ACTA ORTHOPEDICA SCANDINAVICA SUPPLEMENTUM NO. VIII
From The Royal Veterinary College, Stockholm.

ON DISC PROTRUSION IN DOG

(Enchondrosis Intervertebralis)

A STUDY WITH SPECIAL
REFERENCE TO RÖENTGEN DIAGNOSIS AND TO
THE VALUE OF DISC FENESTRATION

By
STEN-ERIK OLSSON

EJNAR MUNKSGAARD · PUBLISHER
Copenhagen 1951

Translated by

EBBA ERIKSSON

Printed in Denmark

—

Vald. Pedersens Bogtrykkeri
København

To my Parents

CONTENTS

PREFACE 7

INTRODUCTION 9

CHAPTER I

COMPARATIVE ROENTGENOLOGICAL AND PATHO-ANATOMICAL STUDIES 12
General survey 12
Present investigations 15
Materials and methods 15
Results 15

CHAPTER II

MYELOGRAPHICAL STUDIES 18
General survey 18
Experimental investigations 22
Comparison between epidural and subarachnoid myelography . . . 22
Puncture of the subarachnoid space 24
Choice of contrast medium 25
The value of thorotrast myelography seen against the background of controlling its results at section 28
Materials and methods 28
Results 29
Clinical observations regarding thorotrast myelography 32
Methods 32
Reaction after myelography and effect of forced drainage 33
Complications and contraindications 34
Discussion 35

CHAPTER III

SOME CONTRIBUTIONS TO THE UNDERSTANDING OF THE PATHOGENESIS 37
Clinical data from available literature 37
After-examination of cases treated at the medical clinic during the years 1940-1949 38
Some clinical observations with the guidance of 50 cases in which the diagnosis was determined roentgenologically and/or patho-anatomically . . 40

Discussion of the pathogenesis of the disease 41
What factors determine the symptoms? 42
For what reason does paraplegia caused by disc protrusion oftentimes spontaneously heal? 44
Why do relapses occur? 48

CHAPTER IV

SURGICAL TREATMENT WITH SPECIAL REFERENCE TO THE VALUE OF DISC FENESTRATION 51
Brief survey of different methods of treatment 51
Observed results of laminectomy on dogs 53
Disc fenestration 54
Surgical technique 55
Results 57
Brief summary of casuistry 59
A comparison between conservatively and surgically treated cases . . 60
Patho-anatomical examination of fenestrated discs 63
Material 63
Results 63
Discussion 66

SUMMARY 69

ZUSAMMENFASSUNG 71

REFERENCES 74

ILLUSTRATIONS 77

PREFACE

The investigations on which this work is based have been carried out during the years 1949-1951 at the Royal Veterinary College in Stockholm.

By his very comprehensive research work concerning disc degeneration and disc protrusions, Docent *Knut Lindblom* is especially the one who has directed my interest to these problems. I wish to tender my warmest thanks for his keen interest in my investigations as well as for all valuable advice, and for the help he has willingly rendered me.

During my own studies extensive investigations concerning disc degeneration in dog have been carried out at the Patho-anatomical Department of the Veterinary College. These investigations have been invaluable to me.

I wish to express my cordial thanks to Prosektor *Hans-Jörgen Hansen* for his never-failing helpfulness, and for interesting discussions.

Professor *Gerhard Forssell* and Professor *Nils Obel* have contributed with valuable advice and have kindly placed the resources of the Surgical Clinic at my disposal.

Professor *Birger Carlström*, who has generously permitted me to use the material of the Medical Clinic, has faciliated my work to a great extent.

Professor *Sten Friberg* has kindly revised my dissertation and given me the opportunity of sharing his great experience.

Professor *Åke Åkerlund* has permitted me to follow the work and take part in the teaching at his department. He has thus laid the basis of my work.

Docent *Sven Roland Kjellberg* has to a great extent contributed to the early completion of this work through his great enthusiasm and wealth of ideas.

Professor *Sven Rubarth* has readily placed the resources of his institution at my disposal and thus greatly supported my work.

Professor *Knut Sjöberg* has helped me with the chemical analyses.

Dr. *Gösta Norlén* and Dr. *Thor Hiertonn* have given me valuable advice.

My colleagues at the surgical and medical clinics have faciliated my work in different ways.

Preparator *Eric Eklund* and Miss *Karin Lundin* have assisted me in photographing.

To all these persons I wish to express my appreciation and gratitude.

Finally, I proffer a special thanks to my coassistants in the Roentgen Department Mrs. *Inga Lindgren* and Miss *Puck Runefeldt*. They have never even hesistated about strenuous overtime work. Without their ready helpfulness my work would not have been completed in such a reasonable time.

My investigations have been financially faciliated by contributions from "Anslag till främjande av medicinsk forskning vid Veterinärhögskolan".

Stockholm, March, 1951.

STEN-ERIK OLSSON

INTRODUCTION

In human medicine one has not until the last two decades become clearly aware of how great a rôle disc degenerations and disc protrusions[1] play as causative factors in lumbago and sciatica. It is true that *von Luschka,* in 1858, described two cases of disc protrusion in man, but no importance was attached to this observation. *Schmorl* and *Andrae* reported their anatomical investigations in 1929 and occasional clinical studies were also published, but it was *Mixter*'s and *Barr*'s work of 1934 that first drew attention to the fact that herniations give symptoms very similar to those of low back pain and sciatica, when they are situated in the lumbar spine.

It is therefore rather remarkable that *Dexler* already in 1896 reported a disease in dog, the symptoms of which were posterior paralysis caused by compression of the spinal cord.

As compression-causing factors he found neoformations from the discs. He did not regard the changes as protrusions but more as proliferations. The connection between the morbid processes of the discs and the nervous symptoms was, however, clear to him.

On account of the fact that the spinal cord in dog extends to the 7th lumbar vertebra, and because most disc protrusions are located at the transition between the thoracic and the lumbar portion of the spine, they cause a compression of the spinal cord. This circumstance explains why the symptoms in dog usually are severer than in man. In man lumbar protrusions, which seem to be the most common, only cause compressions of the nerve roots and *cauda equina.*

Later the above mentioned disease in dog has been subjected to patho-anatomical investigations. Works by *Joest* (1921) and *Wiedemann* (1922) may be mentioned.

These pathologists were also of the opinion that proliferative processes, which had been caused by degenerations of the discs, were essentially responsible for compressions of the spinal cord. The most common name of the disease has hitherto been *enchondrosis intervertebralis.*

---

[1] Disc protrusion a synonym for disc herniation and disc prolapse.

Tillmanns (1939) and *Fankhauser* (1948) guardedly expressed the opinion that such neoformations might be disc protrusions.

Independent of Tillmanns, *Riser*, in 1946, maintained that the disease in dog was identical with disc herniations in man.

Not until *Hansen*'s investigation (1951) has the fact been established that these neoformations are nothing but disc protrusions. Hansen shows that three breeds of dogs are more disposed to disc protrusions than others; *viz.*, French bulldog, dachshund, and Pekinese. According to Hansen certain signs of chondrodystrophy should be common to these dogs.

Briefly expressed, the anatomy of the disc is the following. The disc has two main parts: the *annulus fibrosus* and the *nucleus pulposus*. The *nucleus pulposus* forms the centre of the disc and consists of a slightly differentiated gelatinous tissue which is bounded towards the vertebrae by two cartilage plates and for the rest is enclosed by the *annulus fibrosus* peripherally. The *annulus fibrosus* is composed of strong bundles of fibers directed obliquely between the vertebral bodies, crossing one another.

The normal disc undergoes certain typical age changes. At first the *nucleus pulposus* has a very high water content and is very elastic. (Fig. 34). With advancing age a dehydration is noticed, and the elasticity becomes diminished.

Degenerative changes often appear in the *nucleus pulposus* and *annulus fibrosus*. The way is then paved for ruptures of the *annulus fibrosus* resulting in nuclear protrusion. (Fig. 32).

Hansen observed the very interesting fact that the fundamental cause of the widely spread and early appearing disc degenerations and protrusions in the above-mentioned breeds of dogs is to be sought in the disc itself. Characteristic of this group of dogs is a rapid chondroid transformation of the *nucleus pulposus*. The normal elasticity of the disc therefore disappears and degenerative processes are found earlier here than in other breeds. Hansen emphasizes the difference between disc protrusions in the so-called chondrodystrophoid group and such formations in other dogs. This work mainly deals with disc protrusions in the first-mentioned group.

Disc protrusions can vary in size to a great extent; from only slight bulges of the *annulus fibrosus* dorsally to protrusions consisting of the whole *nucleus pulposus*. (Fig. 32).

The fact that slight interest in this rather common disease in dog has been shown by clinicians is to a certain extent understandable. As a matter of fact there has been uncertainty as to the actual nature of the disease, and its topographic diagnosis has been difficult. Bear-

ing these circumstances in mind, the author's aim has been to examine the disease more from clinical viewpoints than has previously been done.

The problems that arise in this connection are of such proportions that they comprise roentgenological as well as medical and surgical ranges of work. This is natural, since, as is previously mentioned, most of these problems are unsolved.

The writer has, however, had to limit the investigations to his special disciplines: roentgenology and surgery. On purpose, medico-neurological questions are not discussed to any great extent in this work. When observations have been possible in this field, they are, however, included as contributions to the debate. In spite of these limitations a desired examination of details in all these problems has not been possible.

The main object of this work is to make a contribution to an improved roentgen diagnosis of disc protrusions in dog. With the help of anatomical and roentgenological examinations the author further wishes to give some explanations of certain typical phenomenons in the pathogenesis of the disease. Finally, the value of surgical treatment is studied. In the latter respect the greatest importance is attached to a new method of operation, according to *Lindblom*, called fenestration. The reason herefore is especially that an experimental trial of this method on animals might be of some interest in human medicine.

CHAPTER I

COMPARATIVE ROENTGENOLOGICAL AND PATHO-ANATOMICAL STUDIES

GENERAL SURVEY

In more advanced cases, the diagnosis *disc protrusion* is clinically not difficult to make. Experience shows that most cases of paraplegia in dogs, at least in breads disposed to disc protrusion (*Hansen,* 1951), are caused by disc herniations.

Slight cases are, however, usually not diagnosed and as long as a protrusion is not definitely provable, the diagnosis will always be a diagnosis of probability and a localization hardly possible.

In man, there are two principal ways of diagnosis; namely one neurological and one roentgenological. Supported by their experience, the neurologists *Frauchiger* and *Fankhauser* (1949), doubt that a localization is possible in dog by neurological means.

A perfectly objective method of investigation like the roentgenological offers certain advantages concerning the diagnosis of animal diseases. Supported by the above-mentioned statements, the author has therefore concentrated his attention entirely upon the roentgenological part of diagnosis.

In human roentgenology two different methods for localizing protrusions are now used. Myelography and discography. Discography is a new method, which aims at detecting ruptures of the disc by injecting a contrast medium into the inner part of the disc and letting the patient identify the pain he feels when the injection is made. It requires a possibility of limiting the disorder to a couple of discs.

In dog there is no such possibility. Further, the anatomical conditions that are found and make a disc puncture easy in man, do not exist in dog. Concerning animals the examiner is moreover deprived of the patient's subjective symptoms. Therefore, discography will offer no practical solution of the problem in question.

By means of this method a rupture of the disc was, however, very clearly noticed in one case of the present investigation. It concerned a lumbar disc protrusion.

In animals myelography is most likely a better expedient than is

discography. Before such a specialized examination is made, one must, however, know for sure what changes may be expected in the ordinary roentgenogram of a disc protrusion.

Regarding man, the problem is thoroughly studied. In this connection the writer only wishes to cite *Lindblom* (1946). This author points out that the following changes may be found in inveterated degenerations of discs: osteophytes on the edges of the vertebrae, narrowing of the intervertebral space, disc protrusions into the spongiosa of the vertebrae, loosened anterior edges of the body of the vertebra without trauma, vacuum phenomenons in the discs, calcified discs, retroposition of the upper vertebra, and arthrosis of the intervertebral joints. He mentions, that these symptoms are, however, indirect changes which by no means guarantee that the disc protrusion is situated at this or that disc.

As comprehensive as the human medical literature is regarding roentgenological changes, as meager is the veterinary literature in this respect. In available literature, there only seem to be four authors that have paid any attention to these problems.

In *Tierheilkunde und Tierzucht* published by Stang and Wirth, *Pommer,* in 1937, published an article called *Calcinosis und Ekchondrosis intervertebralis*. First Pommer mentions some different diseases which cause compressions of the spinal cord in dog and then writes: "Drucklähmungen können weiters auch durch Entartungen der Zwischenwirbelscheiben hervorgerufen werden, die mit Kalkablagerungen in den zentralen Anteilen der Bandscheiben (Calcinosis intervertebralis) beginnen und im weiteren Verlauf zu Elastizitätsverlust und Vorwölbung, bzw. Wucherung des knorpeligen Gewebes in den Rückenmarkskanal hinein (Ekchondrosis intervertebralis) führen". After that, he gives a brief survey of what has previously been written about disc protrusion in domestic animals. He continues, "Am lebenden Tier ist die Diagnose der Calcinosis und Ekchondrosis intervertebralis nur durch die Röntgenuntersuchung möglich. Diese bringt volle Klarheit über die Häufigkeit und die Entwicklung dieser Prozesse, von den kleinsten Kalkablagerungen in den Bandscheiben, ohne klinische Erscheinungen, bis zu den hochgradigen Fällen mit Verengerungen der Zwischenwirbelspalten, Vorwölbung und Verkalkung des Knorpelgewebes, Kompression des Rückenmarkes und Paralysen der Nachhand". Further Pommer gives an account of the anatomy of the intervertebral disc and points out where the calcification arises in the disc. Then he writes, "Ob die bisher beschriebenen Verkalkungen, solange die normale Breite der Zwischenwirbelspalten erhalten bleibt, klinische Erscheinungen hervorrufen, ist nicht entschieden; sie sind häufig Zu-

fallsbefunde. Bei den fällen mit klinischen Symptomen sind in der Regel gleichzeitig Verengerungen der betroffenen Intervertebralspalten nachweisbar. Die degenerierten Bandscheiben werden in den Rückenmarkskanal vorgedrängt. Verkalkungen in ihren dorsalen Randzonen und Randwulstbildungen, nur diese sind röntgenologisch darstellbar, ragen als unterbrochene oder zusammenhängende, von einem Wirbelkörper zum anderen reichende, kalkdichte konvexe Bogen, bzw. Hauben in die Zwischenwirbellöcher vor. Bei vorgeschrittenen Prozessen sind an der dorsalen Fläche eines der beiden anstossenden Wirbelkörper halbkugelförmiche Vorwölbungen, die durch Kalkeinlagerungen einen homogenen Schatten geben, zu finden. Dieses Stadium entspricht den von Dexler, Cadeac, Jacob, Joest und Marek als 'Enchondrosis intervertebralis' mitgeteilten pathologisch-anatomischen Befunden".

In 1162 dogs and cats whose spinal column had been X-rayed on account of paresis or paraplegia, Pommer, in 342 cases (29.5 %), could find degenerations of the discs developed to such an extent that they could explain the clinical findings. In yet 76 cases the degenerations were secondary findings.

If intervertebral calcifications are found in posterior paralysis but no other disorder of the vertebral column, Pommer believes that there must be a connection between these calcifications and the symptoms. He considers this statement, however, difficult to prove. Pommer reports no comparing patho-anatomical investigations. One is apt to believe that Pommer is of the opinion that a calcification of the disc would be noticeable in all cases of disc protrusions.

In his book *Radiology in Small Animal Practice* (1950) *Schnelle* has devoted a few pages to disc protrusions in dog. Among other things, he writes, "From a radiographic standpoint there is no practical method of diagnosis unless calcification of the disc or ruptured contents of the disc has occurred". Schnelle thus whishes to emphasize that by far all disc protrusions may be noticed roentgenologically. Not until a calcification is found, should we be able to suspect a protrusion. Elsewhere he says that trauma may cause a rupture of the disc with protrusion of the liquid contents into the vertebral canal. "In such an instance the fluid then hardens to act as a foreign body. The radiograph then is one either of calcification of the disc or absence of the space which should normally be seen between the vertebral bodies. Absence of normal space constitutes justification for diagnosis of rupture of the disc when symptoms have led to this condition as a tentative diagnosis".

In this last sentence he contradicts his first statement to some extent.

Riser (1946) mentions only very briefly that roentgenograms without myelography "are not always diagnostic, for the discs contain little calcium and infrequently cast a shadow".

Boddie (1949) writes that he has seen compressions of discs in roentgenograms but later adds, "I have never seen either ossification of the intervertebral discs or prolapse of the disc".

This short summary of what has been written in the veterinary literature about roentgenograms of disc degenerations and disc protrusions in dog, shows that the statements differ in some respects. The author has therefore considered it valuable to draw a comparison between sectional and radiological findings.

PRESENT INVESTIGATIONS

MATERIALS AND METHODS

Roentgenograms of the spinal column of 33 dogs with one disc protrusion or more have been thoroughly studied.

The first 17 cases are dogs registered at the medical or surgical clinic of the Veterinary College sometime during the period of 1942-1949, and then have been subjected to postmortem examinations. The remaining 16 cases are dogs that the author has had the opportunity of X-raying during 1949 and 1950. Postmortems of these dogs have also been made[1]. There has been no selection. All the possible cases have been included. Several cases that have been fit for use in other respects have had to be discarded on account of unsatisfying quality of the roentgenograms. The majority of dogs have only been X-rayed in lateral projection. This applies especially to the first part of the material.

RESULTS

Noticeable roentgenological changes in or near the protruded discs are:

1. *Calcification of the protrusion.* (Fig. 3).
2. *Diminished space between the surrounding vertebrae.* (Figs. 4-5).
3. *Calcification of the disc.* (Fig. 3).
4. *Osteophytes of the surrounding vertebrae.* (Fig. 6).

These changes may be noticed separately or several together in a

[1] Postmortems performed by H. J. Hansen, the Patho-anatomical Department of the Veterinary College.

protruded disc. The following schematic survey represents occurrence and combinational possibilities of the different changes.

FIFTY-FOUR PROTRUDED DISCS

No changes in the roentgenogram	12
Diminished space between the surrounding vertebrae	8
Diminished space + calcification of the disc	2
Diminished space + calcified protrusion	1
Diminished space + calcified protrusion + calcification of the disc	2
Calcification of the disc	14
Calcification of the disc and the protrusion	10
Calcification of the protrusion	2
Osteophytes of the surrounding vertebrae	1
Calcified protrusion + osteophytes of the surrounding vertebrae	1
Calcification of the disc + osteophytes of the surrounding vertebrae	1 .

In the examined material, including 54 protruded discs, only 12 showed a normal roentgenogram. (Fig. 1). The protrusions from these discs showed no special characteristics. They varied in size from a small bulge in the disc to an almost complete emptying of the contents of the disc.

Calcification of the disc was a frequent phenomenon in protruded discs. Disc calcifications were, however, common also in discs that did not show the slightest bulge towards the vertebral canal (Fig. 1). As Pommer has already pointed out, one can therefore attach no other importance to calcification than the fact that it is an expression for a degeneration.

On the contrary, lacking normal space between the vertebrae seems to be a good sign of protrusion. The fact that the disc, so to speak, collapses when part of its contents protrudes, is rather understandable. But, on the other hand, one may, however, find rather large protrusions without seeing the disc narrow.

It is rather difficult, however, to estimate the spatial changes that appear between the vertebrae. The reason herefore is especially that these changes are rather slight. Furthermore, the disc protrusions are often situated at the transition between the thoracic and the lumbar portion of the spine where the discs widen in a caudal direction, the lumbar discs being slightly wider[1] than the thoracic discs. The widening begins about at the 10th-11th-12th thoracic vertebrae and ends at the 13th thoracic-1st lumbar vertebrae. As a practical, but very approximate rule, one may say that a disc should not be narrower than the surrounding discs. Regarding the transitional part, the disc should

[1] wide = thick = high (human med.).

be just as wide or somewhat wider than the disc orally to it. Slight deviations from this rule occur, however, and one should be very cautious about judging, as the roentgenogram only gives an approximate idea of the space between the vertebrae.

In case the protrusion itself is entirely or partly calcified, the diagnosis will be rather simple. Complete or incomplete bridges like the ones Pommer has described, may be noticed in several cases (Fig. 6). One must remember, however, that the dorsal margin protrudes somewhat over the level of the surrounding vertebrae. Calcification in this part of the disc must not be considered as a calcified protrusion (Fig. 2). Furthermore, calcifications of a protrusion may be very heterogeneous. Sometimes they appear as very limited calcified formations. In other cases, when a calcified disc has emptied its contents into the vertebral canal, the calcification may appear as a diffuse slightly distinguishable mass in the intervertebral foramen (Fig. 3).

It is best to make the exposures of the spinal column in two directions, laterally and ventrodorsally. Due to the fact that the neural arches are not in the way, the lateral pictures give the best information about changes of the described type. It may be of the greatest importance, however, to study the ventrodorsal picture to find out if formations visible in the intervertebral foramen, really are situated in the vertebral canal or not (Fig. 3).

In the present material osteophytes of surrounding vertebrae were not very often seen. As we know, such deposits also occur around discs that are not protruded into the vertebral canal.

On purpose, the author does not mention instability and abnormal mobility as symptoms of disc degeneration and disc protrusion. No definite signs of displacements of the vertebrae could be noticed in the roentgenograms. Nor was abnormal mobility noticeable in any of 10 cases subjected to fluoroscopy.

According to the author's opinion, this investigation proves that a disc protrusion may be diagnosed and its location determined to a fairly great extent with the help of ordinary roentgenograms.

In the author's material, 26 protrusions of 54 could be diagnosed in an ordinary roentgenogram. It is rather clear, however, that a method discovering, on an average, only 50 % of all protrusions, is a rough method. A surgical treatment, for instance, may not be based on such a method.

In this connection the fact must also be emphasized that chronic protrusions that cause no symptoms are oftentimes the ones that can be diagnosed in the roentgenogram, while symptom-causing protrusions are undetectable.

CHAPTER II

MYELOGRAPHICAL STUDIES

GENERAL SURVEY

By myelography is understood a visualization of the contour of the spinal cord by means of a contrast medium.

The ideal intraspinal contrast medium should, according to *Coe, Otell* and *Hedly* (1933), have the following qualities:

1. It should be nontoxic.
2. It should be of sufficient atomic weight to cast a clear-cut shadow.
3. It should be nonirritating.
4. It should be miscible with cerebrospinal fluid.
5. It should be readily eliminated.

Of the four different types of contrast media that have proved practically useful in myelography, none is satisfactory in all these respects.

The contrast medium first used was air or oxygen. It was suggested by *Dandy* (1919) and with the help of it he could, in 1925, localize a tumour that totally blocked the spinal canal. In 1934, *Coggeshall* and *von Storch* mention that they had noticed deformities of the contour of the dural sac when using air as contrast medium.

Reichert, Scott and *Young,* in 1937, diagnosticated disc protrusions by means of air. Furthermore, a work by *Lindgren* (1939) may be mentioned. So far as the author knows, there is nothing particularly written in veterinary literature about air myelography on dogs. The advantage of air and especially oxygen is that it is readily resorbed and acts but slightly irritating.

In 1922, *Sicard* and *Forestier* introduced iodized oil as a suitable means for visualizing an obturating spinal tumour.

Odin and *Runström,* in 1929, also recommended the use of iodized oil in cases of nonobstructing lesions. The literature on myelography with iodized oil is very comprehensive.

