cent (27/33 animals) and 39.1 per cent (25/64 animals). If, on the other hand, the number of animals which recovered completely is taken into consideration, one will find that in Groups I and II of the operated material the percentage has been 75.0 per cent (12/16 animals) and 71.4 per cent (10/14 animals) respectively; the corresponding figures for the conservatively treated animals are 33.3 per cent (11/33 animals) and 14.1 per cent (9/64 animals). With a longer observation time there may have occurred, however, some increase in these latter figures (See discussion in Part II).

When considering the value of the above-mentioned comparison between the animals operated upon and those treated conservatively, the following should be pointed out:

1. The animals treated conservatively had their first examination at different times counted from the onset of paralysis. Because of this, part of the animals at the maximum of the attack could have had a worse neurological status than is indicated in the table.
2. The material treated conservatively may comprise a larger number of animals in which the compression developed rapidly. Thus there may have been little possibility of performing decompressive treatment before the damage to the spinal cord was irreversible.
3. The selection of animals in Group I for the various types of treatment was not performed at random. To a considerable extent, those cases that had shown progress of the symptoms of motor loss during the first hours of the stay at the clinic were selected for surgical treatment.

Nos. 1 and 2 of these possible sources of error may have given a too favourable picture of the value of the operation while no. 3 may have contributed to make the figures of recovery too high for those animals which were treated conservatively.

To reduce the effect of factor no. 1, a comparison has been made in Table 3 between animals in the conservatively treated group which were examined within 12 hours after the onset of paralysis (after they had lost their ability to walk) and those surgically treated animals which were operated upon within the same time. The group of operated cases (18) includes 2 animals

which died during operation and on the 5th postoperative day respectively; the latter had previously shown good postoperative improvement of motor functions. The table shows that the 16 surviving operated animals regained their ability to walk; 13 recovered completely. In the conservatively treated group, 14 of the observed 24 animals regained their ability to walk and 7 (of these 14 animals) have recovered completely. Prolongation of the observation time may have increased — at the best — the last-mentioned figure to about 9 according to the discussion in Part II of this paper. One should also consider that all the animals treated conservatively during the first 12 hours after admission had shown stationary symptoms, while 10 of the 18 operated animals had shown obvious progress of the symptoms during the hours just before the operation.

One can investigate material that is not to any considerable degree influenced by factor 2 by studying Group I of Table 3. In this group all animals treated conservatively arrived at the clinic so early (remaining voluntary movements) that a surgical decompression probably could have been done before the damage to the spinal cord was irreversible. All of the 11 operated animals in this group which survived the operation (12 animals in the group) regained their ability to walk, and 9 of these regained complete normal movements. Of the 10 conservatively treated animals 8 regained their ability to walk, 4 recovering completely. As discussed in Part II, the number of animals completely recovering after conservative treatment may — at the best — have increased to 6 if the time of observation had been prolonged.

The above-mentioned comparison between the primary results of conservative and surgical treatment can be summarized in the following way: The presented material speaks in favour of surgery but the small number of operated animals and the discussed differences in the composition of the material make it impossible to judge definitely the value of the operation performed. It would be of particular interest to continue with further studies using the type of operation performed on cases belonging to Group III where the results of conservative treatment are very unfavourable (Table 1, Part II). The results of the 2 operated cases in this group are not in conflict with the assumption that surgery may have a positive effect if done early.

In the operated animals there has been a tendency voluntary motor action to return at an earlier stage than in conservative

treatment (Diagram a compared with Diagram a in Part II). When the operation consisted of only decompressive laminectomy without any attempt to remove the protruded disk substance situated ventrally to the spinal cord, there were no signs of aggravation during the postoperative period. However, temporary loss of voluntary motor activity subsequent to an initial improvement during the postoperative period was observed in 3 animals in which attempts were made to remove the disk protrusion.

Because of the limited data it is impossible to evaluate the more radical type of surgery, which includes removal of the disk protrusions of type 1 and 2. Similarly, a comparison of this operation with decompressive laminectomy alone is not possible. One can just point out that postoperative impairment has been observed only after removal of the disk protrusion. On the other hand, the successful final outcome in 2 cases with radical surgery demonstrates that removal of the disk protrusion can be accomplished without irreversible damage to the spinal cord, at least if the operation is started with a dorsal decompression.

