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MYELOGRAPHIC LOCALIZATION OF SPINAL CORD COMPRESSION IN DOGS

A COMPARISON BETWEEN CISTERNAL AND LUMBAR INJECTIONS OF METRIZAMIDE "AMIPAQUE" IN DIAGNOSING AND LOCATING SPINAL CORD COMPRESSION

By

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FUNKQUIST, BERIT: *Myelographic localization of spinal cord compression in dogs. A comparison between cisternal and lumbar injections of metrizamide "Amipaque" in diagnosing and locating spinal cord compression.* Acta vet. scand. 1975, *16*, 269—287. — Metrizamide is a new water-soluble contrast medium possessing unique properties, one of which is that even in an isotonic solution it has a radiographic density sufficient for a diagnostic myelogram. Whereas in the past myelography with water-soluble preparations invariably entailed lumbar injections, which are technically difficult in dogs, the fact that isotonic metrizamide causes so little tissue irritation has made it possible to inject the contrast solution into the cisterna magna. The author has compared metrizamide myelograms obtained with both cisternal and lumbar injections. Myelography with a cisternal injection is preferable for demonstrating cervical cord compressions and also in cases in which it is desirable to obtain myelographic information on both the cervical and the thoraco-lumbar areas. If, on the other hand, it is necessary to determine exactly the extent of a thoraco-lumbar compression before decompressive laminectomy, the contrast should be injected in the lumbar region in such an amount and at a pressure high enough to ensure that the contrast is forced past the site of the compression. The safety of metrizamide will probably enable a better prognosis following surgery than was previously possible.

myelography; spinal cord compression; contrast medium.

The first reports of the diagnosis of spinal cord compression in dogs by means of subarachnoid contrast injection were based on investigations in which use was made of suboccipital (cister-

nal) injections of fat-soluble contrast media (lodipin — *Henkels* 1926, Lidiodol — *Brook* 1936, Pantopaque — *Hoerlein* 1953) and of thorotrast (*Meyer* 1937, *Olsson* 1951). In those investigations the contrast medium was allowed to sink down towards the compressed portion following elevation of the animal's forequarters. In cases of extreme compression this method was limited to localization of the anterior limit of the compression since the contrast medium did not pass consistently beyond the compressed portion of the subarachnoid space in diagnostic amounts. Most of the preparations have long since been abandoned owing to long-term side effects.

In human medicine a water-soluble contrast medium, sodium methiodal (Abrodil; synonyms Kontrast U, Skiodan), has been used since 1931 (*Arnell & Lindström*) for the diagnosis of root compression in the lumbar region. In the concentrations that are needed to give diagnostic radio-opacity these solutions are very hypertonic and irritative and therefore were regarded as unsuitable for myelography of the spinal cord itself. However, in dogs, *Funkquist* (1962 a) introduced a method of diagnosing spinal cord compression which was based on the use of this preparation. This method reduced the immediate effects of the irritant properties of the contrast medium since

a) the preparation was injected in the lumbar region so as to avoid high concentrations within the cranial subarachnoid space

b) xylocaine was added to the solution (in a carefully titrated concentration) in order to reduce the tonic muscular contraction and the sharp rise in blood pressure that otherwise result from the introduction of the preparation into the subarachnoid space

c) immediately prior to the contrast injection the animal received an intravenous injection of succinylcholine iodide designed to prevent the initial spasms which — despite the addition of xylocaine — otherwise arise immediately when the injection is made and which can result in blurred radiographs.

It will be clear from the foregoing that up to now myelography with water-soluble contrast media has been a rather complicated and lengthy undertaking. On the other hand, the lumbar site of

injection allows sufficient pressure to be exerted to force the contrast beyond the compressed area and outline the cranial parts of the lesions, with little risk of high concentrations entering the cranial subarachnoid space.

This method proved usable also for cervical myelography (*Funkquist* 1961 a) after certain modifications (lumbar injection with the hind-quarters elevated after suboccipital removal of most of the cerebrospinal fluid (CSF) from the spinal subarachnoid space).