This is not the place to discuss this subject to any great extent; some authors should, however, be mentioned, *e.g., Mixter* (1937), *Bell*

and *Spurling* (1938), *Lowe* and *Walsh* (1938), *Camp* and *Addington* (1939), *Hampton* (1940), *Epstein* and *Davidoff* (1944), *Copleman* (1944).

The advantage of iodized oil is that it gives a good contrast effect. As it can not be resorbed, it will remain in the subarachnoid space and cause some irritation. (*Tschugunoff*, 1929, *Bruskin* and *Propper*, 1931, *Garland*, 1940, *Marcovich*, *Walker* and *Jessico*, 1941). Different methods have therefore been used to remove it from the subarachnoid space immediately after examination. (*Kubik* and *Hampton*, 1941, *Friberg*, 1941).

There are two principle types of iodized oil, one lighter and one heavier than the cerebrospinal fluid. The very latest form of oil contrast medium is pantopaque which has a lower viscosity than other oils.

If the passage of the cerebrospinal fluid is not totally blocked, one must follow the movements of the oil by flouroscope in order to see if there are any disturbances in the normal outlining of the dural sac.

In veterinary literature, there are some descriptions of myelography with iodized oil. *Brook's Experimental and Clinical Studies of the Spine of the Dog* (1936) may be mentioned. Brook has made experimental investigations regarding dogs using Lipiodol Descendant (Lafay).

His material includes healthy dogs with the exception of two cases. In one of the latter cases he succeded in showing a disc protrusion between L. 7 and S. 1, in the other a compression of the spinal cord caused by a fractured vertebra.

He considers the method rather good, but points out that it has the following disadvantages.

1. The rate of descent is slow.
2. The oil adheres in all positions along the subarachnoid space and the diagnosis of partial or incomplete block, particularly at certain points, would be a matter of some difficulty.
3. The oil is not perfectly tolerated.

Schnelle (1945), *Riser* (1946) and *Boddie* (1949) mention myelography referring to Brook's work, and Riser also shows a roentgenogram of a partial block.

In their book *Die Nervenkrankheiten unserer Hunde*, *Frauchiger* and *Fankhauser* (1949) show a roentgenogram of a complete block.

Furthermore, *Pukanić* (1941) has written a rather comprehensive work about myelography in dog. Regarding iodized oil he mentions, among other things, that it is a good contrast medium, valuable lumbosacrally as well as suboccipitally.

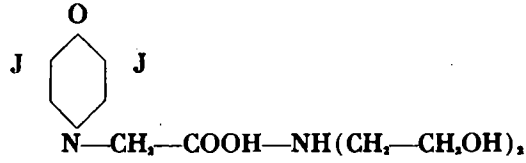
A water-soluble substance suitable for myelography was intro-

duced in 1931 by *Arnell* and *Lidström*; namely, Abrodil (JCH_2SO_2Na). In 1944 *Arnell* described this method closer, and in 1948 he published a dissertation on the subject.

Several authors have written about abrodil myelography. A work by *Lindblom* (1946) may especially be mentioned. In 1947, he gives a survey of the complications and warns against using other water-soluble media than solutions of 20 % abrodil or Intron (J_2CHSO_2Na). One must combine myelography with spinal anaesthesia, as cramps otherwise appear. Cramps and shocks that appear in spite of such measures, may be caused by the circumstance that the spinal anaesthesia ceases to act, before the contrast medium has been absorbed.

Denstad (1949) emphasizes the importance of keeping the patient's head high. Otherwise one will risk getting the concentration of the contrast medium too high in the *cisterna magna*. According to his opinion, a high concentration here might explain cramps and collapses which are sometimes seen from 2 to 3 hours after myelography.

In the veterinary literature available to the author, only two articles on myelography with water-soluble contrast media could be found. One is *Pukanić*'s in *Veterinarski Arhiv* (1941). Pukanić used Perabrodil.



He is of the opinion that this medium gives a rather slight contrast effect and can not be used suboccipitally on account of its very irritating effect.

The other article is written by *Meyer* (1937). He does not consider water-soluble contrast media suitable on account of their poor contrast effect.

In 1932, *Radovici* and *Meller* introduced Thorotrast as a contrast medium in encephalography. Since 1926 one had then used colloidal thorium dioxide in roentgen diagnosis for clinical purposes especially for hepato-lienography, arteriography and in urology.

In 1933, *Wustman* published a large experimental work on thorium contrast medium in periencephalography.

Moreover, works by *Capua* (1933), *Jacobi* and *Löhr* (1933) may be mentioned.

The literature on thorotrast is very comprehensive. It seems unnecessary to give further details about it in this connection. Anyone interested will find a thorough bibliography of what is written on this

subject before 1938 in an article by *Reeves* and *Stuck* (1938). This article is called *Clinical and Experimental Results with Thorotrast* and published in *Medicine*.

The form of thorotrast (Heyden) used by the author, is a stabilized emulsion of thorium dioxide containing 25 per cent of thorium dioxide, and a protective colloid of a carbohydrate nature. It also contains a preservative.

By its contents of thorium, thorotrast is slightly radioactive.

The radioactivity of thorotrast has been summarized in a report of the *Council on Pharmacy and Chemistry* (1932) as follows:

"Alpha rays—25 c.c. of thorotrast is equivalent to a maximum of 1 and a minimum of 0.5 microgram of radium (Schlundt).

"Beta rays—"Too feeble to be of physiological significance" (Schlundt).

"Gammarays—25 c.c. of thorotrast is equivalent to 0.4 microgram of radium (Radium Instit. Bergakademie, Freiberg); equivalent to approximately 0.3 microgram of radium (Flinn) "Too feeble to be of physiological significance" (Schlundt)".

In human medicine, thorotrast has not been so extensively used as one had expected from the beginning. The principal reason is most likely its irritating effect and its radioactivity. As a contrast medium in ventriculography and periencephalography it has been tried by, among others, *Radovici* and *Meller* (1933), *Twinning* and *Rowbotham* (1935), *Freemann, Schoenfeld* and *Moore* (1936).

Long animal experiments have indeed shown that the animals are able to stand rather large doses of thorotrast subarachnoidally, but some investigators, however, point out some disadvantages.

In their imposing general article, Reeves and Stuck believe that thorotrast partly acts somewhat irritating and partly may increase the intracranial pressure, like all colloidal substances injected into the cerebrospinal fluid, thus causing hydrocephalus.

Furthermore, it might perhaps cause granuloma-resembling formations in the meninges, a slight acidosis of the cerebrospinal fluid, and a chronic meningitis.

Well knowing the disadvantages of thorotrast, *Nosik* and *Mortensen*, in 1938, showed that a large part of the injected thorotrast could be removed in animals after myelography by using so-called forced drainage primarily suggested by *Kubie* and *Retan* in 1933.

In myelography in lumbar disc protrusions in man, *Nichols* and *Nosik*, in 1940, and *Nosik*, in 1943, used this method.

So far as the writer knows there are only two authors in the literature of veterinary medicine that have used thorotrast in myelography.

Meyer (1937) considers it a suitable contrast medium and *Pukanić* (1941) is of the opinion that it may very well be used lumbarly but not suboccipitally were the reaction will be too strong.

EXPERIMENTAL INVESTIGATIONS

COMPARISON BETWEEN EPIDURAL AND SUBARACHNOID MYELOGRAPHY

Myelography may be carried out not only with different contrast media, but also using different methods. The contrast medium may either be injected subarachnoidally by cisternal or lumbar puncture, or epidurally through the lumbosacral foramen.

In this connection it might be well to observe that anatomical conditions regarding the meninges of the spinal cord do not seem to be quite identical in dog and man. *Heiligtag* (1938) was the first one to demonstrate that the arachnoidea in dog realy consists of a complete membrane that divides the subdural and the subarachnoid space. The subdural space is merely a capillary space. From rough anatomical examinations, the writer concludes that one does not practically have to take the subdural space into consideration in dog. A consequence hereof would thus be that such complications as subdural injections of the contrast medium, which might occur in man at myelography, never would appear in dog.

Epidural contrast myelography was first subjected to investigations. This is very reasonable, as lumbosacral puncture is very simple. It is performed almost every day by veterinary surgeons working in a dog clinic.

Varying amounts of Kontrast U (synonymous to abrodil) and intron were injected into carcasses still of body temperature, one of which was affected with disc protrusion. The result was rather depressing. The pictures are extremely varying and irregular. One gets no distinct concept of the medullar contour. It is impossible to localize the disc protrusion.

In man similar negative observations have been made in epidural myelography (*Lindblom* 1946).

There is a considerable difference in pictures obtained in subarachnoid and in epidural myelography (Figs. 7, 8, 9, 10, 11).

This circumstance is rather natural as the subarachnoid space is a hollow space filled with fluid and the epidural space almost completely filled with adipose tissue.

In this connection it might be well to refer once more to Meyer's work *Die Röntgenkontrastdarstellung des Wirbelkanals beim Hunde* (1937).

Meyer recommends thorotrast as a suitable contrast medium in myelography in dog. According to his opinion, a suboccipital injection into the *cisterna magna* is rather difficult and risky. For this reason he recommends lumbosacral injection of the contrast medium. By such an injection he considers it possible to inject the contrast medium subarachnoidally even if spinal fluid does not drip from the needle.

The three roentgenograms that Meyer has included in his work show very distinctly, however, that the contrast medium has been injected epidurally. The most reliable sign hereof is that a lateral picture shows a garlandlike line above every disc in addition to the two contrast lines that bound the spinal cord ventrally and dorsally. These formations are never seen, if the contrast medium remains subarachnoidally. This circumstance is proved by the fact that these contrast lines are never seen when an injection is made suboccipitally. To make assurance doubly sure both epidural and subarachnoid injections of thorotrast added with methylrosanilin were made. The position was then controlled at section. The fact was proved that these lines only could be seen when the contrast medium was injected epidurally.

Meyer's explanation of these contrast lines is thus wrong. Their occurrence proves that the contrast medium remains epidurally, and only for this reason are they of interest in this connection.

Characteristic of epidural localization of the contrast medium is further that one gets a picture more of the contour of the vertebral canal than of the spinal cord. When the contrast medium is seen epidurally, extremely vague contours are seen in the ventrodorsal picture. Towards the *cauda equina*, the spinal nerves are seen far outside the dural sac (Figs. 7-8).

After subarachnoid filling of contrast medium, the margins of the spinal cord, on the other hand, distinctly appear. The small budlike dural pouches at the nerve roots are seen, and one can also see the dural sac narrow towards the sacrum (Figs. 9-10-11).

No definite estimation of the value of epidural myelography can be given by the author. With regard to obvious superiority of subarachnoid myelography, there is neither any reason for investigating the value of it to any greater extent. Sometimes it happens, however, that one wishes to make a lumbar injection supplementary to a suboccipital injection. The contrast medium might then, by mistake, stop epidurally. In such a case the contrast medium will not be able to pass the protrusion which subarachnoidally has caused a total block.

An obturating protrusion may thus be detected, but the spread of the contrast medium within the epidural space is to such an extent irregular that no definite conclusions may be drawn from a broken contrast line.

PUNCTURE OF THE SUBARACHNOID SPACE

Almost every one that has performed myelography on dog points out that the best way of puncturing the subarachnoid space is to puncture suboccipitally into the *cisterna magna*. There are several good descriptions of how the puncture should be made, the best perhaps given in *Brook*'s previously mentioned work.

Therefore, there is no reason for a closer discussion of the technique. The fact might, however, be emphasized that suboccipital puncture is the only absolutely safe method. In every other part of the subarachnoid space within reach of puncture, the space is very small. Partly on account of this circumstance and partly because of the structure of the neural arches, lumbar puncture is difficult in dog. Brook writes: "The only interarcual space in the lumbar region of the dog which is sufficiently large to permit the passage of a needle, is the lumbo-sacral space. Reference to the dimensions and the disposition of the subarachnoidal space at this level, as shown by outlining it with lipiodol, confirms the well-recognized clinical fact that subarachnoid puncture at this level is either difficult or impracticable".

The last statement is true, but the first one is not in full accordance with facts.

Cadiot (1917) describes lumbar puncture in dog not only at the lumbosacral foramen, but also at the interarcual space between the 6th and 7th lumbar vertebra.

According to the present author's experience, a lumbar puncture in dog should be performed in the following way.

An attempt is first made to reach the dural sac lumbosacrally. The dog should be placed with the chest resting against a table and the hindquarters hanging on the edge of the table. In this manner a suitable kyphosis is brought about, and one gets the best filling of the dural sac. One can easily feel when the membrane that joins the arches of the vertebrae is pierced through. By small seeking movements one should then try to get beneath the dura. If the manipulation is successful spinal fluid will drip rather amply from the needle. While injecting, one must be very careful of not moving the needle, nor must one inject too rapidly. If one does, the needle may easily slip and the injection be made epidurally. *If spinal fluid does not drip*

the position is epidural and it is then well to try an injection between the 6th and the 7th lumbar vertebra.

The needle is introduced approximately one or two millimeters at the side of the spinous process of the 7th lumbar vertebra; the oral direction deviating about 30° from the vertical plane. In case one should not succeed at this place either, one may try between the 5th and the 6th lumbar vertebra. The skin is then pierced through about one cm. at the side of the spinous process of the 6th lumbar vertebra. After that one punctures somewhat in an oral direction with a sagittal deviation of about 30°.

Even if one reaches the vertebral canal, which is easily seen by slight twitches appearing in the hind legs and in the tail of the dog when the nerves and the cord are touched, this does not guarantee that spinal fluid will drip from the needle. As is previously mentioned, one will then have to try to draw back and insert the needle in order to reach the subarachnoid space.

When puncturing between the 5th and the 6th lumbar vertebra there is, of course, a risk of injuring the spinal cord. With the exception of some cases of slight cramps in the tail and hind legs, no complications have, however, been seen in connection with such punctures. The cramps have never lasted very long. In contradistinction to punctures of this type, suboccipital punctures are, as is previously mentioned, easy to perform in dog. One succeeds almost to a hundred per cent in getting the contrast medium into the subarachnoid space without complications. The following figures may give an idea of how difficult a lumbar puncture is.

Of 23 lumbar injections of contrast medium performed on clinical material, 11 were completely successful, 6 to such an extent successful that part of the contrast medium got into the subarachnoid space. Finally, 6 punctures failed completely inasmuch as the contrast medium in these cases remained epidurally.

CHOICE OF CONTRAST MEDIUM

Considering the fact that no excellent results (*Brook*, 1936, *Fankhauser*, 1948) have been reported in veterinary medicine on using oil myelography, the author gave up the thought of employing this form of myelography. Only by a contrast medium that mixes homogeneously with the spinal fluid, are we able to obtain roentgenograms that are as detailed as desired. It is true that air does not have this quality, but it is, however, rapidly resorbed and simple to use. For this reason it seemed well to try air myelography.

An experiment was carried out on four dogs, one of which had a disc protrusion, but the small column of air produced too poor contrast effect. Consequently the only choice left was a water-soluble or colloidal contrast medium.

According to *Lindblom* (1947), a 20 per cent solution of abrodil is the least irritating of all water-soluble contrast media. A 20 per cent solution of intron might possibly also be used.

In four experiments on dog kontrast U was used. In one of these cases the injection was suboccipital, in the other three they were lumbar. The dog that received the contrast medium suboccipitally was seized with severe clonic contractions in direct conjunction with the injection of 2 ml. of a 20 per cent solution. The animal died after 30 minutes.

The other three dogs (also under nembutal anaesthesia) received the contrast medium lumbarly mixed with equal amounts of 1 per cent xylocain[1] solution. Of these three dogs the first one received 5 ml. of a 20 per cent solution of kontrast U (a dose of 5 ml. is about as much as is required for a medium-sized dog in order to produce a fairly good contrast in most of the subarachnoid space). After an hour this dog was seized with severe clonic contractions which could, however, be cured by epidural anesthesia. But the dog died after 5 hours. The other two dogs survived. In these cases the dose was, on the other hand, very small and therefore gave a very low contrast.

These observations support the current opinion that this contrast medium is only useful in lumbar myelography.

In the literature of human medicine, importance is attached to the fact that the patient must be kept in a position that prevents the contrast medium from reaching higher than to the upper lumbar vertebra (*Denstad,* 1949).

After these experiments thorotrast was the only remaining contrast medium.

Regarding the usefulness of thorotrast in myelography, statements differ. According to *Pukanić* (1941) one should not be able to use this contrast medium suboccipitally. His opinion is perfectly contradictory to experimental investigations carried out by *Radovici* and *Meller* (1932), *Wustmann* (1933), *Jacobi* and *Löhr* (1933), *Nosik* and *Mortensen* (1938) and others.

After a preliminary experiment with thorotrast myelography on five young healthy dogs and a number of carcasses, the writer decided to try thorotrast on a large scale. For, as a matter of fact, the dogs

[1] Local anaesthetic.

showed very slight reaction after this myelography, and the roentgenograms that were obtained were very good.

The objections one might have, according to the literature, against thorotrast as a contrast medium in myelography are:

1. It is somewhat irritating.
2. The elimination of thorotrast is slight. It thus stays subarachnoidally rather long and is only gradually transported via the perineural lymphatic ducts by phagocytosis.
3. There may be a risk of increased intracranial pressure resulting in hydrocephalus.
4. Thorotrast is radioactive and, even if the activity is slight, it may be suspected to affect the organism (Reeves and Stuck, 1938).

These objections are serious enough. Observations concerning the first three particulars will be explained further in connection with a report on myelography on clinical material.

The fourth particular may, however, be discussed now. For natural reasons the author has no observations of his own to report, but the following statements may be given. The largest dose of thorotrast that one needs in myelography for a very big dog is 5 ml. Regarding alpha rays this dose should correspond to 0.2 microgram of radium at the very most. According to *Martland* (1929) alpha rays should be of much greater importance concerning injuries of the organism than beta and gamma rays. Even if their penetrative power is slight, they may inside the organism have a local injurious effect.

According to *Flinn* (1932), 1 or 2 micrograms of radium may be enough to cause radioactivity intoxication in man.

The absolutely largest dose that may be required for myelography is 5 ml. of thorotrast. A trained roentgenologist will manage to use half this dose. Considering this circumstance and the fact that a rather great part of thorium dioxide may be eliminated by a suitable method of drainage, one would be apt to believe that possible radioactivity injuries would develop very slowly.

Naegeli's and *Lauche*'s (1932-1936) experiments point towards that direction.

Knowing that disc protrusions usually occur in middle-aged dogs (*Fankhauser*, 1948, *Hansen*, 1951), we may be rather sure that no radioactivity injuries will appear during the rest of the dogs life; especially with regard to the fact that the central nervous system is comparatively resistant to radioactive influence. One must understand, however, that a risk might be involved in this respect when using thorotrast.

From every point of view, it would be best to try to remove the thorotrast from the cerebrospinal fluid after myelography.

In these experiments different methods of draining the subarachnoid space with physiological salt solution by means of needles inserted lumbarly and suboccipitally, were tried; but the altered pressure that occurred caused severe cramps.

A practical method is, however, the one suggested for the first time by *Kubie* and *Retan* (1933); later practiced by *Nosik* and *Mortensen* (1938).

This method, which Kubie and Retan called forced drainage of the cerebrospinal fluid, aims at provoking an oedema tendency by using large doses of a hypotonic NaCl solution intravenously. If the pressure in the subarachnoid space thus goes down by means of the inserted needle, the cerebrospinal fluid will be rapidly restored and flow out through the needle.

THE VALUE OF THOROTRAST MYELOGRAPHY SEEN AGAINST THE BACKGROUND OF CONTROLLING ITS RESULTS AT SECTION

MATERIALS AND METHODS

A detailed description of the best technique for thorotrast myelography on dog will be given subsequently.

A comparison between myelogram and sectional picture will be reported here. Myelography was performed on dogs which had been handed in for euthanasia and which at the time had clinical symptoms of disc protrusions, or had previously shown such symptoms. Furthermore, some dachshunds were included. In these cases the anamnesis gave no information about previous diseases. The material also included a couple of dogs which died directly on account of disc protrusions. The investigation comprised 34 dogs. Myelography was performed on the dogs either immediately before they were killed or directly after death except in two cases where the examination was not made until 24 hours after death. The live dogs were anaesthetized intravenously with nembutal. After that a cisternal puncture was made and thorotrast in different quantities injected. Finally the dogs were placed, with the head elevated, on a table slanting at an angle of 30° against the floor. After injection of thorotrast into the *cisterna magna*, the dogs that were already dead were hung with the heads high. After about half an hour the dogs were X-rayed; as a rule only in an A.P.

and a lateral projection. In a couple of cases thorotrast was injected lumbarly. All these dogs were subjected to thorough sections. The neural arches were removed and the dorsal surface of the vertebrae studied. Finally the discs were studied in cross-section.

Of these 34 dogs, 20 had one disc protrusion or more. One dog suffered from ankylotic spondylosis with osteophytes towards the vertebral canal. One dog had a granuloma that had grown through the intervertebral foramen and caused a compression of the medulla. One dog had a fracture of the spinous process with subluxation of one vertebra. In one dog widely spread haemorrhages were found in the spinal cord and in the subarachnoid space without disc protrusions. The other 10 dogs showed no changes.

There are reasons for emphasizing that myelography on carcasses should be performed before the body temperature has gone down. Otherwise the contrast picture will not be equivalent to that of a live animal.

RESULTS

Before the results of the comparing investigations are reported, it might be well to mention something about the normal thorotrast myelogram. The good contrast effect of thorotrast renders a very detailed picture possible. In the lateral picture one sees two distinct lines which mark the space of the cerebrospinal fluid dorsally and ventrally to the medulla. As the spinal cord of the dog usually is slightly kyphotic, the medulla is pressed towards the floor of the vertebral canal. The dorsal line will therefore be much broader than the ventral. The latter might even at times become to such an extent thin that it disappears above some disc or discs at the transition between the thoracic and the lumbar portion of the spine. In the posterior parts of the lumbar spine one can distinctly notice the nerve trunks that lead to the nerve roots. In the A.P. projection the lateral contours of the spinal cord and the dural pouches at the nerve roots are seen. Even those portions of the space of the cerebrospinal fluid that are not struck tangentally by the roentgen rays produce a contrast high enough to be slightly seen. Subarachnoid vessels are oftentimes clearly seen against the light background (Figs. 9-10-11).

In order to get a complete idea about the contour of the medulla, one should take some pictures in an oblique projection; *i.e.* the picture should be taken with the rays passing vertically and the dog lying more to the side than on his back. In this position the dural pouches will appear best.

By thorotrast myelography one can acquire a thorough knowledge of the conditions in the vertebral canal. According to what has been found in the present investigations, hardly a disc protrusion will be overlooked if the contrast medium only gets a chance to fill the subarachnoid space over the disc in question. Even protrusions barely one mm. high cause incurves of the contour of the spinal cord, in case they are not cervical or protrude from the two most caudal discs; the cervical and lumbar portions of the vertebral canal having the largest space in relation to the thickness of the medulla. It is not the very disc we see, of course, but only the impression that it causes in the medulla. A slight elevation of the dorsal surface of the disc may at times even be more obvious in the myelogram than at section. It is not only possible to study what discs are protruded but also oftentimes from what part of the dorsal surface of the disc the protrusion has arisen (Figs. 12-13-14-15-16).