Signs of recurrence of disk protrusion have occurred in 6 (22.2 per cent) of the 27 animals which had regained their ability to walk after operation. The average time of observation was about 8 months for these 27 animals. There has been a tendency for the recurrences to appear in the period between 3 and 6 months after operation. In the 52 conservatively treated animals which regained their ability to walk, recurrence occurred in 15 cases (28.9 per cent) during an average observation time of about 11 months. Although the frequence of recurrence does not increase significantly after the operation, there seems to be cause — in considering a possible future use of laminectomy in disk protrusion — for combining this operation with a prophylactic fenestration and evacuation of the calcified disks situated within the region of the vertebral column that is predisposed to disk protrusion.

Some of the recurrences observed were likely due to prolapses originating from disks situated at the ends of the region subjected to laminectomy. While this distribution might be caused by chance, there is nevertheless reason to suspect that a decreased mobility within the region of laminectomy caused an increased stress on the disks located at the ends of this region. A decreased mobility within the laminectomized part of the vertebral column

could be demonstrated in experimental animals (own unpublished observations in connection with studies on the influence of laminectomy on the shape of spinal canal; *Funkquist* and *Schantz* 1962).

The results of a previous work (*Funkquist* and *Schantz* 1962) suggests that sparing the outer compact bone of the vertebral arch in performing laminectomy (technique B) reduces the risk of secondary cord compression during the process of healing (Fig. 6). The results of the patho-anatomic examination of an animal laminectomized according to "B" because of disk protrusion and sacrificed 17 days after operation are in good agreement with the experimental investigations as the cross-section of the spinal cord had a normal shape (Fig. 4). Still more important for judging the risk of late constriction of the spinal canal during the phase of healing after laminectomy according to "B" is the fact that the animals operated upon (except those 3 cases in which attempts were made to remove a ventral disk protrusion) did not show any postoperative impairment of motor functions which could not be referred to recurrence of the disk disease.

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SUMMARY

An extensive laminectomy performed according to a special technique has been used as a treatment in thoraco-lumbar disk protrusions where the effects of spinal cord compression had rendered the animals unable to walk with their hind legs. The main purpose of the operation was to bring about dorsal decompression of the spinal cord; disk substance situated ventrally to the cord was removed in exceptional cases only. Of the 33 operated animals 5 died during the operation or within the first 5 postoperative days. Of the surviving 28 animals 27 regained their ability to walk and 23 of these 27 animals recovered completely. The results of the surgical treatment are compared with the results of conservative treatment.

ZUSAMMENFASSUNG

Thorako-lumbale Bandscheibenbrüche mit schwerer Rückenmarkskompression beim Hund.

III. Behandlung mit dekomprimierender Laminektomie.

Eine nach besonderer Technik ausgebreitete Laminektomie wurde als Behandlungsmethode bei thoraco-lumbalen Bandscheibenbrüchen geprüft, wo die Rückenmarkskompression von einem derartig schweren Grade war, dass das Tier nicht mehr auf den Hinterbeinen zu gehen vermochte. Die Operation bezweckte in erster Linie, eine dorsale Dekompression des Rückenmarks zu bewirken. Die Entfernung prolabierter Bandscheibensubstanz, die ventral vom Rückenmark gelegen war, geschah nur in Ausnahmefällen. Von den 33 operierten Hunden starben 5 während der Operation oder in den ersten fünf Tagen nach derselben. Von den überlebenden 28 Hunden wiedergewannen 27 das Vermögen, sich auf den Hinterbeinen fortzubewegen, und von diesen 27 Tieren erlangten 23 ganz normale Bewegungen zurück. Die Ergebnisse der chirurgischen Behandlung werden mit den Resultaten konservativer Behandlung verglichen.

SAMMANFATTNING

Thorako-lumbala diskbråck med svår ryggmärgskompression hos hund.