Up to now the water-soluble contrast media used for myelography have been solutions of salts of iodinated acids, which have to be made extremely hypertonic if an adequate contrast effect is to be obtained. Under certain experimental conditions (intravenous infusion of hypotonic salt solutions, lowering the arterial blood pressure) subarachnoid injections of these preparations (Kontrast U) have produced damage to the spinal cord in dogs. The subarachnoid injection of common salt solutions that were isotonic with Kontrast U produced similar damage to the spinal cord under identical experimental conditions, indicating that this damage is probably osmotic in character (*Funkquist* 1961 b). It is therefore extremely welcome that in recent years attempts have been made to synthesize water-soluble contrast media with lower osmolality. Almén (in Acta Radiolog. Suppl., 335, 1973) proposed the synthesis of non-ionic monomeric iodinated compounds to lower the osmolality to one-half of correspondent ionic compounds. Almén realized that a proper choice of polar functional groups would confer water solubility of the non-ionic molecule and maintain the low toxicity which characterizes present-day contrast media. Nyegaard & Co., Oslo, Norway, have conducted research on the basis of Almén's proposal and have finally produced a synthesis known as "metrizamide" (Amipaque®). Metrizamide in an isotonic solution provides a satisfactory contrast density for myelography. The irritant effect of this preparation on the nervous system has proved so slight during experiments on dogs that it has been possible to inject it into the cranial subarachnoid space and into the ventricular system of the brain without muscular spasms arising. Clinical tests at present being carried out (i.e. *Grepe* 1974, *Irstam* 1974) regarding the suitability of the preparation for human myelography have produced very promising preliminary results. The properties of the preparation seem to be so remarkable that they justify reconsideration of the

method of myelographic diagnosis of spinal cord compression in dogs *.

MATERIAL AND METHODS

Metrizamide myelography was performed (February—April 1974) on 27 dogs and one cat which exhibited signs that suggested spinal cord compression in the cervical region (eight animals) and the thoraco-lumbar region (20 animals). The breeds, sexes and ages of the animals are given in Table 1. The examinations were carried out under general anaesthesia, induced with Pentothal®** and maintained on Halothane*** and nitrous oxide. As the method of examination required extreme flexion of the occipital joint (for suboccipital cisternal puncture), a special non-kinking (spiral wire reinforced) endotracheal tube was used (Rüsch, Fig. 1).

The metrizamide solution was prepared by dissolving a 3.75 g vial of the powder (480 mg iodine/g) in 8.9 ml of sodium bicarbonate solution containing 5 mg of $NaHCO_3$ per 100 ml sterile water. This solution is isotonic with human plasma although the iodine content is 170 mg/ml. At each examination the volume injected was 0.2**** to 0.3 ml/kg. Twenty animals received cisternal injection only, one animal received only a lumbar injection, while seven animals received both cisternal and lumbar injections at two successive sessions the same day or at intervals of one to five days. In these latter cases the cisternal injection was always given first.

The myelograms made by lumbar contrast injections were obtained according to the method described above (*Funkquist* 1962 a). In a couple of cases, a small quantity (0.2 to 0.3 ml) of the contrast was injected immediately prior to the contrast injection proper in order to check the position of the needle point.

The cisternal injections were carried out according to *Brook* (1936) except that during the puncture the dog was put on its

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* Nyegaard & Co., Oslo, have made the preparation available for clinical tests. A summary of the pharmacological and radiological properties of metrizamide is to be found in Acta Radiolog. Suppl. 335, 1973.

** Pentothal® Sodium Abbott Lab.

*** Halothane®, Hoechst.

**** Larger breeds.

Table 1. Breed, sex and age distribution of the animals examined.

No.	Breed	Sex	Age (Years)
1	Dachshund	♂	7
2	King Charles Cavalier Spaniel	♂	3
3	Newfoundland	♂	7
4	Great Dane	♂	1
5	Dachshund	♀	5
6	Dachshund	♂	3
7	Papillon	♂	4
8	Dachshund	♀	4
9	Dachshund	♂	7
10	Dachshund	♂	6
11	Dachshund	♀	6
12	Dachshund	♂	4
13	Alsatian	♂	8
14	Dachshund	♂	11
15	Saluki	♂	10
16	Grey Elk Dog	♂	8
17	Dachshund	♀	12
18	Dachshund	♂	6
19	Dobermann Pinscher	♂	4
20	Rhod. Ridgeback	♀	9
21	Dachshund	♂	10
22	Dachshund	♀	4
23	Dachshund	♀	5
24	Dachshund	♂	5
25	Dachshund	♀	4
26	Alsatian	♂	10
27	Boxer	♀	5
28	Cat	♂	14

right side with its hind-quarters elevated. A Pitkin needle of 0.7 to 0.9 mm diameter was used. Two different procedures were employed when injecting the contrast cisternally:

Method I

This method was used to assess the effect of the least possible dilution of the contrast (with CSF) on the diagnostic quality of the myelogram. To facilitate the removal of 0.3 to 0.4 ml/kg body weight of CSF, the table and the dog were tilted head down at an angle of 20° to the horizontal plane. The dog was then tilted the other way, head up, at an angle of 20° to the horizontal plane and the contrast solution injected at once. The puncture needle was then withdrawn and the neck extended. The injection time was about 2 min. A complete spinal series was made in the lateral projection, beginning in the cervical

region during injection, taking about 5 min. for the completing of the study. In several animals subsequent examinations followed at 10—15 min. intervals. In certain cases some of these examinations were made in the ventrodorsal projection with the dog on its back.