If such a good idea can be formed about small disc protrusions, it would seem as though extreme protrusions would be still easier to diagnose. Rather paradoxically, however, that is not the case. Large acute protrusions cause a total block of the subarachnoid space (Figs. 17-18). Such protrusions are oftentimes very long and may even extend as far as to the disc next ahead. Furthermore, either the medulla or the epidural tissue, or both, may be sites of swellings in a rather wide region orally and caudally to the protrusion (Figs. 25-26). These conditions contribute to the fact that the contrast lines often discontinue rather far ahead of the protrusion and, provided that no directly roentgenological changes are present to arouse suspicions regarding some disc, one has no possibilities of localization. It should be mentioned that a lumbar puncture must be employed in these cases of total blockage. Even if such a puncture is made, one can not localize a protrusion that is situated between two others which have caused a total block. In such cases it would seem possible to use discography. Such an examination must, however, be made by fluoroscopy and is difficult and time-consuming for clinical purposes. An easier way of using discography would be to perform it while operating, after the suspected discs have been partly exposed.

As a matter of fact, however, the method of fenestration, which will be mentioned in a subsequent chapter, is very simple. It is therefore easier to fenestrate all the suspected discs.

No dogs seem to suffer from having several discs fenestrated.

Another condition that may render a localization impossible or even cause a misinterpretation of the myelogram, is found if subarachnoid haemorrhages complicate the course in disc protrusion (Fig. 19).

In such a case the blood will not allow thorotrast to mix with cerebrospinal fluid in a normal manner. The consequence will therefore be a thin contrast line, which diffusively disappears, or a blockage far in front of the disc in question.

The number of protrusions examined in the present material was 54. All protrusions were included, even the smallest ones measuring about 1×1×1 mm.[1]; regardless of whether they had caused compression or not, or whether a possible compression had caused symptoms.

Of 54 protrusions, 37 could be demonstrated and distinctly localized. Seventeen protrusions were not definitely provable.

Five protrusions had caused no compression of the spinal cord or the dural sac as they were situated between L.6-L.7-S.1 and had most likely caused no symptoms (Figs. 13-14).

As is known, the dural sac is lifted from the floor of the vertebral canal beginning at the 6th lumbar vertebra. A disc herniation in this region must therefore be rather large in order to cause an impression.

Four protrusions could not be established because of the fact that a total block of the passage of the cerebrospinal fluid was present orally to the protrusions. (Only suboccipital injection. All four protrusions occurring in one dog).

Five protrusions could not be diagnosed on account of the fact that subarachnoid haemorrhages had complicated the picture (3 cases).

Two protrusions were not localized on account of probable inflammatory swelling of the tissues of the spinal canal (2 cases).

One small protrusion of a cervical vertebra could not be demonstrated in spite of the fact that the contrast medium excellently filled the subarachnoid space. The reason may have been that the space of the cervical portion of the medulla is comparatively large, and a protrusion here must be larger than in most other parts of the vertebral canal in order to cause a compression.

In 6 dogs of the 20 with protrusions, the likely symptom-causing disc protrusion could not be exactly localized; 3 cases with subarachnoid haemorrhages; 2 cases with reactive inflammatory swellings; one case in which one protrusion had stopped the contrast medium from reaching the other protrusions.

As will be seen later, there is a definite contraindication to myelography in dogs with subarachnoid haemorrhages on account of their poor general condition.

According to the author's opinion, the results of this comparative investigation speak in favour of the belief that thorotrast is a good intraspinal contrast medium for obtaining distinct roentgenograms.

---

[1] Measurements in this work: Length × width × height.

CLINICAL OBSERVATIONS REGARDING THOROTRAST MYELOGRAPHY

METHODS

On the basis of the literature and with the support of results obtained in the present investigations, the following method of thorotrast myelography was worked out.

The dog is prepared for myelography by 24 hours deprival of food. A vein cannula is inserted and kept in position. The dog is anaesthetized with nembutal. It is then placed on its right side and a needle is inserted into the *cisterna magna*. The technique of cisternal puncture has been thoroughly described by, among others, *Brook* (1936) and *Frauchiger* and *Fankhauser* (1949), and details about it are therefore unnecessary. The importance of flexing the dog's neck proberly in order to faciliate the puncture may, however, be emphasized. The thorotrast is not injected until the cerebrospinal fluid has stopped dripping from the needle. The contrast medium is injected slowly. Regarding the dose of thorotrast, one should not dose according to body weight, as has often been suggested, but according to the size of the animal which determines the size of the subarachnoid space. For small dogs, *e.g.*, dachshunds, 1-1.5 ml. of thorotrast suboccipitally is enough for obtaining a clear picture. For a medium-sized dog the dose is 2.5-3 ml. and for a very large dog 3-5 ml.

After the injection is performed, the dog is immediately placed with the head high on a table slanting at an angle of 30 degrees against the floor. It is kept on the table for 10-15 minutes and should in the meantime be turned a few times to promote an even distribution of the contrast medium. Directing the rays vertically roentgenograms are then taken, in lateral—A-P and oblique projections. While lying on the table the dog should have its head on a pad in order to prevent thorotrast from rising into the subarachnoid space of the brain.

If the roentgenogram reveals a total blockage of the subarachnoid space, a supplementary lumbar injection of thorotrast should be made. How this injection is performed, is previously described. The dose of thorotrast varies from about 0.3 ml. for a small dog to 1 ml. for a large dog. Upon completion of the roentgen examination the needle is inserted into the *cisterna magna* again. Forced drainage is then instituted according to the method described for the first time by *Kubie and Retan* (1933) and later by *Nosik and Mortensen* (1938). An amount of 500-1000 ml. of a 0.45 per cent NaCl solution is injected

intravenously with an injection rate of about 30 ml./min. The needle is left in the *cisterna magna* until about 15 min. after completing the intravenous injection.

REACTION AFTER MYELOGRAPHY AND EFFECT OF FORCED DRAINAGE

Five experiment dogs (4-7 months old) on which myelography was first tried reacted very little. During the examination they became slightly stiff in the neck. The next day the temperature rose to 39° C., and the stiffness of the neck still remained. Appetite and general condition were not affected. Two days after myelography nothing abnormal could be noticed. The dogs developed normally and their growth rate corresponded to that of their litter mates. The dogs were killed 3-6 months after myelography. Since then 40 dogs have been subjected to thorotrast myelography for the purpose of diagnosis. The dogs aged from 1-8 years. Thirty-one dachshunds, 3 cocker spaniels, 1 Pekinese, 1 French bulldog, 1 boxer, 1 Airedale terrier, 1 Alsatian and 1 mongrel were represented in the material.

The dogs that were anaesthetized with nembutal showed no reaction whatsoever at injection. After about half an hour a slight stiffness of the neck as a rule appeared, however. This stiffness became more marked if the depth of the anaesthesia was not maintained. As is previously mentioned, one should keep the vein cannula inserted in order to maintain a good surgical anaesthesia. This arrangement also faciliates the X-raying. In five dogs a slight tonic contraction of the extensors of the back was noticed during the examination. The contraction was, however, removed by producing a deeper anaesthesia.

The effect that thorotrast myelography produced on the dogs after the anaesthetic had stopped acting (anaesthetic duration about 8-10 hours) was rather varying. One may divide the dogs into groups according to the manner in which they reacted. If one death, which will be reported under *Complications and Contraindications,* is excepted, the dogs are distributed in the following way:

Twenty-seven only showed slight tenderness and stiffness of the neck. No rise or only slight rise in temperature. Maintained appetite and unaffected temperament.

Ten showed evident tenderness and stiffness of the neck. Rise in temperature, poor appetite and obvious depression. They were also unwilling to move.

Two showed severe reactions. (These cases will be further discribed under *Complications and Contraindications*).

All the dogs in group 1 and 2 had quite recovered after two days.

Forced drainage was carried out on all the dogs except on three. On one of the three only lumbar injection of thorotrast was made. That dog reacted very little, the other two belonged to group 2.

Nosik and *Mortensen* (1938) point out that drainage mitigates the reaction after the examination. The author is not able to confirm this statement. There is too little material for comparison. Forced drainage is, however, such a simple method for removing part of the potentially injurious thorium dioxide that it may definitely be defended. By forced drainage one may withdraw as much as 12 ml. of cerebrospinal fluid from a small dog. Without forced drainage one can get 3-4 ml. at the most.

In 13 dogs the thorium dioxide contents of the cerebrospinal fluid that was obtained by forced drainage, was determined. Calculated in per cent of the suboccipitally injected thorium dioxide, values between 27 and 64 were obtained.

On an average about 40 per cent of the thorium dioxide that had been injected suboccipitally was removed by forced drainage. If a lumbar injection would also be made in cases of total blockage of the subarachnoid space, the percentage would be lower. Should one wish to drain the spinal fluid caudally to an obturating protrusion, the lumbar puncture would have to be repeated; a procedure that might be rather difficult and might not always succeed.

COMPLICATIONS AND CONTRAINDICATIONS

As is previously mentioned, one dog died after myelography.

Different causes contributed to this result. The dog was in a shock-like condition on account of an acute protrusion. Myelography was first carried out with air but failed. Thorotrast myelography was therefore immediately performed.

Furthermore, 1.5 ml. of nembutal was by mistake deposited extravascularly. The dog did not return to consciousness but died 16 hours after the examination.

One dog showed a violent reaction. Except for severe pain, this dog showed lameness of the right front leg similar to that found in injuries to the radial nerve. A disturbance of the static sence with a tendency to manège movements was also noticed. The symptoms gradually disappeared and were gone after three weeks.

Another dog showed extreme exitation for 12 hours.

Once suboccipital puncture failed, in spite of several attempts. Most likely a vein was injured already at the first attempt resulting in a haemorrhage. Myelography could not be performed. The next day the

dog showed a very slight reaction. After that it left the clinic, and there was no possibility of finding out why the injection had failed.

In two cases a certain aggravation of the nervous symptoms was noticed. This aggravation soon disappeared, however.

If the author should, on the basis of the comparatively limited material, dare to express an opinion about contraindications to thorotrast myelography, the following statement might be given.

A contraindication to thorotrast myelography is most likely present in shocks or when the general condition is poor.

DISCUSSION

There is reason for returning to *Reeve*'s and *Stuck*'s (1938) four main objections to thorotrast as an intraspinal contrast medium. Reeves and Stuck point out that thorotrast has an irritating effect. This investigation does not deny this statement. Its irritating effect is, however, to such a degree slight that there would be no reason to reject it in veterinary practice on that account. The reactions that were noticed after myelography at the beginning of these experiments were graver than those appearing after one had learnt to work with smaller doses. If small doses are thus used, and myelography is completed by applying forced drainage, the risks of complications seem to be very slight.

Another objection is that the elimination of thorotrast is insignificant. This disadvantage is undeniable. It is a condition precedent for the other two risks: hydrocephalus and radioactivity injury. Furthermore, this circumstance will cause difficulty in repeating a myelographic examination; it was, however, successfully tried in three cases. Thorotrast seems to disappear rather rapidly from the cerebrospinal fluid. Judging by the author's roentgenograms it is then found in the meninges. *Radovici* and *Meller* (1933) and *Wustmann* (1933) have noticed the same thing. In order to form an opinion about how rapidly thorotrast disappears from the spinal fluid the following circumstances were studied. Cerebrospinal fluid was taken a week after myelography and it then showed a slight opalescence.

After a month the cerebrospinal fluid was slightly yellowish, and the chemical analysis showed only slight signs of thorium.

After two months nothing exceptional could be seen, and the chemical analysis showed no signs of thorium.

On account of the risk of hydrocephalus in ventriculography and encephalography, Reeves and Stuck warn against using thorotrast

in such examinations. Their opinion being supported by their own experience as well as by that of other investigators. Colloid particles of thorotrast would block the resorption of cerebrospinal fluid. One has thus succeeded in causing hydrocephalus in cat by cisternal puncture with only 1 ml. of thorotrast. In order to avoid, if possible, the rise of thorotrast into the subarachnoid space of the brain, the heads of the dogs were always kept high during the examination as well as during the subsequent after-narcosis in the present investigation.

There is still another reason for trying to diminish the amount of thorotrast in the subarachnoid space of the brain. The reaction after periencephalography is much severer than after myelography; a fact that could be proved in 3 dogs.

The heads of 12 dogs on which myelography had been performed, were X-rayed and the fact could be proved that the amount of thorotrast was very small in the subarachnoid space of the brain. In most cases this control was carried out such a long time after the injection of thorotrast that the main part of the thorium dioxide was stationary. No dog was noticed to suffer from increased intracranial pressure. All the dogs could not be re-examined it is true, but contact was kept up with their owners.

Finally the author wishes to emphasize that thorotrast renders possibilities, which have not previously existed, for studying, *intra vitam,* morbid conditions in the spinal canal of dogs, even if it is not an ideal intraspinal contrast medium.

CHAPTER III

SOME CONTRIBUTIONS TO THE UNDERSTANDING OF THE PATHOGENESIS

CLINICAL DATA FROM AVAILABLE LITERATURE

The clinical symptoms of disc protrusion in dog are considered very changeable. As early as 1896 *Dexler* gave a clear view of this fact when describing the course and symptoms of 11 cases of the disease. He arrived at the conclusion that the disease could be insidious and chiefly of a rheumatic nature, or it could be acute causing sudden paraplegia. As varying as the symptoms and the course could be, as varying did the prognosis seem to be. Some cases would heal very quickly, others would require a long time for healing, finally, many would never improve.

Riser (1946) also emphasizes the great differences in the symptoms of the disease.

Fankhauser (1948) gives a good description of the disease. The following lines may be quoted from his work: "Häufig pflegt den klinischen Haupterscheinungen, den Lähmungen im Gebiet des Hinterkörpers (die der Krankheit auch den laienhaften Namen "Dackellähmung" eingetragen haben), ein Stadium heftiger rheumatoider Schmerzen der Rücken- und Lendenmuskulatur vorauszugehen. Die Tieren werden ausserordentlich bewegungsscheu, liegen fast beständig, erheben sich nur mit Mühe von ihrem Lager und reagieren auf das Tasten der gespannten Rückenmuskulatur, besondern aber auf Hochheben mit heftigen Schmerzäusserungen. Charakteristisch ist das Aufbiegen der Lendenwirbelsäule zu einem Katzenbuckel, was man wohl als eine "attitude antalgique" (Sicard) deuten darf. Allgemeinstörungen pflegen nicht zu bestehen; immerhin kommt es vor, dass die Tiere aus bewegungsunlust die Futteraufnahme verweigern. Nach und nach treten dann — unter Nachlassen der Schmerzerscheinungen — die eigentlichen neurologischen Symptome hervor. Die Bewegungen der Hinterbeine werden steif und ungeschickt, die Schritte tappend, ataktisch, die Pfoten werden mit dem Rücken aufgesetzt und nachgeschleift. Innerhalb von Tagen oder Wochen wird die Lähmung immer ausgeprägter,

bis die Tiere ihren Hinterkörper schlaff und bewegungsunfähig hinten nachziehen (sogen. Fischrobbenstellung).

Später nimmt der Tonus der Muskeln wieder zu, sie werden rigide und setzen der passiven Beugung der Gliedmassen erheblichen Widerstand entgegen. Die Tiere rutschen alsdann in sitzender Haltung, mit steif unter den Leib gestreckten Hinterbeinen, umher. Die gelähmte Muskulatur verfällt allmählich der Atrophie. In manchen Fällen ist auch der Schwanz gelähmt, der eigenartigerweise schlaff und tonuslos bleibt. Bei der Untersuchung der Sensibilität, die sich beim Hund leider auf die Prüfung der Schmerzempfindlichkeit beschränken muss, stellt man an ganzen Hinterkörper Hypo- oder sogar Analgesie fest bis in die Mitte der Lendengegend, wo sich oft deutlich eine schmale, gürtelförmige hyperalgetische Zone bestimmen lässt. Ihre kaudale Grenze liegt erfahrungsgemäss etwa zwei Wirbel tiefer als die Läsionsstelle des Rückenmarks. Die Patellarreflexe sind fast immer gesteigert, oft mit unterschieden zwischen rechts und links, der Analreflex häufig aufgehoben. Nicht selten treten, als mit Recht gefürchtete Komplikation, Störungen der Sphinkterenfunktion hinzu. (Retention oder Inkontinentz.) Die Untersuchung des Liquors (beim Hund nur suboccipital zu gewinnen) ergibt keine diagnostisch verwertbaren Resultate.

Der Verlauf ist recht ungleich. Viele Fälle gehen nach Wochen oder Monaten (dies wenn nicht langdauernde Sphinkterstörungen bestehen und wenn die Geduld des Besitzers so lange anhält) in mehr oder weniger vollständige "Heilung" über, rezidivieren aber meist nach etwa ein bis anderthalb Jahren wobei dann die Störungen bedeutend längere Zeit zu bestehen pflegen."

AFTER-EXAMINATION OF CASES TREATED AT THE MEDICAL CLINIC DURING THE YEARS 1940-1949.

In order to control, if possible, the correctness of the different opinions proposed in the literature about the course and prognosis of the disease, the author, in addition to his own material of 50 dogs, studied a number of cases registered at the Medical Clinic.

When re-examining records one may of course only to a certain extent determine the correctness of the diagnosis, if it has not been verified by roentgenological or patho-anatomical examinations. Therefore, only cases which, according to the records, showed definite signs of disc protrusion are included in this work.

During the 10-year period 1940-1949 all together 149 such dogs

with typical symptoms of disc protrusions were registered for treatment at the Medical Clinic. In these cases the disease showed the following course:

Five dogs died most likely directly on account of disc protrusion. (Spinal shock with subarachnoid haemorrhages).

Four dogs died from intercurrent diseases.

Thirty-four dogs were killed. (16 after more than two weeks' treatment).

Fifteen dogs left the clinic unimproved. (5 after more than two weeks' treatment).

Ninety-one dogs left the clinic showing improvement. (25 after more than two weeks' treatment).

The treatment included rest and daily injections of vitamin B_1.

The effect of vitamin B_1 will be briefly mentioned elsewhere. In this connection the circumstance might only be noted that vitamin B_1, which has a favourable effect on the metabolism of the nervous tissue, most likely only promotes the normal course of recovery of the disease. The figures, therefore, seem to indicate that the disease has a tendency towards self-healing; a fact that has been especially mentioned by *Riser* (1946) and *Fankhauser* (1948). One must, however, be cautious about drawing too far-reaching conclusions from these figures. Most dogs were far from cured, when they left the clinic.

In order to find out how the prognosis would turn out in the long run, certain questions were put to some owners of the above-mentioned dogs. All dogs from Stockholm, which had left the clinic alive during the years 1945-1949 after treatment for disc protrusion and whos owners had their telephone numbers in the records were included. Of 26 dog owners, 21 answered the questions which were the following:

1. Has the dog entirely recovered and if so, in how long a time?
2. Has the dog later on had similar trouble?
3. If the dog is dead, what did it die from?

The answers showed that the course of the disease in these 21 dogs had been the following:

Three dogs had recovered completely and had not been ill after they had left the clinic.

Two dogs had regained their faculty of locomotion but had not quite recovered.

Five dogs had recovered but had later had relapses. After that they had entirely recovered.

Two dogs had recovered but had later relapsed and had after that only partially shown changes for the better.

One dog still suffered from total paraplegia after 1¾ years.

Four dogs had been killed on account of nonrecovery.

Four dogs had been killed on account of one relapse or more.

As it is seen from this material, the prognosis seems to be poorer in the long run than one would expect, when studying the figures from the clinic.

On the basis of this material the problem in question will be further discussed in Chapter IV. There an attempt will be made to form an opinion about the time for recovery in conservatively treated cases.

SOME CLINICAL OBSERVATIONS WITH THE GUIDANCE OF 50 CASES IN WHICH THE DIAGNOSIS WAS DETERMINED ROENTGENOLOGICALLY AND/OR PATHO-ANATOMICALLY

The author himself had the opportunity of investigating 50 cases of disc protrusions. With the support of experience collected from these cases, the following viewpoints may be given.

In all the cases in which a compression of the spinal cord was suspected clinically, it was also proved by myelography and/or at section. Even in cases with very slight symptoms of a myalgic type were surprisingly large compressions found.

M 831/50. Dachshund, 7 years old, female.

Anamnesis: In the middle of October, 1950, the dog became unusually apathetic and was constipated. It preferred to remain lying and would at times howl, as if it were suffering from pain.

Status: On the 7th of November 1950: The dog was somewhat apathetic and showed slight tenderness of the belly. No other changes indicating disc protrusion could be noticed.

Myelography: Compression located at the disc between T. 11 and T. 12 with a total block of the subarachnoid space.

Having had the possibility of performing myelography even in very slight cases, the writer could get a better idea of the spread of the disease than was previously possible, when a positive diagnosis could be made only *post mortem.*

Judging from obtained results, it is most likely not an overstatement to say that most so-called rheumatism and myalgia in breeds exposed to disc protrusions are symptoms caused by such protrusions.

The great complexness of the symptoms in disc protrusion in dog renders it difficult to classify the disease into limited symptomatic groups. An attempt will, however, be made to report summarily, how the above-mentioned 50 cases were distributed from a symptomatical point of view. This is done especially for the purpose of directing

attention to symptoms which are often overlooked, or not put in connection with disc protrusions.

Five dogs were affected with paraplegia following trauma or great physical strain (4 died severely shocked by the disc protrusion).

Fourteen dogs fell ill with severe posterior paresis or paraplegia within 10 hours, without the owner having previously noticed anything wrong with the animal.

Nine dogs showed posterior stiffness, pain when being touched, apathy, and poor appetite for a few days or a week before they finally fell ill with paresis or paraplegia.

Seven dogs showed similar slight symptoms for several weeks or longer before they were affected with paresis or paraplegia. In many cases the first symptoms seemed to be constipation and slightly rigid abdominal muscles. Oftentimes paraplegia was initiated by a jump.

One dog showed slight paresis and pain for several months, only temporarily recovering.

Five dogs only showed "psychic depression", unwillingness to walk up and down stairs, and slight stiffness. These symptoms lasted for about a week.

Four dogs apparently suffered from back ache and were somewhat unwilling to move for many weeks. Their gait was stiff, and their backs were slightly arched.

Three dogs showed the same symptoms as the ones in the previous group, but were free from symptoms at long intervals.

Two dogs showed no symptoms, according to their owners. (At section the disc protrusions were secondary findings).

Of the whole material, 23 dogs had several attacks of the disease.

DISCUSSION OF THE PATHOGENESIS OF THE DISEASE

Previous clinical material as well as the present material supports what experience has proved to be typical of disc protrusion in dog; namely, varying symptoms, tendency, in many cases, to spontaneous healing, but also to relapses.

Thorough knowledge regarding the reasons why the disease shows a development like this, seems to be of great importance in choosing method of treatment. Therefore, this passage will be devoted to studying this problem.

As is already mentioned in the introduction, it is outside the scope of this work to discuss to any great extent neurological problems that might appear in this connection.

An endeavour is, however, made to put the above-mentioned characteristics in relation to the changes that appear in the intervertebral discs.

No thorough patho-anatomical examination has been made of the

parts of the nervous system that are dealt with here. Such an examination is perhaps not necessary although desirable as most likely the severeness of the symptoms may be put in direct relation to the injuries of the medulla and nerves.

With this limitation and mainly for the purpose of directing attention to problems which have hitherto been overlooked or only superficially dealt with in previous literature, an attempt will be made to answer the following questions:

1. What factors in connection with a disc protrusion determine the symptoms?
2. For what reason does paraplegia caused by protrusions oftentimes spontaneously heal?
3. Why do relapses occur?

WHAT FACTORS DETERMINE THE SYMPTOMS?

Riser (1946) writes: "Symptoms which accompany this condition depend upon two things, the location of the protruding discs and the degree of compression injury to the spinal cord".

According to the present writer's opinion, our knowledge concerning which factors determine the compression injury to the spinal cord is insufficient. From the literature one often gets the impression that the size of the protrusion should be decisive of the injury to the spinal cord. The rate of development of the protrusion and its way of developing seems, however, to play a still more important rôle.