III. Behandling med dekomprimerande laminektomi.

Utbredd laminektomi utförd enligt en speciell teknik har prövats som behandlingsmetod vid thorako-lumbala diskbråck där ryggmärgskompression varit av sådan svårighetsgrad, att djuret förlorat förmågan att gå med bakbenen. Operationen har i första hand utförts i avsikt att åstadkomma en dorsal dekompression av ryggmärgen. Avlägsnande av prolaberad disksubstans, som varit belägen ventralt om ryggmärgen har utförts endast i undantagsfall. Av de 33 opererade hundarna ha 5 dött under operationen eller under de första 5 dagarna efter denna. Av de 28 överlevande hundarna ha 27 återvunnit förmågan att gå med bakbenen och av dessa 27 djur ha 23 återfått helt normala rörelser. Resultaten vid kirurgiska behandling jämföras med resultaten vid konservativ behandling.

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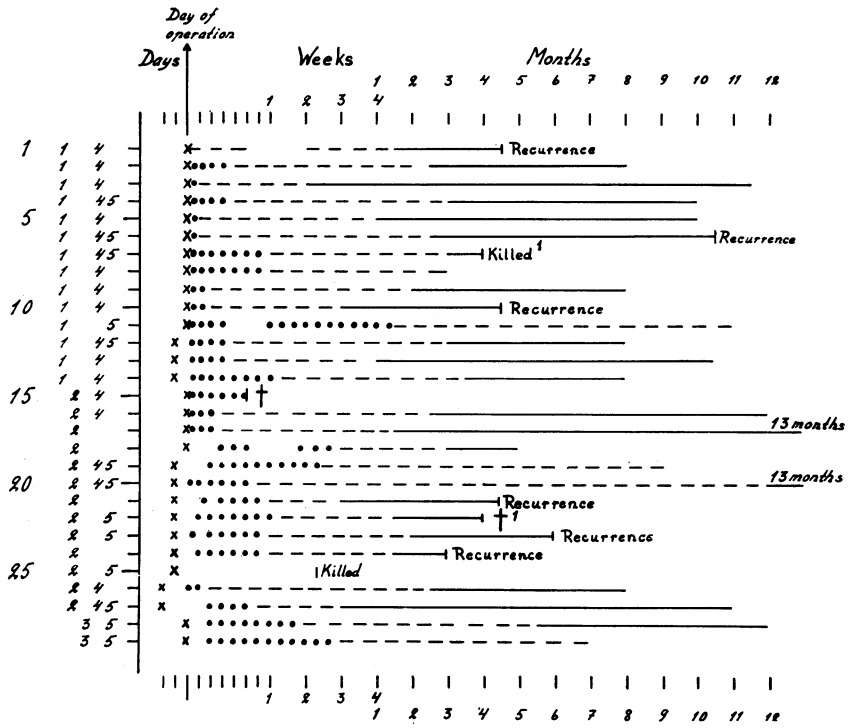

[1]) Killed or dead (†) because of intercurrent disease.

Diagram a. Postoperative course for the dogs, operated according to "B", which survived the operation and the first 2 postoperative days. The animals are arranged initially according to the degree of motor loss immediately before operation. Animals with the same degree of motor loss are then arranged according to the length of the interval between onset of paralysis (loss of ability to walk) and the time of operation. The numbers in sequence are given in the margin to the left. Zero line indicates the day of operation. The cross on, or to the left of the zero line indicates the onset of paralysis.

Table of signs (the meaning of the signs is principally in accordance with the legend of Diagram a, part II).

Functional state of spinal cord.

1.—3. Degree of motor loss immediately before operation:

1. Dog unable to walk; some voluntary motor activity.
2. Total paralysis of voluntary motor activity of the hind legs. Muscular tone of varying strength is present.
3. Total paralysis of voluntary motor activity of the hind legs. Absence of muscular tone.

4. Presence of pain sensitivity before operation.
5. Time of development of symptoms of motor loss to the stage "inability to walk" $\leqq$ 12 hours.

Course of recovery

..... the dog is unable to walk but shows some voluntary motor activity of the hind legs.

------ the dog can walk but is shown disturbance of movements (unsteadiness) of varying degree.

——— the dog walks normally.