One may get some idea of how important this dynamic factor is, if one bears in mind that slowly growing intraspinal tumours for a long time only cause slight symptoms, while, on the contrary, severe complications may follow an intraspinal operation, even if the medulla is carefully handled.

One's attention is directed still more to this dynamic factor when one sees, *e.g.*, how protrusions, which are almost equal in size, cause extremely varying symptoms. This circumstance is found in the cases mentioned below. The difference in symptoms of these dogs may hardly be explained by different localization of the protrusions.

K 753/50. Dachshund, 5 years old, male.

Anamnesis: **The dog had previously been healthy. For about a week, however, the owner had noticed that the dog had changed. It preferred to remain lying and would not come out to greet its owner when he came home. Nor did it like to walk up and down stairs.**

Status: **The dog moved normally. The only remarkable thing about it was slight rigidity and tenderness of the abdominal muscles. Reflexes were normal.**

Course: As the dog died after an operation, section could be performed. The following conditions were then found.

On the disc between T. 13 and L. 1 a protrusion 7 mm. long and about 4 mm. high was found. The protrusion was as wide as the vertebral canal and was rough and uneven. The surface showed comparatively severe haemorrhages.

M 865/50. Dachshund, 4 years old, male.

Anamnesis: For a year the dog had at times been unwilling to move. A few days before it was taken to the clinic it had started to show tenderness of the belly and arched back. Later it had difficulty in walking up and down stairs.

Status: On arriving at the clinic the dog had slight posterior paresis. When being strapped to the table for roentgen examination it cried out with pain, was seized with total paraplegia and was seriously shocked.

Course: The dog's condition grew worse and worse. Finally the dog was killed *in agone.*

Section revealed the following conditions.

On the disc between T. 12 and T. 13 to the left of the *ligamentum longitudinale* was a greyish, calcified protrusion measuring 6×3×3 mm. The protrusion was firm and incapsulated in connective tissue. It was partly broken through by a second protrusion extending in a cranial direction on the left side of the vertebra. In front of and to some extent behind it spread subarachnoid haemorrhages were seen.

K 758/50. Dachshund, 4 years old, female.

Anamnesis: Before admission to the clinic the dog had had a paraplegia for 4 days. The condition had developed in 12 hours.

Status: Spastic paraplegia with hypaesthesia.

Course: The dog was operated upon, but it showed no improvement and died from distemper 4 weeks later.

Section: The discs between L. 1 and L. 2 and L. 2 and L. 3 showed a ridgelike bulge in the *ligamentum longitudinale.* Concerning disc L. 2-L. 3 this ridge, besides, showed a cranial protrusion of the size of a pin's head. The preceding vertebra was covered with a greyish-yellow, rough tissue which made the bottom of the vertebral canal flat instead of concave.

Many more examples could be given. Here the fact will only be added, however, that the protrusions seemed to have had the character of an explosive emtying of the *nucleus pulposus* in all four cases in which total paraplegia and death had occurred in connection with the disc protrusions. The soft nuclear tissue had spread within the spinal canal and caused haemorrhages in and around the spinal cord, but it had caused no very noticeable compression.

To what extent the dynamic factor appears in the continued course of a protrusion is more difficult to find out. There are many circumstances, however, that speak in favour of the belief, that this factor plays a rather essential rôle in the maintenance of symptoms.

As is previously pointed out, slight symptoms of disc protrusion in dogs may show considerable duration in some cases, while in others a spontaneous healing occurs very quickly.

As will be particularized later, natural healing mainly seems to occur through a stabilization of the protrusion. One might then have a right to presume the following course at prolonged symptoms.

Via the rupture of the *annulus fibrosus* the protrusion is in contact with the *nucleus pulposus*. The altered pressure, which occurs within the disc when the animal moves and which is normally distributed over the disc, may then be transmitted to the protrusion and support an irritation of the nerves and spinal cord. After gradual stabilization of the protrusion alterations of pressure will be prevented from acting. Thus the symptoms will wane.

Many previous observations speak in favour of the belief that a dynamic factor may be expected to play a certain rôle in causing and supporting the symptoms of disc protrusions.

According to *Bradford* and *Spurling* (1947), the pain of spinal cord tumours is usually made worse by resting in bed, while the pain from a ruptured intervertebral disc is made worse by activity.

Fankhauser (1948) mentions a case in dog in which he could clearly notice that a protrusion increased when the dog's previously kyphotic back became less kyphotic. He considers this circumstance to explain why the dog in question had kept its back as kyphotic as possible. A pain relieving attitude has also been described in disc protrusions in man.

In discography in man (*Lindblom*, 1950) the patient may at times feel how his sciatica grows worse when the injection is performed into the ruptured disc. This circumstance may probably be due to increased pressure spreading to the affected nerve root.

The direct reason for emphazising the importance of the dynamic factor are, however, the results obtained especially in cases of prolonged symptoms by a new method of operation, called fenestration. Fenestration and its results will be closer discussed in Chapter IV. Here the fact will only be mentioned that disc fenestration mainly seems to act as a pressure-relieving factor. In this capacity it contributes to stabilizing the protrusion. In the above-mentioned cases prolonged symptoms were very quickly removed, as it seems, thanks to these qualities of the operation.

FOR WHAT REASON DOES PARAPLEGIA CAUSED BY DISC PROTRUSION OFTENTIMES SPONTANEOUSLY HEAL?

Principally there should be two ways of healing, provided that the changes which appear in the medulla are repairable. Either the com-

pression may decrease or the medulla may adapt itself to its new space.

Riser (1946) wishes to explain the healing in the following way: "The cases which have a tendency to improve are of the herniated type, where the *annulus fibrosus* bulges into the canal. The cases in which there is a complete rupture of the *annulus fibrosus* allowing an escape of *nucleus pulposus* into the canal cause a complete flaccid posterior paralysis and no improvement can be expected". Elsewhere he writes: "If the damage is mild, with only resultant edema and hemorrhage to the part, the paralysis will be only temporary and normal function will be restored when the hemorrhage and edema disappear.

"The injured disc, when of the herniated type, may also diminish in size by loss of edematous fluid, if the patient rest quietly and the body function remain normal. The disc which ruptures allowing the *nucleus pulposus* to flow out will never reduce in size. Cord damage is great in such cases and no hope can be given for recovery of these patients".

Frauchiger and *Fankhauser* (1949) write: "Da wäre einmal der schubweise Verlauf zu erwähnen, wobei die Attacken merkwürdigerweise etwa ein Jahr auseinanderliegen in der Folge jeweils stärker und länger werden aber von symptomlosen Interwallen gefolgt sind. Bei zur Jagd verwendeten Tieren beobachtet man ein vermehrtes Auftreten von Attacken in Zeiten starker Beanspruchung. Eine sichere Erklärung für die Tatsache, dass selbst anfängliche Schübe mit schweren Erscheinungen noch nach Wochen abklingen können, haben wir nicht, vermuten aber, dass hier Ödeme und beginnende entzündliche Reaktionen, also reversible Vorgänge die Symptome bewirken. Nicht zu vergessen ist das Stufenweise Nachlassen des Zentralnervensystems gerade komprimierenden Einflüssen gegenüber".

Studying different possibilities on the basis of the present material, the following circumstances may be noted.

In one case a diminishing of a calcified protrusion could be noticed in roentgenograms from different periods of time. (Figs. 22, 23, 24). One may of course raise the objection that the formation seen in the roentgenogram, can be something else than a calcified protrusion, as no patho-anatomical examination has been made to verify the absolute fact. The position of the formation over the disc, and its roentgenological appearance supports the opinion, however, that it very likely is a disc protrusion.

In another case, in which a dog (O 277/50) had had several relapses only one protrusion was seen at necropsy. In two other discs

were ruptures extending away out towards the spinal canal, but no nuclear material seemed to have protruded. The possibility must not be excluded that this might have been a resorption of protruded tissue of the type that *Hultqvist* and *Lindblom* (1950) describe.

The first one of these cases is, properly speaking, the only case here, in which one is able to see that a protrusion diminishes in size.

As a rule, considerable parts of the protrusions seem to become permanent in the vertebral canal, thus maintaining a certain compression of the spinal cord.

An acute protrusion seems to differ from a chronic mainly by being associated with severe acute inflammation of the surrounding tissues. When the protrusion turns chronic this inflammation heals, hence the compression should diminish somewhat even if the protrusion itself does not change very much. (No proliferative processes of importance seem to occur in protrusions according to *Hansen*, 1951).

As is previously mentioned in this work, the interpretation of a myelogram may at times be rendered difficult by the contrast medium being prevented from reaching the site of the compression. In certain cases this disadvantage seems to be caused by swollen tissues in the vertebral canal. An illustrative example of how such swelling may disappear, when the protrusion becomes chronic, is found in a case (O 935/50), in which myelography was repeated after 7 weeks (Figs. 25, 26).

It is seen how the contrast medium in the second myelography, but not in the first, reaches as far as the protrusion. This observation may support *Riser*'s, *Frauchiger*'s and *Fankhauser*'s statement that reversible processes like oedema may contribute to spontaneous healing.

In 1948 *Fankhauser* mentioned how very great the adaptiveness of the spinal cord is. This should be manifested by the fact that the cord is capable of normal function in spite of extreme compression. According to *Fankhauser*'s opinion this circumstance shows that we have functional possibilities regarding the canine medulla which are not found in man.

Here it might only be mentioned that the present material definitely supports *Fankhauser*'s belief that the spinal cord is able to function very well in spite of extreme compression. In many cases section revealed two protrusions of about the same size, one acute, the other chronic. In these cases it was seen from the anamnesis that the dog had been paralyzed once before, but had later been healthy until it relapsed.

O 852/50. Dachshund, 4 years old, female.

A year earlier the dog had suffered from posterior paralysis but had recovered in about a week. One day when the dog came running down the stairs, it was suddenly seized with paraplegia. The dog was then sent 500 km. by train to the Veterinary College.

Status: The dog was shocked. It lay on its side and could not get up. Subnormal temperature. Total paraplegia. No reflexes. Posterior numbness. Cystitis.

Course: The dog was killed *in agone.*

Section: On the disc T. 10-T. 11, to the right of the *ligamentum longitudinale,* was a comparatively fresh, greyish-yellow to greyish-red, partly calcified protrusion extending along the whole oral vertebra. It was about 4 mm. wide and 3 mm. high; brittle and rough. The disc was very thin. On the disc T. 13-L. 1 was a chronic protrusion with a fibrous adhesion to the dura. The protrusion was median and measured 4×2×1 mm.

The present material also includes a case in which the myelogram taken after the dog had recovered, is identical with the one taken while it was suffering from paraplegia. In this case recovery thus began without the myelogram showing any changes of the protrusion[1].

To secure further evidence regarding the statement that it is the trauma of the developing protrusion and not the protrusion itself that plays the most important rôle as symptom-causing factor, the following experiment was carried out.

Three dogs of about the same age and size were used as experimental animals. In all three dogs compression of the spinal cord was brought about in the following manner. After partial laminectomy a rounded piece of bone was placed in each of the dogs' spinal canal at the level of L. 1 and at the side of the medulla. One piece was twice as large as each of the other two. One of the small pieces was left. The other two were carefylly removed after 48 hours.

The symptoms were somewhat severer in the dog (O 462/50) that had had the largest piece inserted. All three dogs contracted paraplegia, however.

Dog O 462/50 (the one with the large piece of bone which had been removed after 48 hours) showed no signs of improvement for two months.

Dog O 463/50 (the one with a small piece of bone which had been left) *gradually improved and had almost recovered after two months.*

Dog O 470/50 (the one with a small piece of bone which had been removed after 48 hours) had recovered after about 6 weeks.

The dogs were killed 2 months after the interventions. Section showed evident compression of the spinal cord in the dog (O 463/50) in which a piece of bone had been left while, on the other hand, the

[1] Later many dogs have been myelographed after having recovered from paresis. In these cases complete block of the subarachnoid space has been found.

other two dogs only showed an adhesion between the dura and the epidural tissues at the site of the previous compression.

Histologically the following conditions could be noticed in the parts of the spinal cord that were affected by the compression.

O 462/50. In the whole section the spinal cord showed rather spread degenerative changes; on one hand very large holes in both halves of the spinal cord, on the other hand rather diffuse malacia and gliosis.

O 463/50. Compression myelitis affecting practically the whole right side except the most median part. The central canal was destroyed. Extreme gliosis and hole formations.

O 470/50. Compression myelitis affecting great parts of the right side. Rather extreme gliosis, hole formations.

The question how to explain recovery in cases of disc protrusion in dog, may perhaps summarily be answered as follows:

In most cases compression seems to decrease to some extent mainly owing to disappearance of the inflammatory reaction caused by the protrusion. However, it seems as though healing is conditioned mainly by the spinal cord's adaptability to altered space and by stabilization of the protrusion. The possibility of resorption of the protruded tissue must not, however, be excluded. Further, one example shows that a calcified protrusion can diminish in size.

Riser's opinion that only cases of the herniated type, may show improvement, is not shared by the present writer. On the contrary most protrusions that give symptoms are protrusions in which the *nucleus pulposus* has protruded into the spinal canal. The present material shows very clearly that cases with such protrusions are improvable..

WHY DO RELAPSES OCCUR?

With regard to the knowledge we have concerning the multiplicity of protrusions, it might seem easy to answer this question. A second protrusion from some other disc would thus be the most reasonable explanation of relapses.

In this investigation dogs that were subjected to post mortem examinations usually had a greater number of protrusions than the anamnesis gave occasion to suspect. Most likely many of the small protrusions had caused no symptoms; at all events no symptoms noticeable to the owner. This is proved by two cases. Together these two dogs had five small protrusions. According to the owners, the dogs had had no trouble, however.

As is previously mentioned, 23 dogs of 48 had several attacks of

the disease but were at intervals free from symptoms. Without doubt 6 (very likely 8) of these 23 dogs had fewer protrusions than attacks of the disease. Three dogs of the eight were subjected to post mortem examinations and five were diagnosed by myelography.

In at least six cases the relapses could thus not be explained by later occurrence of a protrusion at some other disc.

The causes of relapses have not been discussed to any great extent in the veterinary literature.

Owing to the fact that recurrent episodes of pain often occur in sciatica in man, some theories regarding the causes of these conditions have been proposed in human medicine.

Mauric (1933) suggested that herniation occurs by degrees rather than all at one time. It is possible that with a small herniation the streched nerve root might adapt itself gradually to its more circuituos course with cessation of pain. When more *nucleus pulposus* herniates, adaptation becomes impossible and pain persists.

Deucher and *Love* (1939) proposed the theory that intermittent oedema of the herniated material is responsible for the recurrent episodes of pain.

Bradford and *Spurling* (1947) write that herniation of the *nucleus pulposus* can occasionally become nonpainful by physiological destruction of irritated nerves. If only one or two spinal nerves are involved, the neurological deficit will be slight. The symptom could again become painful by the enlargement or shifting of the herniation to involve different roots.

As is mentioned in a preliminary report (*Olsson*, 1950), it may happen that a disc protrusion in dog gradually increases and thus causes relapses. Anyhow, in the 6 above-mentioned cases the explanation of the relapses was most likely to be sought in such a condition.

It might not, of course, be entirely excluded, that other factors than increase in size of an existing protrusion or protrusions from other discs may cause relapses. Observations have been made, however, that speak directly in favour of the belief that a protrusion may gain in size and thus cause a relapse. An illustrative example is found in the previously mentioned case M 865/50. (p. 43). In this dog an existing protrusion suddenly had increased when more nuclear material had been pressed out through the existing rupture.

Case M 210/46 may be mentioned as another interesting example. (Figs. 21, 22). This dog was seized with paraplegia in December, 1945. It improved rather quickly but relapsed in January, 1946. After two months' resultless treatment the dog was killed. Only one protrusion was found at section; namely, between T. 13 and L. 1. A roentgeno-

gram taken in December shows an evident calcification of this disc. Another roentgenogram taken 3 months later shows that the disc had diminished in volume and that its calcification had disappeared. Between the two attacks of the disease the disc had thus undergone a change. Most probably more nuclear material had protruded after the first roentgenogram had been taken. (*Pommer* (1937) has previously noticed that a calcification of a disc may disappear. He considers this condition a resorption).

By *Hansen*'s histological examination of disc protrusions (1951) in which he found pictures indicating that disc protrusions may occur by degrees, the present writer has received support for his opinion in this respect.

Finally, it will only be added that thorougher clinical and pathoanatomical studies are necessary for a proper understanding of the intervertebral disc problems that are discussed in this chapter.

CHAPTER IV

SURGICAL TREATMENT WITH SPECIAL REFERENCE TO THE VALUE OF DISC FENESTRATION

BRIEF SURVEY OF DIFFERENT METHODS OF TREATMENT

The methods of treatment of so-called *enchondrosis intervertebralis* in dog have varied in the course of time.

Hitherto the treatment seems, however, to have been conservative.

As *Bradford* and *Spurling* (1947) in perfect justice point out, the results of treatment in any disease which is characteristically subject to spontaneous remissions are, at best, difficult to evaluate. Improvement of symptoms is too often credited to the method of treatment, using the argument *post hoc, ergo propter hoc* without allowance for the natural course of the disease.

Electricity and strychnine treatment, injections of irritating substances and rubbing with skin-irritating ointments belong to a bygone time.

The modern conservative treatment aims at faciliating natural healing especially by rest, and thorough care; care for avoiding complications often following the disease.

By sphincteric disturbances ascending infections of the urinary tract occur. If the animals are not able to keep clean and dry decubitus and dermatitis are common phenomenons.

Riser (1946) attaches special importance to the fact that the affected animal is kept in a high state of nutrition.

Löfstedt (1941) especially recommends vitamin B_1 as an excellent means in so-called *enchondrosis intervertebralis*. He considers the effect to such an extent striking that he almost questions the conventional causal genesis.

In the light of later observations as to what actually happens in a spontaneous recovery, one need not, however, carry things so far as to question the genesis of the disease in order to find an acceptable explanation of the effect of vitamin B_1.

Knowing that vitamin B_1 can contribute to an improved metabolism of nervous tissue, one would be apt to believe that this vitamin by such an effect could contribute to quicker reparation of the nervous injury caused by a protrusion.

During the last 10-year period most cases of posterior paralysis in dog have, by routine, been treated with vitamin B_1 at the Veterinary College.

Even if surgical treatment never has been described in the literature, some authors have pointed out that such treatment might be tried.

Riser (1946) briefly writes: "Surgery is successfully performed in man in many of these cases. It remains to be seen to what extent surgery will be useful in the dog".

Frauchiger and *Fankhauser* (1949) write that their own experiments have shown that laminectomy is performable on dog, but that the small operation area, the multiple occurrence of protrusions, and the difficulty in exact localization to a great extent render surgical treatment difficult.

In human medicine one began in the 1920's to show greater and greater interest in disc protrusions and in surgical treatment of them. Especially cervical and thoracic protrusions with grave symptoms were then described.

Not until the thirties was it made clear how common especially lumbar disc protrusions are and what a great rôle they play as causative factors in lumbago and sciatica.

The credit for having directed attention to this circumstance is especially due to *Mixter* and *Barr* (1934). In Sweden *Friberg*'s work in 1941 opened up new ground for understanding these problems. Since the last part of the thirties the literature on surgical treatment of disc protrusions has been constantly growing.

At first the operation was performed radically by laminectomy and sometimes by transdural resection of the protrusions. Gradually the surgical technique was simplified especially in lumbar disc protrusions. In these cases a partial hemilaminectomy is, *e.g.*, now considered satisfactory. After such a hemilaminectomy the protrusion is removed and an incision is sometimes made into the disc for removal of nuclear material.

Another method is facetectomy.

The object with this method is partly to provide better space for the spinal nerve, partly to get at dorsolateral protrusions in the intervertebral foramen (*Hirsch*, 1947).

Disc degeneration in man does not only seem to cause disc protrusions and consequent compression of the nerve roots and the spinal cord, but it is also considered able to cause lumbago by certain phenomenons of instability in which influence on sensible nerves in the outer layers of the disc possibly might play a rôle (*Wiberg*, 1949).

The surgical methods applied in lumbago are especially different kinds of fusion. (*Unander-Scharin*, 1950).

Whether lumbago in this sense exists in dog or not, is difficult to determine. One may state, however, that in all cases with such symptoms in which myelography has been performed in this investigation protrusions have been found.

OBSERVED RESULTS OF LAMINECTOMY ON DOGS

From human medicine it is well known that interventions into the spinal canal, may cause nervous complications, however carefully the operation is performed. Animal experiments have shown the same thing (*Key* and *Ford*, 1948, *Junge*, 1950). Dogs were used as experimental animals for studying reactions of the disc to certain surgical interventions.

Key and Ford performed laminectomy or hemilaminectomy on 14 healthy dogs. Of these dogs 7 became affected with paraplegia and paresis. The only thing that struck the spinal cord was that it was carefully moved aside.

In the present investigation 5 dogs were hemilaminectomized. The operations were performed very carefully in order not to injure the medulla.

Two dogs were operated on, only for the purpose of finding out what technique to use. The dogs were very slightly affected by the operation.

The other 3 dogs were dogs in which clearly diagnosed disc protrusions existed. Two of the dogs which had only had pain and comparatively slight paresis before the operation were, it is true, releaved from their pain, but contracted postoperative paraplegia instead. After about 2 months they regained a certain faculty of locomotion.

One was killed after about 9 months on account of a relapse (protrusion of a different disc), the other was very vital after 8 months but had still not regained complete faculty of locomotion.

The third dog suffered from total paraplegia already before the operation. After 2 months it had improved to some extent. It was not possible to get any information respecting what later happened to the dog.

At hemilaminectomy in dog one must remove the articular processes of the vertebrae which surround the disc.

Othervise, one will not be able to expose enough of the dorsal part of the disc. The space of the spinal canal is very limited and it is very difficult to keep the medulla intact when trying to remove a protrusion. Healing after hemilaminectomy at times seems to reduce the space for the medulla due to voluminous cicatricial tissue. This circumstance is seen from sections performed in hemilaminectomized dogs.

The results of the above-mentioned radical intervention were not unexpected. Even from the very beginning the author's intention was to try to find a method of surgical treatment aiming at stabilization of the protrusion rather than at resection. The reason herefore was that natural healing seems to occur to a great extent by stabilization. Further, an intervention in the spinal canal causes a trauma to the previously injured medulla of such a nature that one might fear aggravation of the symptoms.

DISC FENESTRATION

For several reasons the decision was made to try the method of fenestration suggested for the first time by *Lindblom* in 1943 and modified by him in 1950. Primarily the method seemed to be simpler and safer than laminectomy.

Therefore, if it proved effective, it might be suitable in veterinary practice.

Secondarily, this was an excellent occasion to try experimentally a new surgical method. The results of such a trial might perhaps also be of some value to human medicine. (A number of cases, not yet published, have been operated upon at *Karolinska sjukhuset* and *Norrbackainstitutet.* The method is new in the respect of not aiming at intercorporal fusion but at unloading the pressure in the disc.)

The theoretical background of disc fenestration is the following.

Via the rupture of the *annulus fibrosus* the protrusion is communicated with the *nucleus pulposus*. By body motion the *nucleus pulposus* is exposed to pressure which is transmitted mainly to the protrusion via the rupture instead of being evenly distributed over the whole disc. To fenestrate means here to make an incision in the *annulus fibrosus* into the *nucleus pulposus* outside the vertebral canal.

The pressure on the protrusion should then decrease because of most of the pressure being conducted through the fenestra.

In cases of incomplete protrusions with only a bulge of the outer

layers of the *annulus fibrosus* this bulge should decrease; a fact shown by *Lindblom* in anatomical preparations.

From the general appearance of canine disc protrusions it would seem very reasonable that this would be the course of fenestration in dog. For, as a rule, the *annulus fibrosus* is comparatively intact, the rupture is slight, and the *nucleus pulposus* is fairly loose in consistency.

SURGICAL TECHNIQUE

A brief description will here be given of the surgical technique that proved to be suitable in this investigation.

An operation was never performed until 2 or 3 days after myelography in order to allow the reaction after this intervention to wane. Two variations of the method were used depending on the localization of the protrusions. If the protrusions were located between T. 12 and T. 13 or caudally to this disc the intervention was made dorsolaterally, as the discs were then within easiest reach. After a vein cannula had been inserted and the dog had been anaesthetized intravenously with nembutal and had been properly prepared for operation, it was placed in a prone position with a pad under the belly for obtaining a suitable kyphosis. (Fig. 29). The skin and *fascia lumbo-dorsalis* was cut through in line with and immediately adjacent to the *processi spinosi*. In dachshunds the length of the incision was from 12 to 15 cm. The dorsal muscles were stripped from the vertebrae with a raspatory far enough to expose at least 3 or preferably 4 vertebrae laterally down to their *processi transversi* or to the ribs respectively. (Figs. 27, 28).— It is very important not to injure vessels and nerves from the intervertebral foramen. Orientation is rather easy starting from the 13th rib. It should be emphazised here, however, that one should make sure that the triangular space formed between the 13th thoracic vertebra, the 13th rib, and the *processus transversus* of the first lumbar vertebra is localized. As the dorsal part of the 13th rib forms a very sharp angle against the spine, one may otherwise misjudge which of the vertebrae is the 13th thoracic one.

A self-retaining retractor was applied to widen the opening maximally. The disc in question was then fenestrated dorsolaterally with a small knife or lancet. (Fig. 28). The fenestra in the disc was made rather large (a diameter of 3 to 4 mm). As much as possible of the loose contents of the disc was removed with a scoop. The surrounding discs could easily be fenestrated through the same opening. For prophylactic purposes this was done in some cases. In

others it was done because the roentgenological localization had not been quite definite. In cases of several protrusions the protrusions are often located at discs near each other. (*Hansen*, 1951).

The fascia was sutured with catgut and the skin with stainless-steel wire. The wounds usually healed excellently.

After about 8 to 10 days the sutures of the skin could be removed.

As is seen from the description above, nuclear material was scooped out in addition to what *Lindblom* suggests for fenestration. This was done in order to remove such parts of the disc as could be expected to protrude later on. As a matter of fact this should not be necessary, however, even if, as will be demonstrated later, the outermost part of the fenestra becomes filled with a plug of granulation tissue.

With the exception of one case, only a few cases of slight complications were noticed in connection with this type of fenestration.

When the disc in the unsuccessful case was to be fenestrated, the lancet was directed to far ventrally and happened to get beneath and at the side of the vertebral column, and then pierced into the aorta. The dog died as the bleeding, which followed was noticed to late.

In two cases a slight temporary aggravation of the symptoms was seen on account of the operation. The reason herefore must most likely have been that too much violence was committed on the spinal cord while the muscles were being stripped. Very likely the medulla had been injured.

Sometimes serous exudate made drainage or puncture necessary after operation.

In cases in which the protrusions were located cranially to disc T. 12-T. 13 disc fenestration was performed transthoracically, as the position of the ribs and the thick layers of muscles here rendered dorsolateral fenestration difficult.

Intravenous anaesthesia with nembutal or a combination of intravenous and inhalation anaesthesia was used. In the last-mentioned case the dog was at first anaesthetized with pentothal sodium intravenously. With the skin over the left part of the thorax shaved it was then placed on its right side. After intubation anaesthesia was continued by inhalation of a mixture of Trilene (trichloroethylene) and oxygen according to a method described by *Obel* (1951).

The following surgical technique was used for transthoracic disc fenestration.

A piece about ten cm. long was removed just dorsally to the costochondral junction from the rib of the vertebra cranially to the protruded disc. The resection of the rib was performed in the usual manner *i.e.* leaving the periosteous hose (Fig. 30). Before opening the

thoracic cavity, which was done by an incision lengthwise in the periosteous hose, artificial respiration was initiated by rhythmic insufflation into the trachea (manual compression of the rubber balloon of the anaesthetic apparatus). The animal was overventilated in order to stop the spontaneous breathing-exercise. When using anaesthesia with trilene the tonus of the abdominal muscles had to be reduced with the aid of curare (0.2 mg. per kg. of body weight) in order to make the artificial respiration effective enough to induce apnoe. In nembutal-anaesthesia hyperventilation apnoe was easily brought about without curare. After the periosteum and the pleura had been cut through, the opening was widened maximally by hand retractors. The nearest 4 or 5 discs were thus within reach. The pleura was divided with a blunt instrument over the discs in question. Any vessels and nerve trunks on the ventrolateral surface of the vertebrae were carefully pushed aside. The fenestration was then performed in the previously described manner. (Fig. 31). The *pleura costalis* and the periosteum of the ribs were sutured with catgut. Before tighing the last sutures, the lungs were blown up to a maximal state of inspiration in order to avoid pneumothorax. The muscles were sutured with catgut, and the skin with stainless-steel wire. Healing advanced without complications[1].

RESULTS

As is previously mentioned, it is very difficult to make a statement about the therapeutical results of a disease which oftentimes heals without any treatment. Statistical analyses of treated and nontreated similar groups, should therefore be a good means of assistance. Dogs previously registered at the Veterinary College were the only material for comparison available to the author. Many factors rendered it rather difficult, however, to use this clinical material for such a purpose.

The records of the clinic are not of the kind that one can really form an opinion as to the disease and its course.

Despite lack of perfectly reliable material for comparison the author ventures to give an account of his observations, owing to the fact that the results in many cases have been such that they must very likely be ascribed to fenestration. Moreover, patho-anatomical examinations of fenestrated discs revealed many circumstances to

[1] After completion of this work several dogs have been fenestrated. No less than 3 have had protrusions of one cervical disc or more. Method and results of operation will be reported later. Observations made emphasize still more the value of fenestration.

support the view that the effect pursued, when using this method of operation, really was attained.

Before the results are examined, one should take into consideration what effect fenestration might likely be expected to produce.

In cases of extreme paresis or paraplegia one may hardly expect an improvement in direct connection to the operation. If a likely dynamic factor may be eliminated, it should be possible to promote recovery, it is true, but under all circumstances damage to the spinal cord caused by a protrusion necessarily requires a certain length of time for healing.

In cases of slighter symptoms conditions are different. The likely effect of an operation then, should be noticeable rather soon.

For this reason it was considered correct to divide the matreial into two main groups.

The first group consists of dogs in which symptoms of pain were predominant and motor disturbances less prominent.

The other group comprises dogs in which injury to the nerves and spinal cord was to such an extent grave that paresis and paraplegia dominated the symptoms.

Twenty-eight dogs were subjected to fenestration. The dogs aged between 1.5 and 8 years. The distribution among breeds was: 25 dachshunds, 2 cocker spaniels, and 1 Pekinese.

At first only the discs that had protruded were fenestrated, but gradually fenestration of adjacent discs was performed by routine. A couple of dogs had even 5 or 6 discs fenestrated. The dogs did not seem to suffer any distress from having as many discs as that fenestrated.

Group I comprises 12 surviving dogs.

These dogs all recovered. Considering the existing possibility of self-healing, this result must not quite simply be ascribed to the operation. *It is very remarkable, however, that 8 of these dogs did not only recover, after operation, but also regained a vitality not seen since long before their owners had noticed the disease. Being very astonished at the remarkable change, the owners themselves reported this circumstance.*

The explanation of this phenomenon seems to be that the dogs were relieved from pain which they had most likely suffered from for a very long time. Their pain had not caused objective symptoms noticeable to the owner.

One dog in this group died on account of the operation.

Group II comprises 13 surviving dogs.

In one dog the intervention produced the same surprising result as in the previously mentioned 8 cases.

In this group, however, only a few cases showed a *restitutio ad integrum*, but all the dogs except one regained their faculty of locomotion. Only a trained observer could notice slight ataxia.

One dog was killed 2 months after fenestration, one died from an intercurrent disease.

BRIEF SUMMARY OF CASUISTRY

The letters and figures in parenthesis indicate the dogs number in the records. M = Medical clinic. K = Surgical clinic.

Naturally, an arrangement like the one made below will be somewhat schematic as the varying symptoms would not otherwise allow classification.

Group I.

a) (M 720/50, M 853/50, M 930/50, M 992/50).

The four dogs showed evident symptoms of pain and unwillingness to move for 1 to 2 weeks. In one case slight paresis and in another *incontinentia urinae*, gradually, complicated the symptoms. After operation the dogs recovered within 1 to 2 weeks. In three cases the owners even wanted to call their dogs "new" after the operation. The dogs had a better appetite, were livelier, and had a better coat of hair than they had had for many months.

b) (M 591/50, M 875/50, M 935/50, K 557/50).

Before these dogs were operated upon they had had rather prolonged trouble (from 3 weeks to 3 months). There symptoms had especially been pain and unwillingness to move. Noticeable paresis only occurred in one case. All the animals were treated with vitamin B_1 without results.

After fenestration the dogs recovered completely within 1 to 2 weeks.

It is remarkable how three owners also in these cases spontaneously said that their dogs had become livelier and healthier than they had been for a very long time before the operation.

c) (M 246/50, M 295/50, M 389/50, K 692/50).

For as long time as from 4 months to 2 years these four dogs had suffered from recidivous paresis and pain, with the almost symptomfree intervals being rather long. After operation they recovered from their acute symptoms within 1 to 4 weeks. They became livelier and had a better appetite than before. In one case slight ataxia remained. Two of these dogs became better than they had been for many months before the stated time of falling ill.

Group II.

a) (M 909/50, M 941/50).

These two dogs had suffered from severe posterior paresis for a few days when admitted to the clinic. One case was a relapse after 10 months, the other was a first attack. One of the dogs recovered 12 days after operation, the other in 9 days. The latter dog was livelier than it had been for a long time before falling ill.

b) (M 817/50, K 625/50, K 736/50, K 863/50).

These four dogs fell ill with paraplegia a few days before operation. Their paraplegia was slight, reflexes were well maintained, and the tonus of the tail was unaffected. Certain signs of improvement even before operation. The dogs had recovered after 3, 4, 2, and 2 weeks, respectively.

c) (M 654/50, K 710/50, K 720/50, K 3/51).

For a short time these dogs had suffered from paraplegia of about the same type as that of the previous group. No signs of improvement before operation. All the dogs recovered although not until 9, 3, 8, and 3 weeks, respectively, after operation. Improvement gradual as in all other groups.

d) (M 288/50, M 583/50, M 911/50).

These three dogs had had spastic paraplegia, two for a few days before operation, one for 2 weeks. After operation two of the dogs recovered, but not until 5 and 9 weeks, respectively, after operation. After 20 weeks the third dog still suffered from paresis.

The dog that was killed should have belonged to Group II, c. After 7 weeks it had improved considerably. The dog that died from an intercurrent disease, should have belonged to Group II, d. After 4 weeks it had not recovered.

A COMPARISON BETWEEN CONSERVATIVELY AND SURGICALLY TREATED CASES

The results of an investigation concerning the course of the disease in 21 cases with disc protrusions, are briefly reported in Chapter III.

In this investigation which was based on information from some dog owners, a question about the length of time required for recovery was included.

These 21 conservatively treated dogs may hence be used for comparison with the dogs operated upon, although certain objections might be raised.

For instance, the dog owners might not always have given quite reliable information as to dogs which had recovered 4 or 5 years earlier. (Most of their information was, however, very explecit).

Furthermore, the information given in the records is very meagre.

The above-mentioned sources were the only ones available, however.

One should observe that the conservatively treated dogs are taken from a group which does not quite represent the clinical material. All the dogs that died or were killed at the clinic were not included in the material for comparison. This circumstance emphazises the difference which seems to exist in the two groups.

None of the conservatively treated dogs showed such improvement as did the previously mentioned 9 disc-fenestrated dogs.

GROUP I
Symptoms: Pain or pain and slight paresis.

Treatment: Operation. (Fenestration).

Number of dogs	Time of recovery	Remarks
9	< 2 weeks	—
2	3 „ (approx.)	Remaining slight ataxia in *one* case.
1	4 „ „	—
1	—	Died on account of operation.
Total 13		

Treatment: Vitamin B_1, rest.

Number of dogs	Time of recovery	Remarks
3	< 2 weeks	Remaining slight ataxia in *one* case.
1	3 „ (approx.)	—
2	4 „ „	—
2	—	Killed unimproved after approx. 4 weeks.
1	2 months (approx.)	Still affected with ataxia.
1	—	Killed after 14 months' bad trouble.
Total 10		

GROUP II

Symptoms: Severe paresis or paraplegia.

Treatment: Operation. (Fenestration).

Number of dogs	Time of recovery	Remarks
4	< 2 weeks	—
3	3 „ (approx.)	—
1	4 „ „	—
1	5 „ „	—
1	8 „ „	—
2	9 „ „	—
1	—	Improvement but remaining paresis after 5 months.
1	—	Killed after 7 weeks, noticeable improvement.
1	—	Died from intercurrent disease unimproved 1 month after operation.
Total 15		

Treatment: Vitamin B_1, rest.

Number of dogs	Time of recovery	Remarks
2	< 3 weeks	—
1	4 „ (approx.)	—
1	6 „ „	—
1	—	Some faculty of motion after 5 weeks, gradual improvement.
1	—	Killed after 4 weeks, unimproved.
2	—	Killed after 3 months, unimproved.
1	1 year	—
1	—	Gradual improvement. Still not well after 2½ years.
1	—	Total paraplegia even after 1 year and 9 months.
Total 11		

PATHO-ANATOMICAL EXAMINATION OF FENESTRATED DISCS

MATERIAL

In dogs, *Key* and *Ford* (1948) made interventions very similar to disc fenestration. They studied the reactions of discs at different periods of time after such interventions.

However, they seem to have used young dogs with perfectly normal discs. One must therefore be very careful in drawing conclusions from their investigations regarding the manner in which degenerated discs react to fenestration.

The present investigation includes sound as well as degenerated discs.

A number of discs of 2 dogs of a nonchondrodystrophic type were fenestrated.

In dog No. 1, 5 months old, 2 discs were fenestrated. The dog was killed 6 months later. Together with a number of nontreated discs, the fenestrated ones were subjected to patho-anatomical examination.

In dog No. 2, 1 year old, 5 discs were fenestrated. The dog was killed 2 months after operation. Autopsy was carried out.

Four dogs of a chondrodystrophic type were also subjected to section at different periods of time after fenestration.

One of the dogs (O 973/50) was killed at the age of 5 years 9 months after it had had one disc fenestrated.

Anaother dog (O 935/50), 4 years old, was killed 7 weeks after 6 discs had been fenestrated.

The third dog (O 987/50), 4 years old, died from an intercurrent disease 4 weeks after 3 discs had been fenestrated.

The fourth dog (O 128/51) was killed 10 months after one disc had been fenestrated.

Roentgenograms were taken at different periods of time before and after operation. In all dogs, except in 0 987/50, a narrowing of the intervertebral space was noticed after fenestration. *In dog No. 1 the fenestrated discs had regained normal thickness after a few months.*

Judging from the whole material of dogs operated upon, it seems as though a disc usually decreases in thickness after fenestration.

RESULTS

The following conditions were revealed at patho-anatomical examination.

Dog No. 1.

All the discs, except the fenestrated ones, showed a gelatinous water-clear *nucleus pulposus* (Fig. 34). The thickness of the fenestrated discs was normal. The cut surface was, however, abnormal. The gelatinous *nucleus pulposus* was replaced by firm slightly brownish tissue diffusely merging in the *annulus fibrosus* (Fig. 35). The brown tissue passed through the fenestra of the *annulus fibrosus* to the outermost layers of the disc. These layers were here abnormally thick. *Histological examination showed that chondroid tissue of a type which may appear in discs of old dogs, had replaced the normal nucleus pulposus* (Figs. 36, 37). No distinct boundary could be seen between the inner layers of the *annulus fibrosus* and the new tissue of the *nucleus pulposus.*

Dog No. 2.

This dog mainly showed the same kind of changes as did dog No. 1. The fenestrated discs were, however, not of normal thickness. Nor had the outer layers of the *annulus fibrosus* reacted to any great extent.

Both cases mentioned above were cases having perfectly sound discs. At fenestration the gelatinous tissue of the *nucleus pulposus* had extruded through the fenestra of the *annulus fibrosus.*

Entirely different conditions were found in the other four dogs whos discs had been fenestrated and later been subjected to section.

In these cases the *nucleus pulposus* consisted of a granular mass which had to be scooped out of the disc.

The macroscopic picture at cross-section of the discs of these chondrodystrophoid dogs differed in some respects from the other dogs.

A suitable example to illustrate this statement is dog O 935/50.

After suddenly having fallen ill with paraplegia, this dog, a 4-year-old female dachshund, was subjected to two operations, one 12 days after the other. No less than 6 discs were fenestrated (T. 8-T. 9; T. 9-T. 10; T. 10-T. 11; T. 11-T. 12; T. 12-T. 13; T. 13-L. 1). The reason why that many discs were fenestrated was that no definite localization had been possible.

Improvement advanced slowly. As long time as 7 weeks after the first operation the dog could only walk a few wobbling steps. The owner was then persuaded to have the dog killed.

GROSS EXAMINATION

Section revealed that it was disc. T. 11-T. 12 that had protruded. The protrusion was located on the left side of the 11th thoracic vertebra. It was as wide as quite half the vertebral canal and about ½ to 1 mm. high. It had only caused slight compression of the spinal cord.

The fenestrated discs were thinner than normally. At macroscopic examination of the discs after cross-section it was seen that the fenestrated discs mainly differed from the non-fenestrated by being brownishly discoloured in the centre and by having a fenestra in the *annulus fibrosus* as far as the centre of the disc. This fenestra was filled with brown tissue (Fig. 33).

Some of the fenestrated discs also gave the impression of having a firmer consistency especially in the inner layers of the *annulus fibrosus* than did the nonfenestrated.

The following discs showed roentgenological or histological signs of having been degenerated before fenestration (ruptures of the *annulus fibrosus* very likely existing previously to the intervention, or calcification of the *nucleus pulposus*) T. 8-T. 9; T. 9-T. 10; T. 11-T. 12; T. 13-L. 1; L. 4-L. 5. (The last-mentioned disc not fenestrated).

DESCRIPTION OF HISTOLOGICAL CHANGES

Fenestrated discs.

Disc. T. 8-T. 9.

The *nucleus pulposus* has shrunk. It is the site of granular necrosis in which the chondroid character of the tissue still may be noticed. Via a rupture in the *annulus fibrosus* the nuclear mass dorsomedianly reaches as far as the *ligamentum conjugale costarum*. In its inner layers the *annulus fibrosus* is fairly wide having a rather great collagen content. Ventrolaterally the state after fenestration is seen in the form of a wide fenestra through the *annulus fibrosus*. Near the fenestra the lamellae deviate outwards. The remaining nuclear mass seems to press on. Granulation tissue defined inwards by several layers of mononuclear cells (macrophages) is seen as a plug in the outermost part of the fenestra. Moreover, this plug consists of chronic granulation tissue in which are islands of calcified nuclear necrotic tissue. These islands are enclosed by the same kind of mononuclear cells as well as by polynuclear giant cells (Fig. 40).

Disc T. 9-T. 10.

State after fenestration the same as above. The *nucleus pulposus* is practically emptied. Extreme granular degeneration of the inner layers of the *annulus fibrosus*. Dorsomedian rupture as far as the outer dorsal lamellae. Here a plug of granulation tissue completely blocks.

Disc T. 11-T. 12.

A great deal of the very necrotic *nucleus pulposus* is still left in the form of a loose, finely granulated mass. There are also areas with less advanced necrobiotic tissue in which the structure of the cells may still be noticed. Dorsomedian rupture with protrusion of necrotic parts of the *nucleus pulposus*. In this section the protrusion has stopped, however, at the outermost lamella.

The rupture is vascularized as far as the innermost part of the *annulus fibrosus*.

State after fenestration ventromedianly with the same abrupt margin between the plug of granulation tissue and the other part of the disc. The fenestra also shows some vascularization.

Disc T. 13-L. 1.

The very necrotic chondroid *nucleus pulposus* still exists to some extent. Considerable evacuation seems to have taken place, however. Dorsolaterally the state after fenestration is seen. With a linear boundary towards the disc, granulation tissue of a very cellular and vascular type is seen in the fenestra. Outside are remainders of necrotic *nucleus pulposus*.

Non-fenestrated discs.

C. 7-T. 1.

The *nucleus pulposus* shows no actual chondroid transformation. On the other hand it shows slight fibrosation and degenerative changes.

L. 4-L. 5.

The *nucleus pulposus* is completely transformed into chondroid tissue. It shows very spread regressive changes. The intact areas show extreme progression of cells.

The three other chondrodystrophoid dogs principally show the same changes of their fenestrated discs as do the ones mentioned above. In these dogs progressive changes appear to a somewhat greater extent, especially in the form of thickened inner layers of the *annulus fibrosus* and partial filling of the *nucleus pulposus* with collagenous tissue. In one disc, having been to such an extent injured that the cartilage plates have been damaged, is even a formation of bone.

This examination shows that the difference in reaction against fenestration is very great in young sound discs and in degenerated discs.

While progressive processes play an important rôle in a sound disc, they are of very slight importance in a degenerated disc.

In the degenerated disc one may, however, at times find thickened inner parts of the *annulus fibrosus* possibly as an expression for an effort to fill the "emty space" left after the removal of the *nucleus pulposus*. The thickening of the *annulus fibrosus* is most likely partly apparent, for by its elasticity the *annulus fibrosus* might likely be capable of contraction. Hence, it might be able to partly fill the "emty space". From the histological picture one might sometimes get the impression, however, that a reaction of tissue really is caused within the disc. Collagenous and cellular content seem to increase. (Figs. 38, 39).

DISCUSSION

As is previously mentioned, the comparison between the results of the conservative and surgical treatment is not claimed to secure final evidence as to the effect of fenestration, even if one has the impression that a difference exists in the results between the two methods of treatment.

It must be considered evident, however, that disc fenestration in some of the described cases of spinal compression in dog caused by disc protrusion has produced a manifested effect.

The 9 cases in which the operation did not only cause recovery but also contributed to forming a new opinion about the course of the disease, are then especially borne in mind.

The circumstance that the dogs were restored to a state not seen for months or years before their owners' observations of first attacks of the disease, must most likely indicate that the course had been more

chronic than the anamnesis showed. In these cases the disc protrusions (disc degeneration) had hence caused symptoms long before any symptoms could be clinically diagnosed.

No such effect could be noticed at conservative treatment.

Patho-anatomical examinations carried out after fenestration showed that the reaction of the degenerated discs was comparatively slight. The injured parts of the *annulus fibrosus* were not repared.

It is true that a plug of granulation tissue was formed in the peripheral part of the fenestra of the *annulus fibrosus*, but it was rather slight and of about the same type as the ones that may be seen after spontaneous rupture of a disc.

If the disc is subjected to pressure, this pressure will most likely in the first place be conducted via a great artificial defect of the *annulus fibrosus* and not via a slight spontaneous rupture.

To the extent that proliferative processes occur in a fenestrated disc, they are of such a type that they might serve the purpose of forming stabilized conditions inside the disc. This is especially the case with the thickened inner layers of the *annulus fibrosus*.