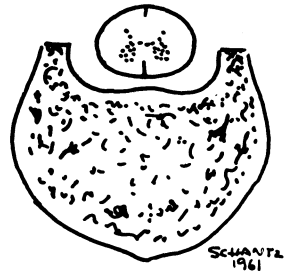

Fig. 1. Outline drawing of the technique of laminectomy with complete removal of the dorsal and dorso-lateral parts of the arch (technique A).

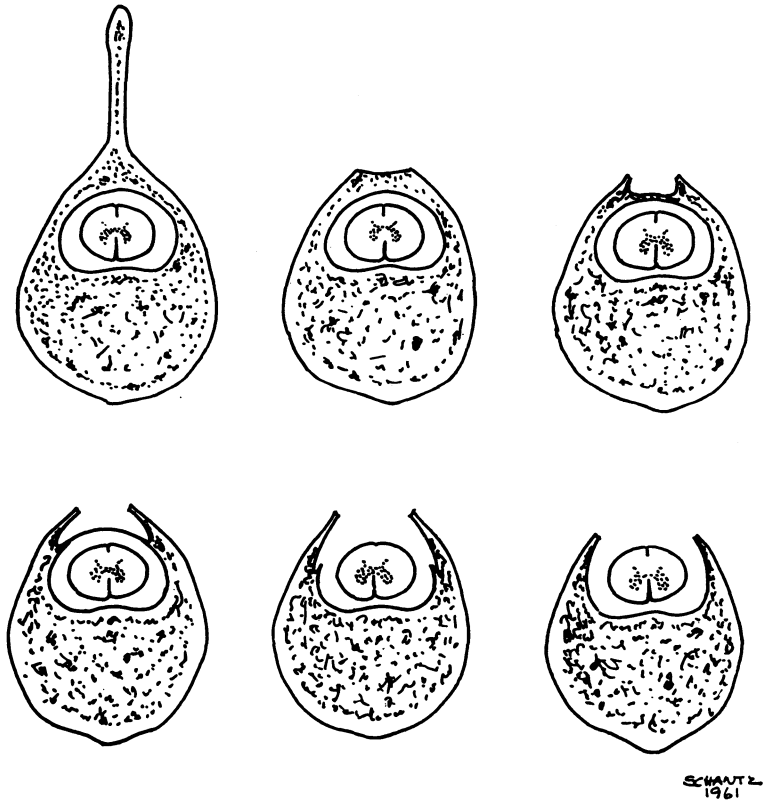

Fig. 2. Laminectomy with retention of the outer compact bone of the dorso-lateral portion of the arch (technique B).
(After *Funkquist* and *Schantz* 1962).

Fig. 3. Cross-section close to the disk T12/T13 from a dog with clinical symptoms of thoraco-lumbar disk protrusion. The animal was killed 17 days after laminectomy according to technique A, because of post-operative impairment of its movements. The spinal cord is compressed to a thin scale between the scar tissue of the defect in the roof of the spinal canal and the protruded disk substance.

Fig. 4. Cross-section through the middle part of L1 from a dog with clinical symptoms of thoraco-lumbar disk protrusion. The animal was killed (because of absence of improvement) 17 days after laminectomy on T12—L2 according to technique B. Moderate elevation of the spinal cord caused by disk substance situated ventrally in the epidural space. No dorso-ventral flattening of the cord cross-section.

Fig. 5. Cross-section through the middle part of L1 in an experimental dog. Laminectomy in T12—L2 according to technique A with simultaneous elevation of the cord, by injection (via the laminectomy opening) of paraffin wax into a polyethylene tube, which was placed in the epidural space ventrally to the dura. The animal was killed 5 weeks after the laminectomy. Severe dorso-ventral flattening of the cord. (After *Funkquist* and *Schantz* 1962).

Fig. 6. Cross-section close to the disk L1/L2. Laminectomy according to technique B with simultaneous elevation of the cord as described under Fig. 5. The animal was destroyed about 5 weeks after the operation. No dorsal flattening of the cord.
(After *Funkquist* and *Schantz* 1962).

Fig. 3.