The results of the reported investigation speak in favour of the view that fenestration can to some extent reduce the dynamic factor that may influence the occurrence of a protrusion or prevent stabilization of an already existing protrusion.

Nothing supports the belief, however, that a protrusion should be able to decrease by fenestration. A bulge in which the outer lamellae still are intact may possibly do so, but a protrusion that has already spread like a layer over a whole vertebra and is attached to the *nucleus pulposus* only by a very narrow rupture may hardly be capable of decreasing.

Very likely the prophylactic effect of fenestration is greater than the therapeutical, for if the whole *nucleus pulposus* is removed there is nothing capable of protruding. If the whole *nucleus pulposus* is not removed, there might be the risk of a protrusion, it is true, but it might first of all develop via the artifical rupture of the *annulus fibrosus*.

For the same purpose as disc fenestration is tried, namely, for preventing more nuclear material from protruding and in order to prevent pressure on the disc from being transferred to a protrusion, other methods have also been successfully used in human medicine.

Surgical interventions similar to fenestration have often been made in connection with laminectomy and resection of protrusions. Bearing in mind that more nuclear material may protrude after resection of a protrusion *Barr*, in 1937, *e.g.*, writes: "What is to prevent further

extrusions of disc tissue with recurrence of root pressure? The one therapeutic defense against this event would seem to be the thorough removal of the nuclear material at the time of the operation plus spinal fusion of the affected area". What Barr pleads for here is a type of fenestration performed from the vertebral canal.

Regarding the indications of fenestration in disc protrusion in dog the following viewpoints may be given. Breeding-hygienic measures should of course come in the first place owing to the fact that the disease is typical for certain breeds. (*Hansen*, 1951).

Oftentimes a dog owner, however, wishes to have all therapeutical possibilities tried on his animal.

As there are prospects of good effect in many cases, such interventions as myelography and disc fenestration may certainly be defended in veterinary practice.

Cases in which the symptoms do not seem to be too serious and in which conservative treatment has been proved ineffective, are the ones that seem to be most fitted for surgery.

Many are the advantages of fenestration over interventions into the vertebral canal.

The risk of injuries to the nerves and to the medulla are minimal.

A very large number of discs may be fenestrated without disadvantage to the animal. In this respect it is of great importance to have the possibility of fenestrating discs which are located near a protruded disc. The risk of relapse might then decrease as it has been proved that disc protrusions often occur at adjacent discs. (*Hansen*, 1951).

Bearing these facts in mind, one may also recommend disc fenestration as a general means of treatment of disc protrusions in dog, of course, with the restrictions necessary from an economic viewpoint and with regard to animal protection.

Finally, the fact might be pointed out that, as far as conditions in disc protrusion in dog and man are similar, the results of this investigation might contribute to the debate on the most suitable surgical technique in disc protrusion in man.

SUMMARY

1. A comparison was made between sectional picture and roentgenogram of 33 dogs with 54 disc protrusions.

According to this investigation the changes found in the roentgenogram are: Calcification of the protrusion, reduced space between surrounding vertebrae, calcifications of the disc, and marginal deposits on surrounding vertebrae.

Of these changes the first-mentioned is the only one that proves occurrence of a protrusion. Whether the intervertebral space is diminished or not is difficult to decide. If such a change exists, however, this will very likely indicate that the disc in question has protruded. The other changes mentioned are not pathognomonic of disc protrusion. Further, many disc protrusions do not show any changes in the roentgenogram. Of the 54 disc protrusions mentioned above, 26 could be diagnosed by ordinary roentgenograms.

2. Experimental and clinical investigations were carried out in order to find out which contrast medium is best for myelography in dog and how it should be applied.

Thorotrast proved better than air, iodized oil, and water-soluble contrast media.

Subarachnoid myelography proved superior to epidural myelography.

3. Twenty dogs with disc protrusions were subjected to section after myelography with thorotrast for the purpose of controlling the diagnostic value of the method. This investigation demonstrates that even very small protrusions may be diagnosed by thorotrast myelography provided that they cause a bulge in the dura and that the contrast medium reaches the protrusion.

The commonest reason why the contrast medium does not reach a protrusion is a total blockage caused by some other disc protrusion, inflammatory swelling in the vertebral canal and haemorrhages in the subarachnoid space.

4. Thorotrast myelography was tried clinically on 40 dogs. The complications seen after myelography are as a rule slight. The only contraindication is poor general condition.

5. The records of 149 dogs, which had been treated at the medical clinic of the Veterinary College, were studied. The continued course of the disease was thoroughly studied in 21 cases.

The circumstance was revealed that disc protrusion in dog is oftentimes characterized by a tendency to spontaneous healing. In spite hereof the prognosis is not good on account of frequent recurrences.

6. On the basis of 50 cases examined by the author, which were definitely diagnosed with the aid of myelography and/or at section, the causes of certain typical characteristics of the pathogenesis are discussed.

The manner in which a disc protrudes and altered pressure in the protruded disc (the dynamic factor) seem to determine the symptoms of disc protrusion in dog to a great extent.

The process of healing mainly seems to depend upon elimination of this dynamic factor as well as on the great adaptiveness of the medulla.

Relapses are not necessarily due to protrusions of other discs. In certain cases a disc may protrude by degrees and thus cause relapses.

Disc protrusion is most likely a common cause of so-called myalgia and rheumatism in dog.

7. Twenty-eight dogs with disc protrusions were operated upon according to a new method called disc fenestration. (*Lindblom*).

To fenestrate means to make a hole in the *annulus fibrosus* as far as the *nucleus pulposus*. Fenestration is performed dorsolaterally or ventrally. The object is to unload the pressure and thus eliminate the dynamic factor.

The effect of disc fenestration was evident in slight cases of the disease. Many dogs operated upon became more vital than they had been since long before the owners had noticed the dogs falling ill. This seems to indicate that the disease runs more of a chronic course than do the symptoms give occasion to suspect. A comparison between conservatively treated dogs and dogs treated by means of fenestration seems to indicate a certain effect even in cases of grave symptoms.

8. Six dogs in which the discs had been fenestrated were subjected to section after varying lengths of time. The changes which appeared in the discs were such that they seemed to confirm the pressure-unloading effect of the operation.

ZUSAMMENFASSUNG

1. Eine vergleichende Untersuchung zwischen Sektions- und Röntgenbild an 33 Hunden mit zusammen 54 Discusprotrusionen wurde ausgeführt.

Entsprechend dieser Untersuchung kann man folgende 4 Veränderungen im Röntgenbild bei Discusprotrusion feststellen: Verkalkungen in der Protrusion, Verengung des spatium intervertebrale, Verkalkungen im Discus und Osteophyten an den Rändern der angrenzenden Wirbel.

Nur die erste der vorgenannten Veränderungen kann als sicheres Diagnostikum einer Protrusion angesehen werden. Inwieweit Verengung einer Intervertebralspalte vorliegt, ist oft schwierig zu entscheiden. Liegt eine derartige Veränderung vor, so kann sie als ziemlich guter Wegweiser angesehen werden. Die übrigen Abweichungen vom Normalbilde sind nicht pathognomonisch. Oft ist sogar das Röntgenbild bei Discusprotrusion völlig normal. Von oben erwähnten 54 Discusprotrusionen konnten 26 auf nativem Röntgenbild diagnostiziert werden.

2. Experimentelle und klinische Untersuchungen wurden vorgenommen um festzustellen, teils welches Kontrastmittel sich am besten für die Myelographie beim Hunde eignet, teils wie das Kontrastmittel appliziert werden soll.

Thorotrast erwies sich Luft, jodiertem Öl und wasserlöslichen Kontrastmittel überlegen.

Subarachnoidale Myelographie wurde für besser befunden als epidurale Myelographie.

3. Zwanzig Hunde mit Discusprotrusionen wurden nach Myelographie mit Thorotrast seziert um den diagnostischen Wert der Methode zu kontrollieren. Diese Untersuchung zeigte, dass auch die kleinsten Protrusionen mit Thorotrastmyelographie diagnostiziert werden können unter der Voraussetzung, dass sie eine Einbuchtung in der Dura verursachen und das Kontrastmittel die Protrusion erreicht. Die gewöhnlichsten Ursachen die eine Kontrastmittelpenetration verhindern, sind totale Blockade auf Grund einer anderen Discus-

protrusion, inflammatorische Schwellung im Wirbelkanal und Blutungen im Subarachnoidalraume.

4. Thorotrastmyelographie wurde klinisch an 40 Hunden geprüft. Die danach auftretenden Komplikationen sind in der Regel unbedeutend und Kontraindikation liegt nur bei schlechter allgemeiner Kondition vor.

5. Einhundertneunundvierzig Journale von Hunden, die in der medizinischen Klinik der Veterinärhochschule in Pflege waren, wurden nachgeprüft. Die postklinische Krankheitsentwicklung wurde in 21 Fällen näher studiert. Es ging daraus hervor, dass Discusprotrusion beim Hunde in vielen Fällen Tendenz zur Spontanheilung zeigt. Trotzdem ist auch hier die Prognose nicht gut, da die Krankheit sehr oft rezidiviert.

6. Ausgehend von 50 vom Verfasser selbst klinisch untersuchten Fällen, in denen definitive Diagnose mit Hilfe von Myelographie und/oder Sektion gestellt werden konnte, werden gewisse Charakteristika der Pathogenese diskutiert.

Die Entstehungsweise der Discusprotrusion und Druckveränderungen im prolabierten Discus (der dynamische Faktor) scheinen die Krankheitssymptome weitgehendst zu bestimmen.

Der Heilungsprozess scheint hauptsächlich von der Eliminierung des dynamischen Faktor und dem Anpassungsvermögen des Medulla abhängig zu sein.

Nicht immer ist die Protrusion anderer Discen die Ursache von Rezidiven. In gewissen Fällen kann eine Protrusion in Etappen stattfinden, wodurch ein prolabierter Discus Anlass zu mehrere Erkrankungen geben kann.

Die sogenannte Myalgi und Rheumatismus beim Hunde wird wahrscheinlich oft durch Discusprotrusion verursacht.

7. Achtundzwanzig Hunde mit Discusprotrusion wurden nach einer neuen Methode, der sogenannten Discusfenestrierung (*Lindblom*) operiert. Unter Discusfenestrierung versteht man eine chirurgische Perforation des annulus fibrosus bis zum nucleus pulposus. Die Fenestrierung wird dorsolateral oder ventral vorgenommen. Eine Druckablastung im Discus wird erstrebt um den dynamischen Faktor zu beseitigen.

In Fällen leichter Erkrankung war die Discusfenestrierung von sichtlichem Erfolg. Die operierten Hunde machten grössenteils nach der Operation einen lebhafteren Eindruck als vor dem vom Besitzer angegebenen Zeitpunkt der Erkrankung. Das scheint darauf hinzuweisen, dass die Krankheit einen mehr kronischen Verlauf hat als die objektiven Symptome vermuten lassen. Ein Vergleich zwischen konservativ

und mit Fenestrierung behandelten Hunden scheint darauf zu zeigen, dass ein gewisser Erfolg mit der letztgenannten Behandlungsmethode auch in Fällen mit schweren Symptomen erzielt werden kann.

8. Sechs discusfenestrierte Hunde wurden zu verschiedenen Zeitpunkten seziert. Die Veränderungen, die nach einer Fenestrierung in der Intervertebralscheiben entstehen, sind derart, das sie die druckablastende Wirkung der Operation zu bestätigen scheinen.

REFERENCES

Andrae, R.: Beitr. z. path. Anat. u. z. allg. Path. 82: 464, 1929.

Arnell, S., Lidström, F.: Acta Radiol. 12: 287, 1931.

— Acta Radiol. 25: 408, 1944.

— Myelography with Water-Soluble Contrast. Acta Radiol. Suppl. 75, 1948.

Barr, J. S.: Journ. Bone and Joint. Surg. 19: 323, 1937.

Bell, J. C., Spurling, R. G.: Radiology 31: 473, 1938. (cited by Weber).

Boddie, G. F.: The Vet. Rec. 61: 511, 1949.

Bradford, F. K., Spurling, R. G.: The Intervertebral Disc, second ed., Springfield 1947.

Brook, G. B.: Experimental and Clinical Studies of the Spine of the Dog. London 1936.

Bruskin, J., Propper, N.: Ztschrift f. d. Ges. exp. Med. 75: 34, 1931.

Cadeac: Maladies du système nerveaux. 1899 (cited by Pommer).

Cadiot, P. J.: Précis de chirurgie vétérinaire. Paris 1917.

Camp, J. D., Addington, E. A.: Radiology 33: 701, 1939.

Capua, A.: La radiol. med. 20: 1376, 1933.

Coe, F. E., Otell, L. S., Hedley, O. F.: Med. Ann. Distr. Columbia 2: 277, 1933 (cited by Nosik 1943).

Coggeshall, H. C., von Storch, T. J. C.: Arch. Neurol. and Psychiat. 31: 611, 1934. (cited by Weber).

Copleman, B.: Am. Journ. Roentgenol. 52: 245, 1944.

Council on Pharmacy and Chemistry Thorotrast J.A.M.A. 99: 2183, 1932.

Dandy, W. E.: Ann. Surg. 68: 5, 1918.

— Ann. Surg. 70: 397, 1919.

— Ann. Surg. 81: 223, 1925.

Denstad, T.: Acta Radiol. 32: 429, 1949.

Deucher, W. G., Love, J. G.: Arch. Path. 27: 201, 1939.

Dexler, H.: Oesterreich. Ztschr. f. Wissenschaftl. Veterinärkunde 7: 1, 1896.

Epstein, B. S., Davidoff, M.: Am. Journ. Roentgenol. 52: 253, 1944.

Fankhauser, R.: Schw. Arch. f. Tierheilk. 90: 143, 1948.

— Schw. Arch. f. Tierheilk. 90: 494, 1948.

— Schw. Arch. f. Neurol. u. Psychiat. 62: 415, 1948.

Flinn, F. B: Am. Journ. Phys. Therapy 9: 65, 1932. (cited by Nichols and Nosik).

Frauchiger, E., Fankhauser, R.: Die Nervenkrankheiten unserer Hunde. Bern 1949.

Freeman, W., Schoenfeld, H., Moore, C.: J.A.M.A. 106: 96, 1936.

Friberg, S.: Acta Chir. Scand. Suppl. 64, 1941.

Garland, L. H.: Radiology 35: 467, 1940.

Hampton, A. O.: Arch. Surg. 40: 444, 1940. (cited by Weber).

Hansen, H. J.: Submitted for publication in Acta Orthop. Scand. 1951.

— Personal communications.

Heiligtag, W.: Diss. Hannover 1938.
Hirsch, C.: Acta Orthop. Scand. 17: 240, 1947.
Hultquist, G., Lindblom, K.: Journ. Bone and Joint Surg. 32 A: 557, 1950.
Hutyra, Fr. v. Marek, J.: Spez. Path. u. Ther. d. Haust. 3: 1922, (cited by Pommer).
Jacob, H.: Münch. Tierärztl. Wchnschr. 54: 305, 1910.
— Inn. Krankheit. d. Hundes. 2 Aufl. 1924. (cited by Pommer).
Jacobi, Löhr.: Deutsche Ztschr. f. Nervenheilk. 130-131: 15, 1933.
Joest, E.: Spez. Path. Anat. d. Haustiere. 2: 490, Berlin 1921.
Junge, H.: Ergeb. d. Chir. u. Orthop. 36: 224, 1950.
Key, J. A., Ford, L. T.: Journ. Bone and Joint Surg. 30 A: 621, 1948.
Kubie, L. S., Retan, G. M.: J.A.M.A. 101: 354, 1933.
Kubik, C. S., Hampton, A. C.: New Engl. Journ. Med. 224: 455, 1941.
Lindblom, K.: Acta Radiol. 22: 711, 1941.
— Nord. Med. 16: 3597, 1942.
— Acta Radiol. 25: 195, 1944.
— Nord. Med. 29: 507, 1946.
— Nord. Med. 30: 1173, 1946.
— Acta Radiol. 27: 1, 1946.
— Acta Radiol. 28: 69, 1947.
— Acta Radiol. 30: 419, 1948.
— Acta Radiol. 34: 321, 1950.
— Ergeb. d. Inn. Med. u. Kinderheilk. 2: 281, 1951.
— Personal communications.
— *Rexed, B.:* Journ. Neurosurg. 5: 413, 1948.
Lindgren, E.: Nervenarzt 12: 57, 1939.
Love, J. G., Walsh, M. N.: Proc. Staff. Meet. Mayo. Clin. 13: 792, 1938. (cited by Weber).
Luschka, H. von: Die Halbgelenke des menschlichen Körpers. Berlin 1858.
Löfstedt, F.: Skand. Vet. Tidskrift 31: 547, 1941.
Marcovich, A. W., Walker, A. E., Jessico, C. M.: J.A.M.A. 116: 2247, 1941.
Martland, H. S.: J.A.M.A. 92: 466, 552, 1929.
Mauric, G. J. J.: Le disque intervertebrale. Paris 1933. (cited by Bradford and Spurling).
Meyer, F.: Diss. München 1937.
Mixter, W. J.: Ann. Surg. 106: 777, 1937.
— *Barr, J. S.:* New Engl. Journ. Med. 211: 210, 1934.
Naegeli, Th., Lauche, A.: Klin. Wchnschr. 11: 2029, 1932; 12: 1730, 1933; 15: 436, 1936.
Nichols, B. H., Nosik, W. A.: Radiology 35: 459, 1940.
Nosik, W. A., Mortensen, O. A.: Am. Journ. Roentgenol. 39: 727, 1938.
Nosik, W. A.: Am. Journ. Roentgenol. 49: 214, 1943.
— Medical Physics. : 1323, 1944.
Obel, N.: Submitted for publication in Nord. Vet. Med. 1951.
Odin, M., Runström, G.: Acta Radiol. Suppl. 7, 1929.
Olsson, S. E.: Nord. Vet. Med. 2: 1074, 1950.
Pommer, A.: Tierheilk. u. Tierzucht (Herausg. v. Stang. u. Wirth). 11: 134, 1937.
Pukanić, I.: Veterinarski Arhiv 11: 434, 1941.
Radovici, A., Meller, O.: Bull. de l'acad. de méd. 107: 314, 1932.
— — Revue Neurologique 1; 541, 1933.
— — Journ. d. radiol. et d'electr. 20: 229, 1936.
Reeves, D. L., Stuck, R. M.: Medicine 17: 37, 1938.

Reichert, F. L.: J.A.M.A. 109: 1270, 1937. (cited by Weber).
Riser, W. H.: The North Am. Vet. 27: 633, 1946.
Scott, M., Young, B. R.: Arch. Neurol. and Psychiat. 38: 1126, 1937.
Sicard, Forestier: Bull. et mem. Soc. des Hop. de Paris. 46: 463, 1922.
Schmorl, G.: Fortschr. a. d. Geb. d. Röntgenstrahlen. 40: 629, 1929.
Schnelle, G. B.: Radiology in Canine Practice. Evanston, Ill. 1945.
— Radiology in Small Animal Practice. Evanstone, Ill. 1950.
Tillmanns, S.: Diss. Giessen. 1939.
Tschugunoff, S. A.: Ztschr. f. Neurol. u. Psychiat. 122: 452, 1929.
Twinning, E. W., Rowbotham, G. F.: The Lancet. 299: 122, 1935.
Unander-Scharin, L.: Acta Orthop. Scand. Suppl. 5, 1950.
Weber, H. M.: Am. Journ. Med. Sc. 206: 687, 1943.
Wiedemann, R.: Diss. Hannover. 1922.
Wiberg, G.: Acta Orthop. Scand. 19: 211, 1949.
Wustmann, O.: Deutsche Ztschr. f. Chir. 238: 529, 1932/33.

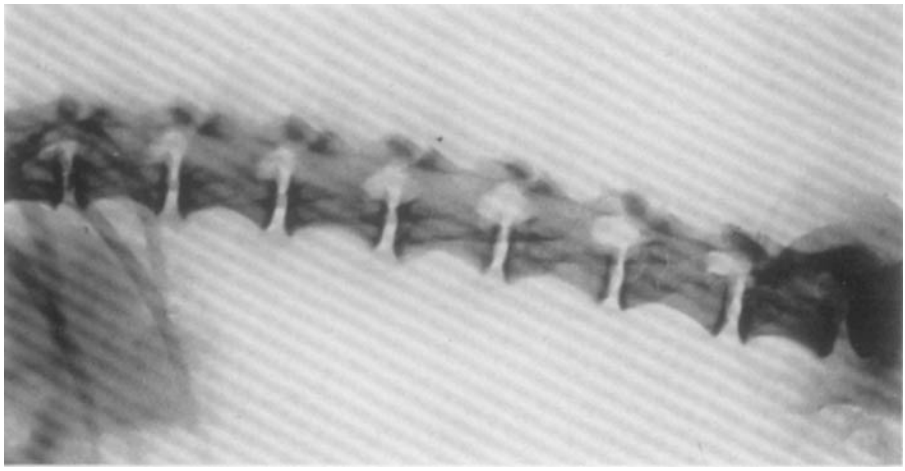


Fig. 1.

Fig. 1. (0 672/46). With the exception of a calcification of the disc between T. 13 and L. 1, nothing abnormal is seen. According to the sectional record, there was a protrusion, half the size of a pea, of the disc between L. 1 and L. 2.

Fig. 2. (0 102/43). L. 3 to the right of the roentgenogram. The calcification of L. 4-L. 5 is situated away up in the most dorsal part of the disc. It must not be interpreted as a calcified protrusion.

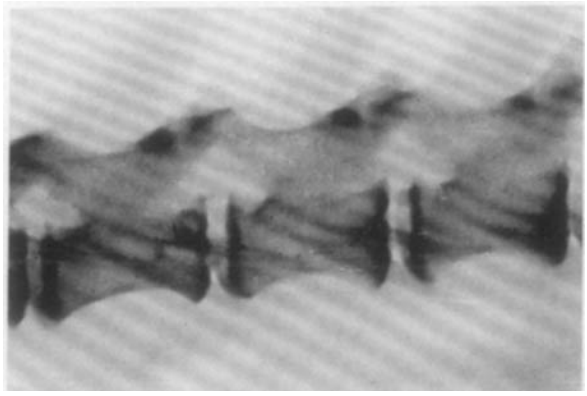


Fig. 2.

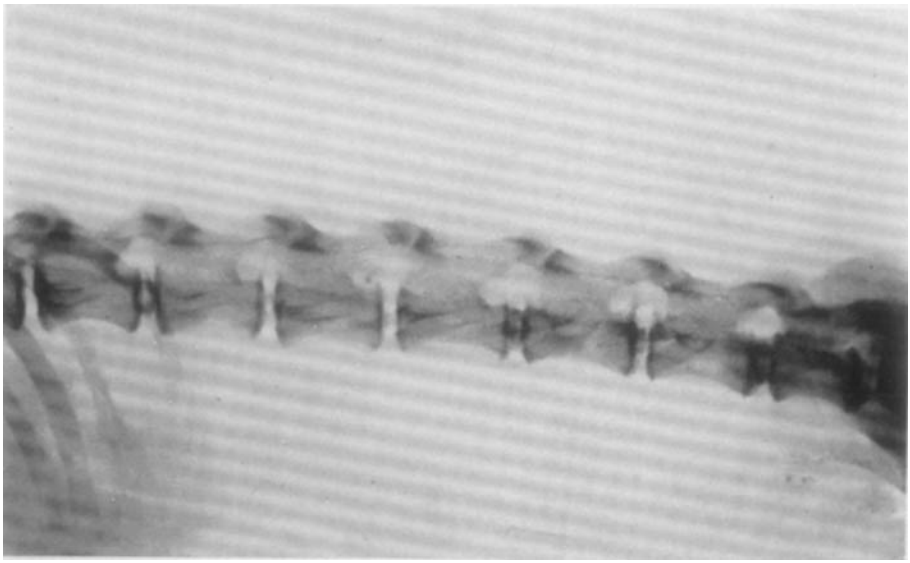


Fig. 3.

Fig. 3. (0 245/50). This dog had disc protrusions between L. 2 and L. 3, and between L. 3 and L. 4. In the roentgenogram these discs show the following changes. In the centre of L. 2-L. 3 a slight calcification is seen. The intervertebral foramen above the same disc is not so distinctly outlined as is the foramen in front of it, owing to an increased roentgen density. This is explained by the fact that a large protrusion at the side of the medulla covers the intervertebral foramen in the roentgenogram (Fig. 32). Just orally to L. 3-L. 4 in the vertebral canal a fairly well defined calcification is seen. In the intervertebral foramen a diffuse calcification is seen, although this calcification is slighter than that of the preceding disc. The formation seen in the intervertebral foramen above L. 5-L. 6 are dorsolaterally located osteophytes and must not be mistaken for protrusions in the vertebral canal. Besides, extreme calcifications of several discs are seen.

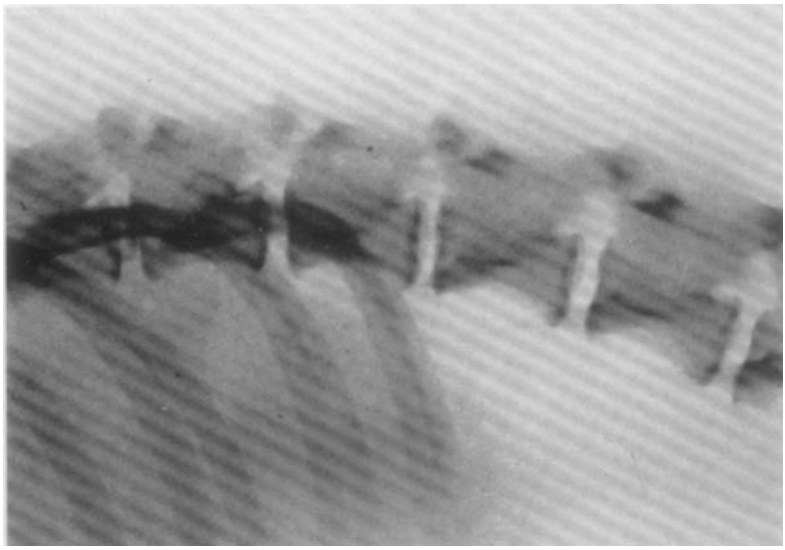


Fig. 4.

Figs. 4-5. (0 110/50). In this case the section showed a very large protrusion of disc L. 1-L. 2. As is seen from the lateral and ventrodorsal views, the space between L. 1 and L. 2 is diminished.

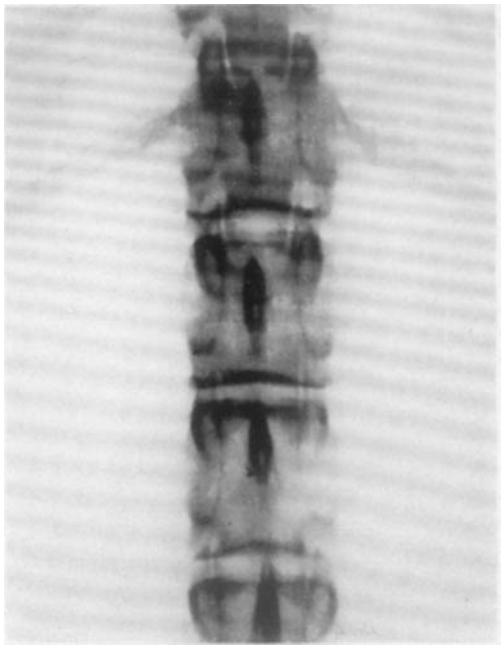


Fig. 5.

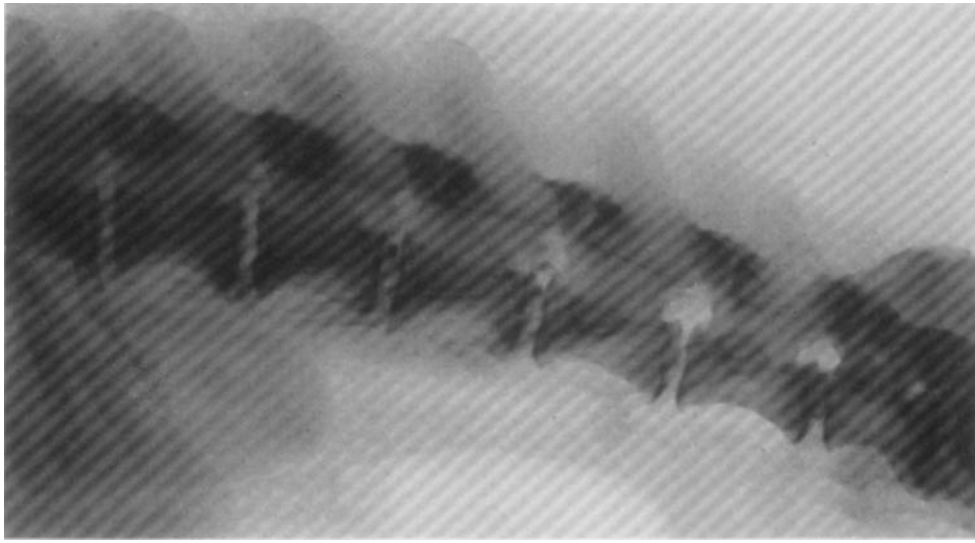


Fig. 6.

Fig. 6. (0 765/50). The vertebra farthest to the left is L. 1. At section protrusions of discs L. 2-L. 3, L. 3-L. 4, L. 4-L. 5 were proved. L. 2-L. 3 shows a slight calcification of the dorsal margin. Osteophytes ventrally on the surrounding vertebrae. L. 3-L. 4 shows almost similar changes. The difference is that the calcification is here more marked, but the osteophytes are less prominent. L. 4-L. 5 shows a calcification. Besides, it has a calcified protrusion appearing as a bridge between the vertebrae. L. 6-L. 7 is the site of an extreme calcification.

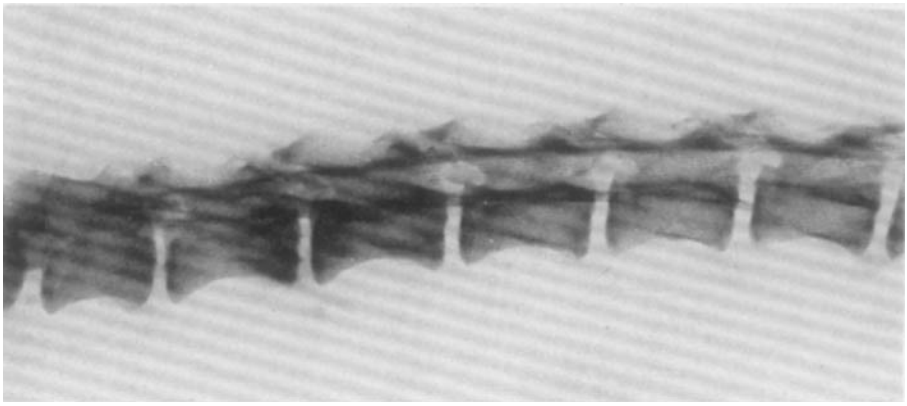


Fig. 7.

Fig. 7. Lateral view.—Note especially the garlandlike formations dorsally to the discs. The contours outlined are rather those of the vertebral canal than those of the spinal cord.

EPIDURAL MYELOGRAPHY

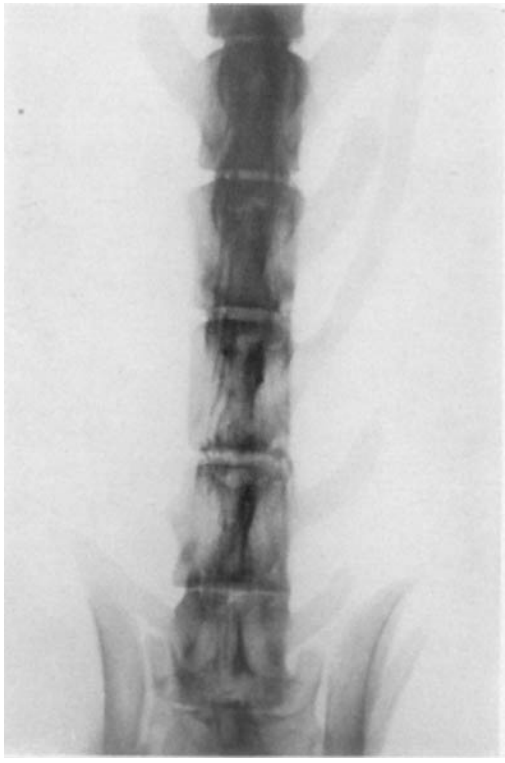


Fig. 8.

Fig. 8. Ventrodorsal view.—In this projection the difference between epidural and subarachnoid myelography is seen still better than in the lateral.

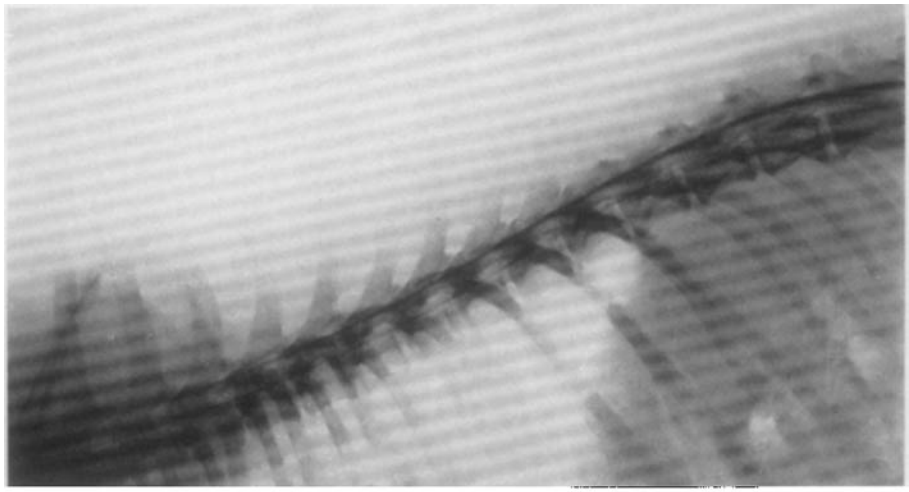


Fig. 9.

SUBARACHNOID MYELOGRAPHY

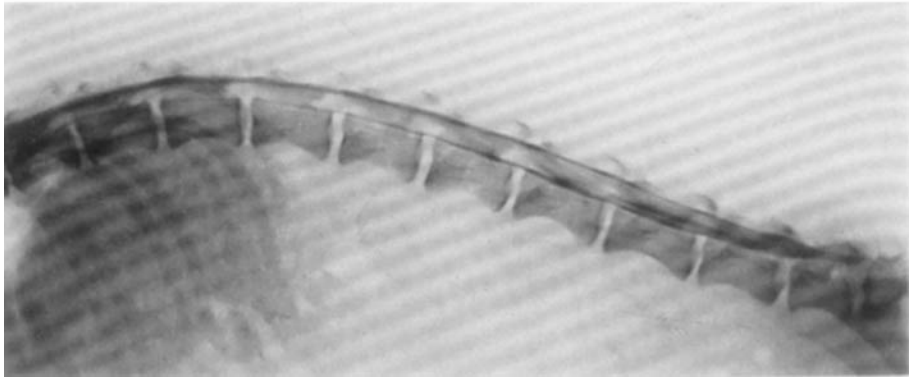


Fig. 10

Figs. 9, 10, and 11. (0 813/49). Normal myelogram of a dachshund.—The contrast medium is injected subarachnoidally. The lateral views show how the two contrast lines, a dorsal and a ventral one, indicate the contours of the spinal cord. From the 3rd lumbar vertebra and caudally one can notice the nerve roots. Further, it is seen that the *conus medullaris* is located at the level of the disc between the 6th and 7th lumbar vertebra. The ventral contrast line is thinnest, and the dorsal broadest at the transition between the lumbar and the thoracic portion of the spine. Here the spinal cord touches the floor of the spinal canal. The ventrodorsal view shows that the dural pouches and the nerve roots are distinguishable. At the level of the 4th lumbar vertebra an extremely winding vessel is seen.

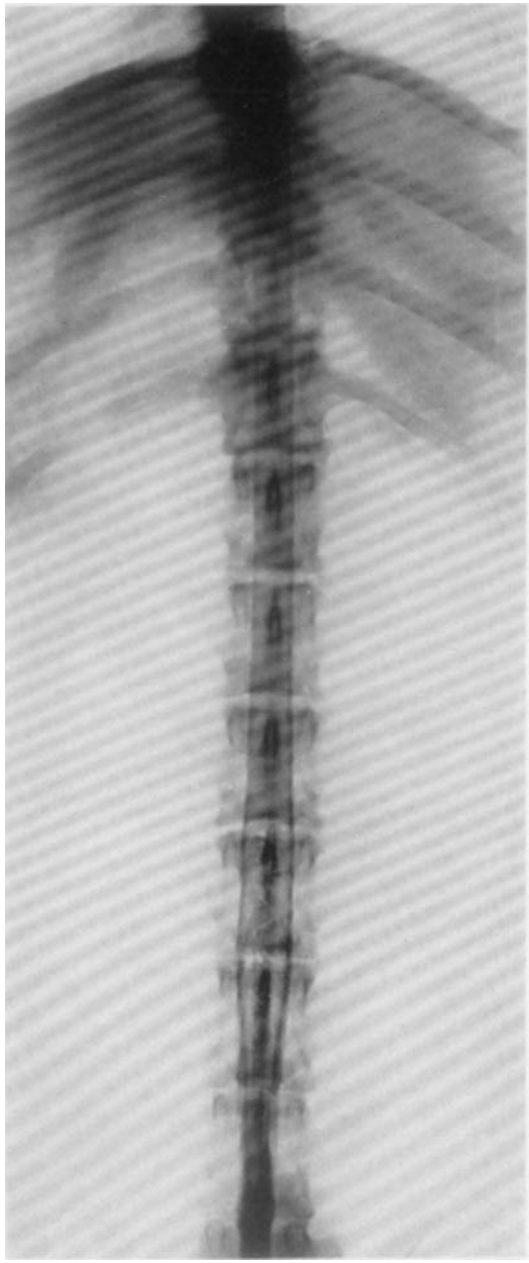


Fig. 11.

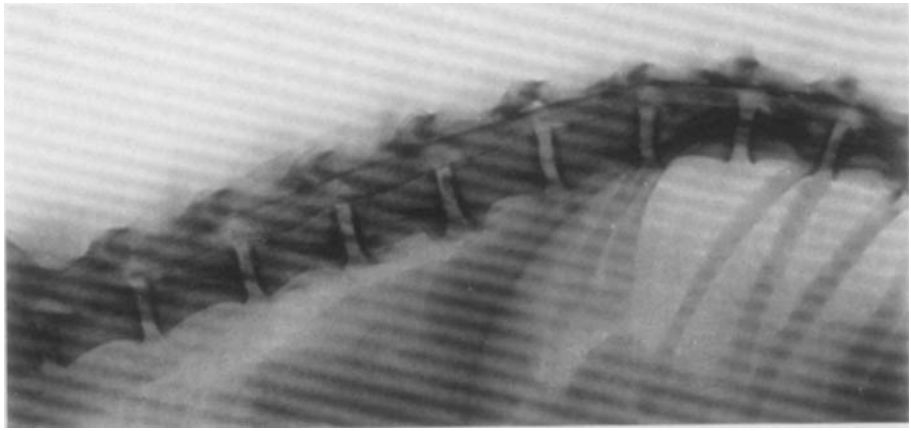


Fig. 12.

Fig. 12. (0 691/49). At section this dog proved to have 6 rather small protrusions, *viz.*, between T. 11 and T. 12 (note that the last pair of ribs are not developed) between T. 13 and L. 1, L. 3 and L. 4, L. 4 and L. 5, L. 5 and L. 6, and finally between L. 7 and S. 1. As is seen from the roentgenogram, all the protrusions except the most caudal one can be seen with the aid of myelography.

Figs. 13 and 14. (0 298/50). These two roentgenograms demonstrate very well the detailed view that one gets of the conditions in the vertebral canal with the aid of thorotrast myelography. The sectional record gives the following information: "Disc. L. 2-L. 3 shows a slight bulge at the side of the *ligamentum longitudinale.* Disc L. 3-L. 4 shows a rather marked threshold formation like an even, soft ridge with a height of about 2 mm. A similar threshold is seen on disc L. 4-L. 5. This formation is, however, combined with a right-sided bulge, measuring $6 \times 2 \times 3$ mm., of greyish white colour and rather firm in consistency. From this protrusion to disc L. 6-L. 7 the dura is fibrously adherent to the epidural space. Disc L. 5-L. 6 shows a rather marked bulge with an $8 \times 3 \times 2$ mm. median comblike bulge rather firm in consistency. On disc L. 6-L. 7 a median yellowish grey firm round formation is seen with a diameter of 3 mm. and a height of 2 mm. Disc L. 7-S. 1 has a similar but lower protrusion". The only unnoticeable protrusion in the roentgenograms is the most caudal one. On account of the anatomical conditions, it has caused no impression of the dural sac.

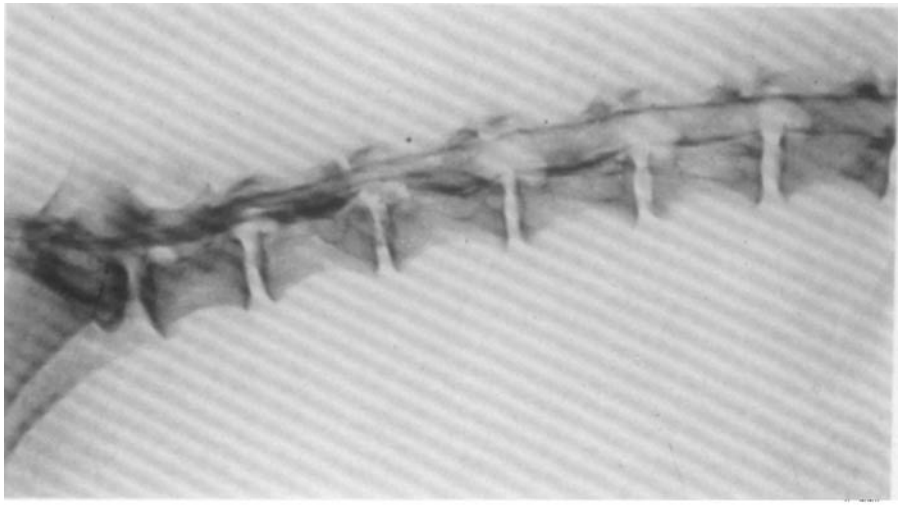


Fig. 13.

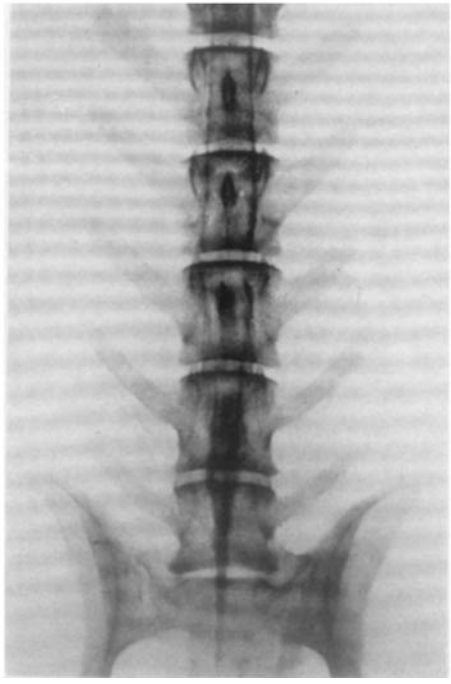


Fig. 14.

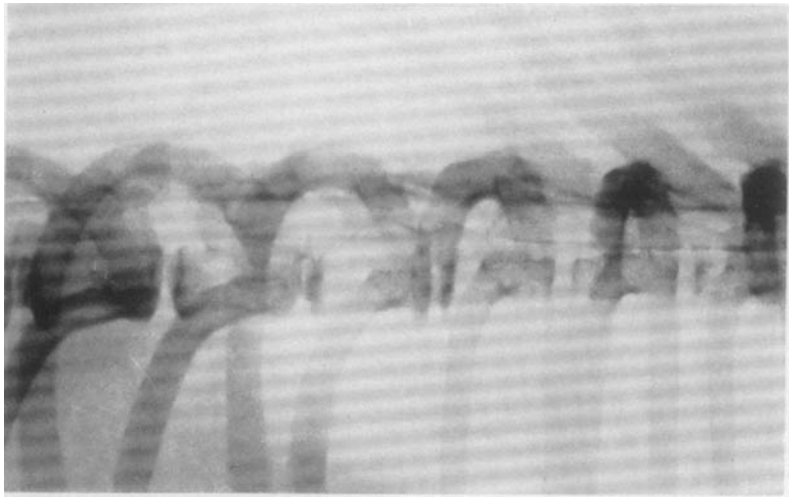


Fig. 15.

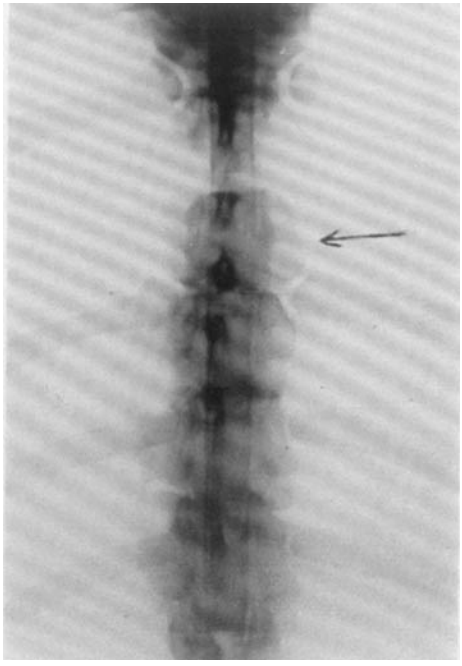


Fig. 16.

Figs. 15 and 16. (0 96/50). The roentgenograms show a compression of the medulla which at section proved to be caused by a protrusion of T. 9-T. 10. The size of the protrusion was 11 × 5 × 3 mm. It was situated medianly and was flat in shape.

Fig. 17.

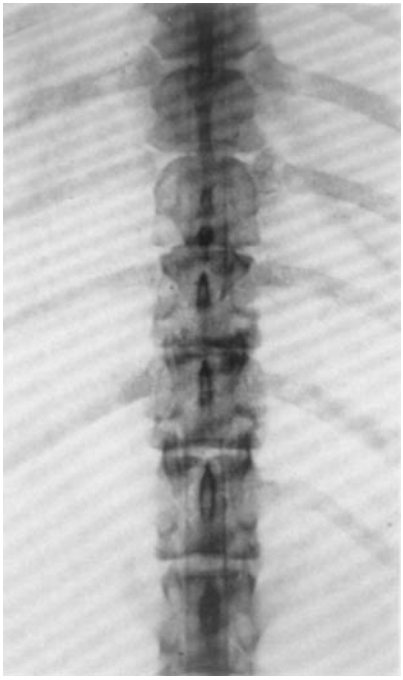


Fig. 18.