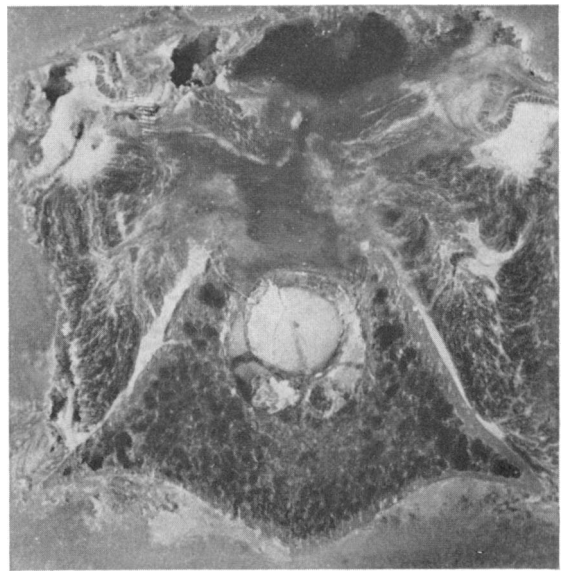

Fig. 4.

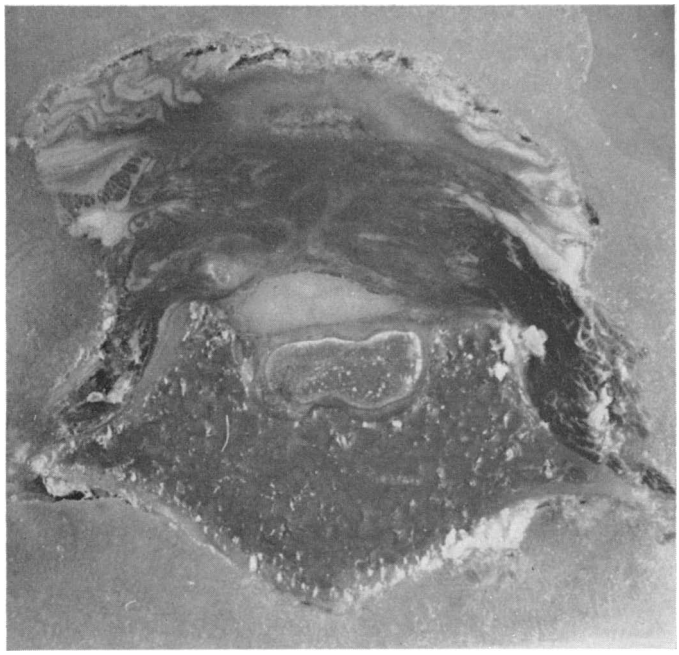

Fig. 5.

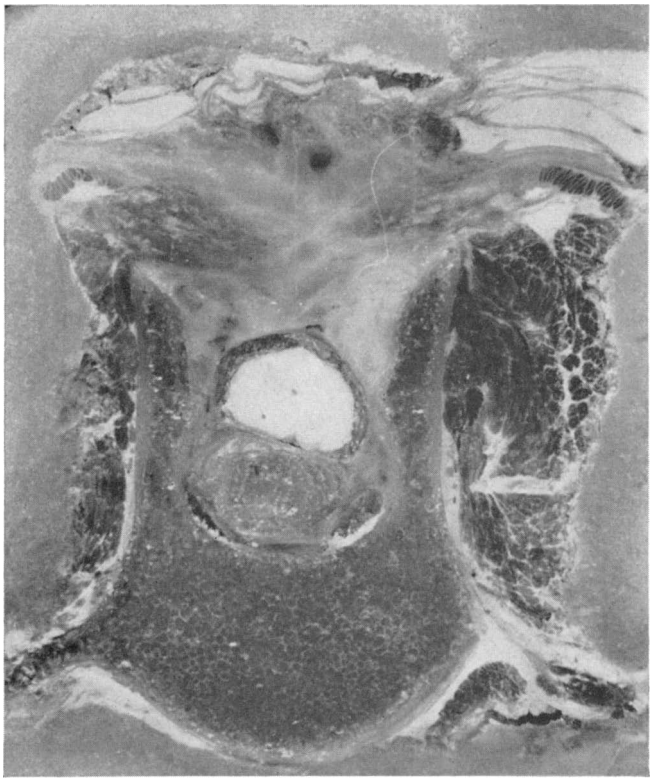

Fig. 6.