Figs. 17 and 18. (M 863/50). The roentgenograms show a case of total blockage of the subarachnoid space at the disc between T. 11 and T. 12. The site of the compression is also defined caudally by contrast medium injected lumbarly.

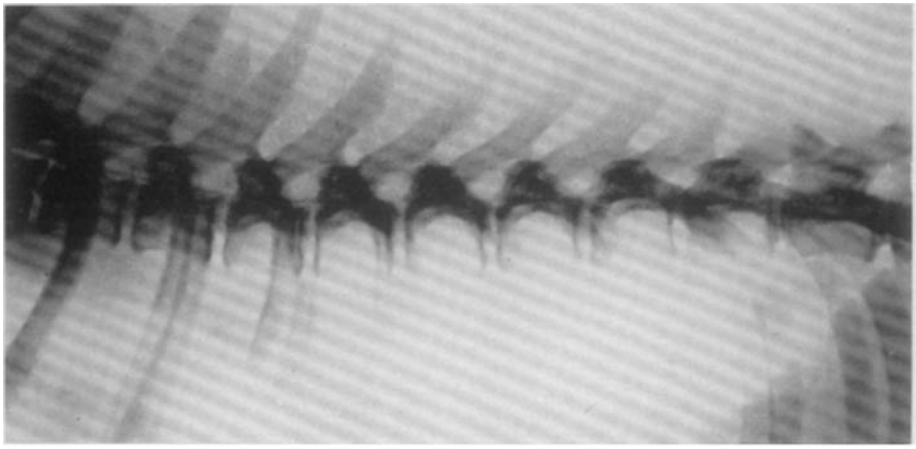


Fig. 19.

Fig. 19. (0 110/50). A myelogram in which it is impossible to localize the disc protrusion. Widely spread subarachnoid haemorrhages prevent the contrast medium from spreading within the subarachnoid space. The contrast lines gradually disappear.

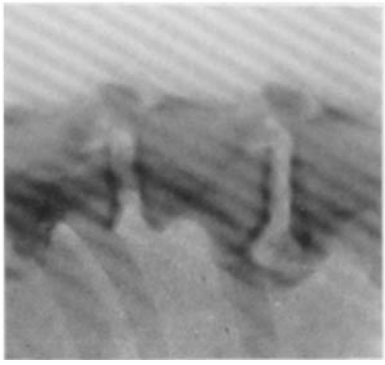


Fig. 20.

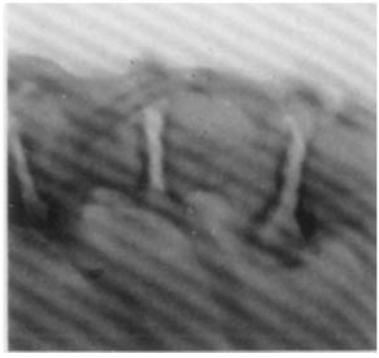


Fig. 21.

Fig. 20. (0 210/46). Roentgenogram taken Dec. 14, 1945. Among other changes, a calcification of the disc is seen between T. 13 and L. 1.

Fig. 21. (0 210/46). Roentgenogram of the same dog as in Fig. 20 taken March 5, 1946. On one hand, it shows that the disc between T. 13 and L. 1 is no longer calcified, on the other, that the space between these vertebrae is diminished somewhat.—The dog was sent to the clinic at the beginning of December, 1945, for paraplegia. It got better but had a recurrence at the beginning of January, 1946. After that it did not improve but was killed March 18, 1946. The section showed only one disc protrusion, *viz.*, T. 13-L. 1. Most likely the course had been the following: First a small part of the disc had protruded. The dog had then been affected with paraplegia but had recovered. For some reason, still more nuclear material had later protruded causing a recurrence. This seems to be the simplest explanation why the calcification had disappeared from the disc. Pommer has previously noticed the same phenomenon, but he gives an entirely different explanation.

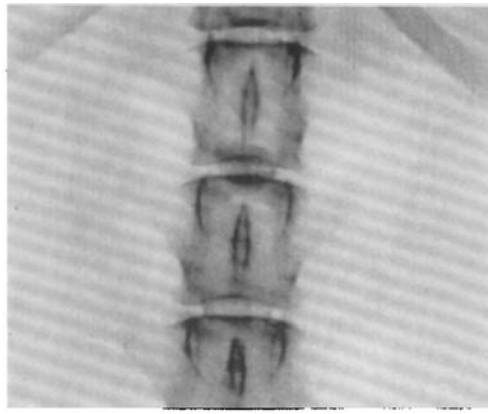


Fig. 22.

Figs. 22 and 23. A neoformation, most likely a large calcified protrusion, between L. 1 and L. 2.— When the roentgenograms were taken, the dog had recovered from a 5-month-long paraplegia. This is remarkable as the roentgenograms clearly show that the protrusion does not leave much space for the medulla.

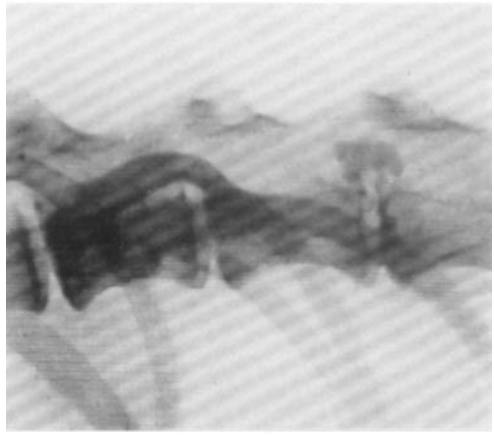


Fig. 23.

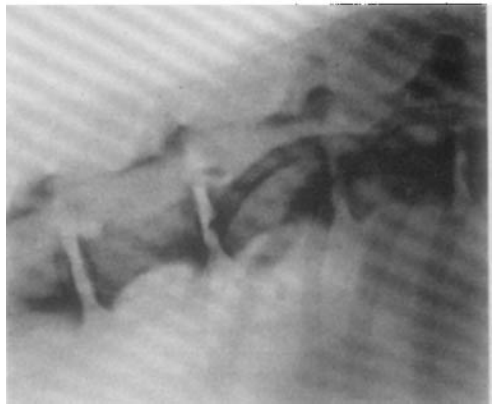


Fig. 24.

Fig. 24. A roentgenogram from the same dog as in Figs. 22 and 23 taken half a year later. The disc protrusion has diminished in size.

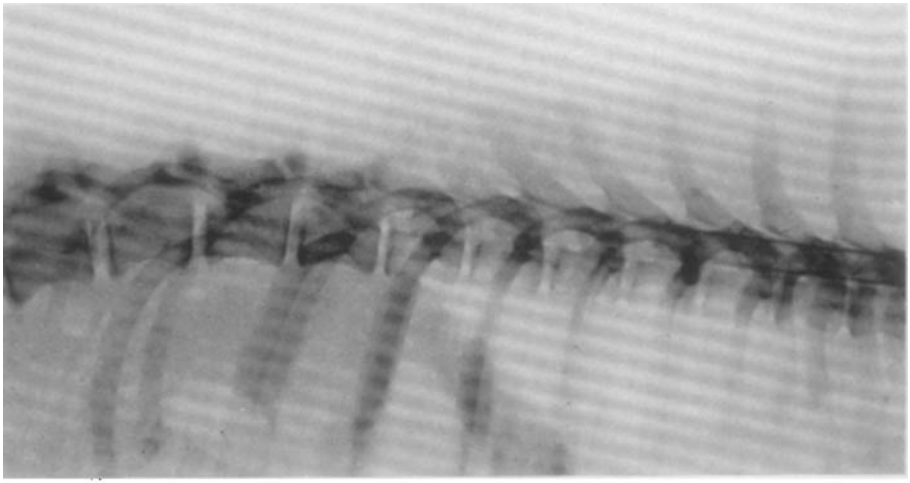


Fig. 25.

Fig. 25. (0 935/50). A myelogram in which the contrast medium stops at the 8th thoracic vertebra.

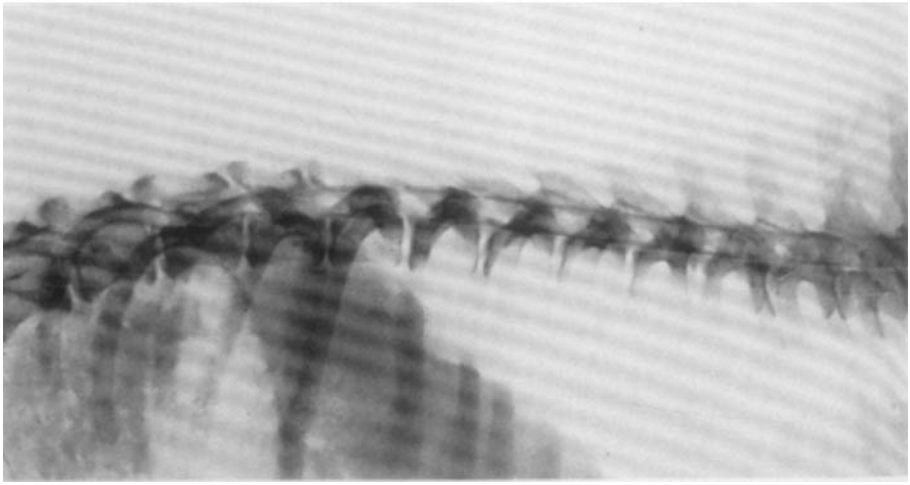


Fig. 26.

Fig. 26. A myelogram from the same dog as in Fig. 25 taken 7 weeks later. — The contrast medium reaches a protrusion which at section proved to be located on the 11th thoracic vertebra. Disc T. 11-T. 12 had protruded. At the first myelography the dog suffered from paraplegia. At myelography no. 2 the dog could walk a few steps. The most probable explanation of the differences of the two myelograms seems to be that an inflammatory swelling of the tissues in the vertebral canal at first had blocked the passage of the contrast medium.

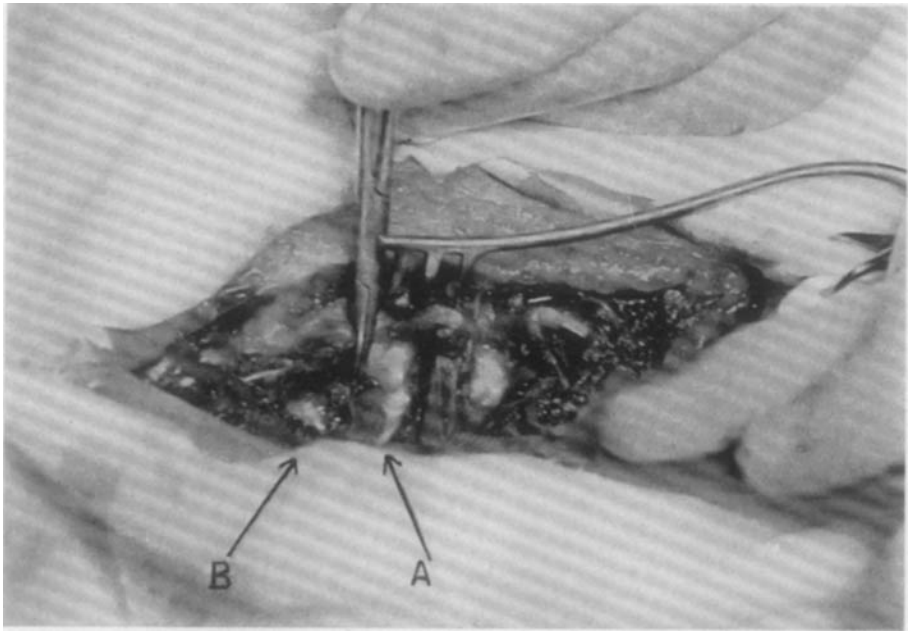


Fig. 27. Operation photograph taken after the vertebrae had been laid bare from muscles. A: The 13th rib. B: The transverse process of the first lumbar vertebra. —Fenestration of the disc T. 13-L. 1 should be performed just orally to the transverse process.

Fig. 27.

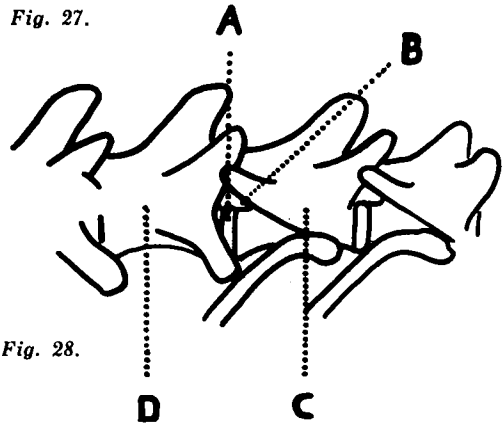


Fig. 28.

Fig. 28. Outline of the operation area of Fig. 27. A. Suitable place for fenestration. B: Exit of the spinal nerve. C: The 13th thoracic vertebrae. D: The first lumbar vertebra.

Fig. 29.

Fig. 29. Photograph of a dog in suitable position for dorsolateral disc fenestration.

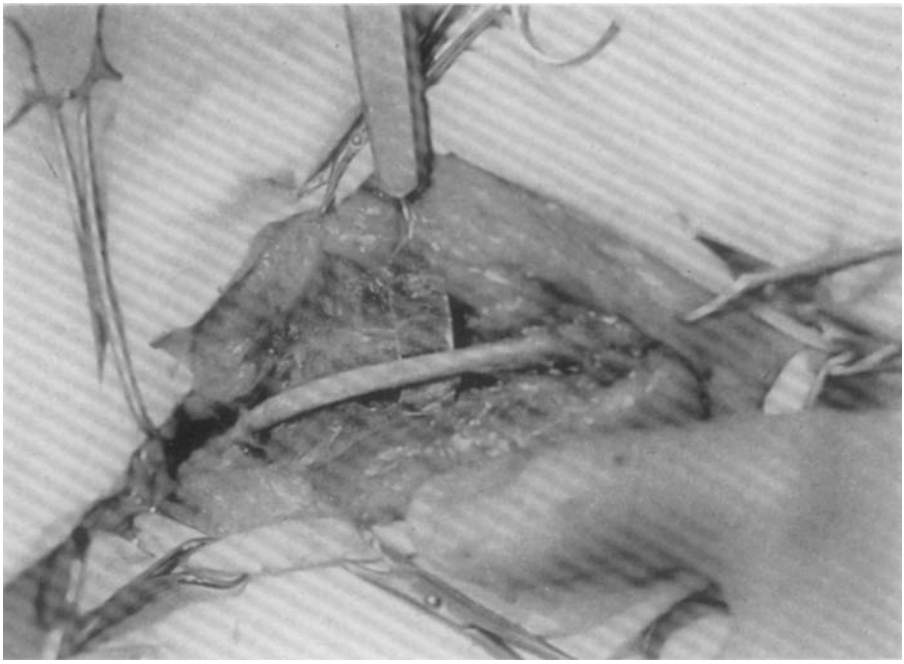


Fig. 30.

Fig. 30. Operation photograph of transthoracic disc fenestration. The rib is just removed from the periosteous hose.

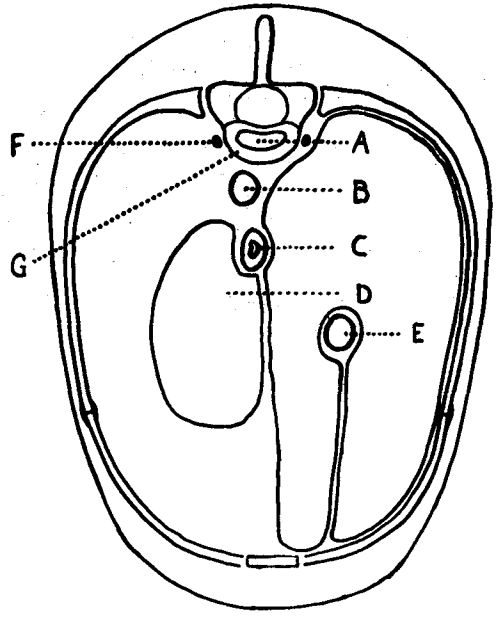


Fig. 31. Cross-section of the thoracic cavity in outline. A: Nucleus pulposus. B: Aorta. C: Oesophagus. D: Left lung collapsed through artificial pneumothorax. E: Vena cava caudalis. F: Truncus nervi sympathici. G: Best place for ventral fenestration of the disc.

Fig. 31.

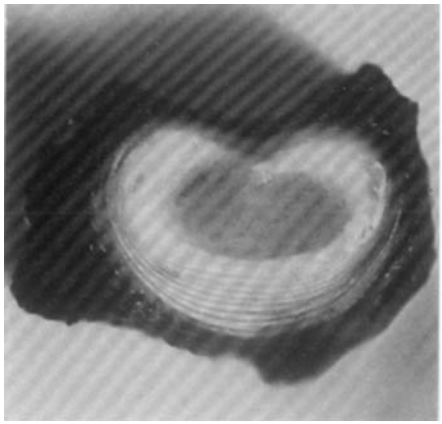


Fig. 32.

Fig. 32. (0 245/50). Large dorsomedian disc protrusion (Hansen. Acta Ortop. Scand. 1951). This disc protrusion was seen in the roentgenogram as a diffuse calcification in the intervertebral foramen. (Disc L. 2-L. 3. Fig. 3).

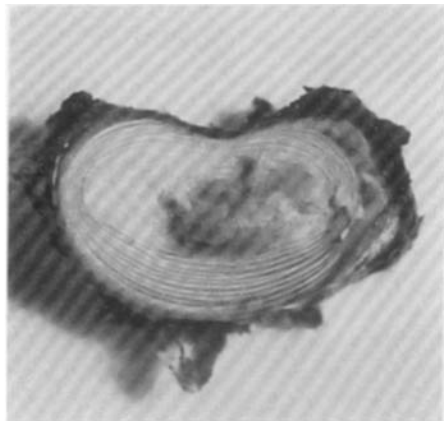


Fig. 33.

Fig. 33. (0 935/50). Extremely degenerated disc with dorsomedian protrusion. The lamellae of the *annulus fibrosus* are turned outwards in the rupture. The disc is fenestrated ventrally. Observe the very dark-coloured hole in the *annulus fibrosus* and the dark colour of the centre of the disc.

Fig. 34.

Fig. 34. Disc from a young nonchondrodystrophoid dog. The *nucleus pulposus* is gelatinous and almost water-clear.

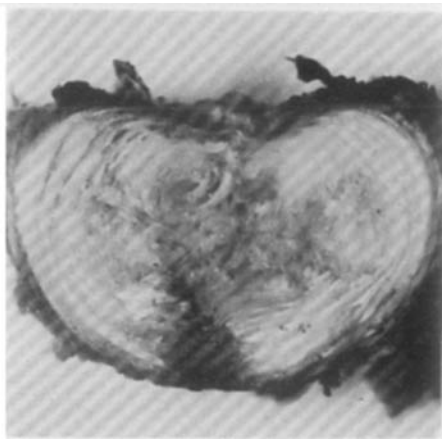


Fig. 35.

Fig. 35. (1). Fenestrated disc from dog with nondegenerated discs. Fenestration from lateral side. The perilamellar connective tissue extremely thickened here. At previous site of *nucleus pulposus* and in the hole in *annulus fibrosus* is a brownish firm tissue.

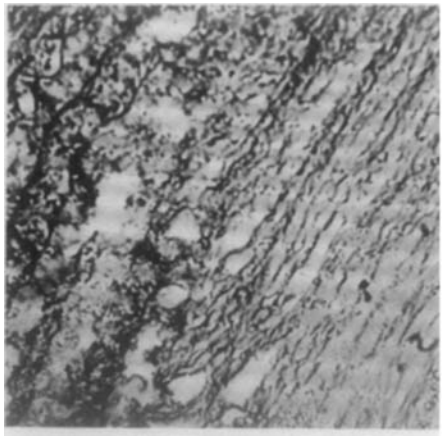


Fig. 36.

Fig. 36. (2). Section of normal *nucleus pulposus* of a young dog.

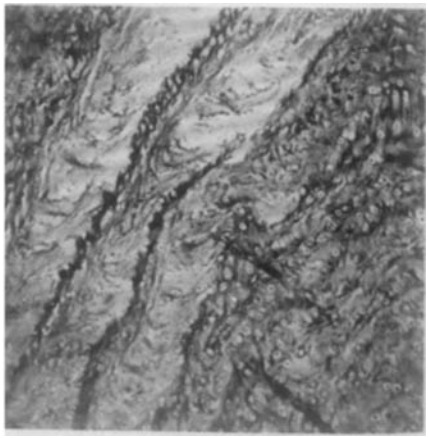


Fig. 37.

Fig. 37. (2). Fenestrated disc of the same dog as in Fig. 36. Section of the tissue which has replaced the original *nucleus pulposus*. The picture shows a chondroid tissue being partly the site of degenerative changes.

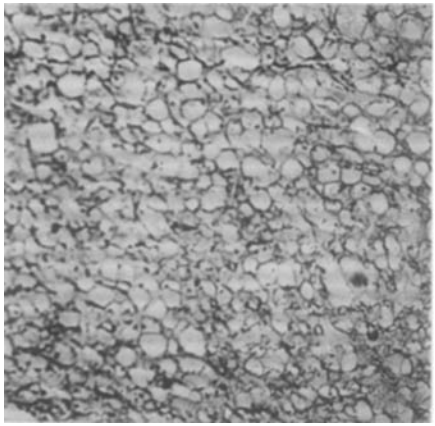


Fig. 38.

Fig. 38. (0 935/50). The inner layers of the *annulus fibrosus* of a degenerated disc.

Fig. 39.

Fig. 39. (0 935/50). The inner layers of the *annulus fibrosus* of a degenerated disc which has been fenestrated. The tissue is here more collagenous and shows a higher cell content than does that of Fig. 38.

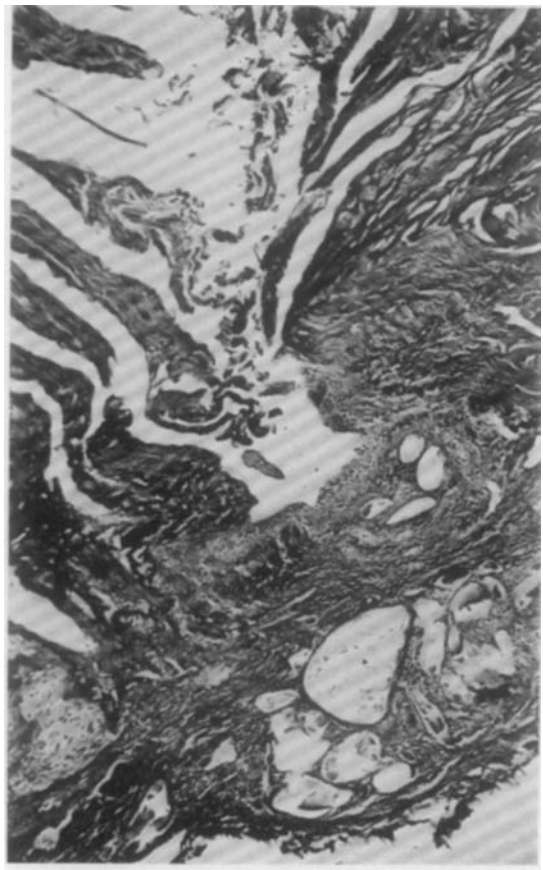


Fig. 40.

Fig. 40. The outer part of a 7-week-old fenestra of a degenerated disc. The lamellae of the *annulus fibrosus* deviate outwards and farthest out there is a granulation tissue. This tissue contains islands of degenerated nuclear tissue and is defined inwards by multiple layers of mononuclear cells.