Method II

This method was an attempt to produce a higher pressure in the subarachnoid space by not withdrawing any CSF. The pressure of the fluid (mixture of CSF and contrast medium) should force the contrast past the site of compression and produce a diagnostic myelogram cranial and caudal to the lesion. The dog was placed on its right side with the table tilted to raise the hind-quarters, and the needle inserted as before. No CSF was withdrawn; contrast was injected over a 1 min. period. With the animal still lying with its head lower than the hind-quarters a lateral radiograph of the skull and cervical region was made. The needle was withdrawn, the neck extended and the table tilted to raise the head higher than the tail (at an angle of 20° to the horizontal). A number of complete spinal radiographic examinations were made as in Method I. In those cases where clinical signs indicated cervical cord compression, lateral cervical spinal radiographs were made with the dog horizontal, before the head was elevated.

If, during any examination using cisternal injection of contrast medium (Method I or II), the radiographs of the first series definitely showed passage of contrast caudal to an area of compression of the subarachnoid space, a supplementary series of radiographs were made with the animal's hind-quarter elevated (about 20° to the horizontal) after finishing the first series. The purpose of this supplementary investigation was to obtain a better picture of the posterior limit of the compression by making use of the contrast that had passed the compression. The elevation of the hind-quarters was usually performed about 5 min. after injection and as a rule the exposures were made within 10 min. after the change of position. During this examination the head of the animal was elevated somewhat by bending the neck, in order to prevent or reduce the flow of contrast into the cranial subarachnoid space. In animals with a slower passage of the contrast medium the supplementary radiographs with the hind-quarters elevated were made if and when a sufficient amount of contrast had passed the obstruction as shown by repeated radiographs made with the animal still lying with its fore-quarters elevated.

If cisternally injected contrast did not pass caudally to an area of compression, attempts were made to force it by the lesion.

Use was made, on the one hand, of (1) prolonged elevation (15—25 min.) of the fore-quarters (with the animal lying on its side, its abdomen or its back on the table in the same angle (20°) or with the dog in vertical position with the head up) and, on the other hand, of (2) "centrifuging" the animal on a specially constructed turntable. This turntable was rotated for about 3 min. at a speed of 60 revolutions per min., the dog lying on its back with its head inwards, and the base of the tail about 70 cm from the centre of the turntable.

The myelographic examinations were evaluated as follows:

The immediate effects of the preparation on the nerve tissues were studied by observing the animal's reaction when the injection was made. The possible occurrence of delayed side-effects was assessed by paying special attention during the recovery period to any possible signs of hyperreflexia and epileptiform convulsions and by studying the animal's neurological condition during the days immediately following the examination. In this connection observations were made of possible changes in the neurological status of the animal caused by the examination.

The reliability of the information yielded by myelography with cisternal injection of metrizamide was assessed by comparison with the lesions observed at operation or necropsy, or the lesions visualized by metrizamide myelography using a lumbar injection, done in conjunction with the preceding examination. Previous studies have shown the latter technique to give a reliable indication of the location and spread of the pathological-anatomical changes (*Funkquist* 1962 a).

The interval between cisternal injection examination and control examination (lumbar injection) is seen in Table 2.

Five of the animals that were examined by means of cisternal injection (in one case with a supplementary lumbar injection) and one animal on which lumbar myelography only was carried out, underwent decompressive laminectomy immediately following the examination because they had shown clinical signs of severe spinal cord compression (Table 2). In 11 other cases (with less severe signs of compression) examination was followed by disc evacuation (without opening the vertebral canal). In five dogs the latter operation was performed on the same day as the myelography and in the remaining dogs between one and three days later.

RESULTS

The effect of the contrast medium on the nervous system

In the cases with cisternal injection and in those cases with lumbar injection where, judging by the resistence to the contrast medium by injection, spinal cord compression was slight or moderate, there were no signs of any irritation of the nervous system during or in direct connection with the injection of contrast into the cisterna. However, in one of three cases of myelography with a lumbar injection, in which the preparation had to be introduced under very high pressure to enable the medium to pass the constricted part of the subarachnoid space, mild transient spasms of the hind limb muscles took place. In most cases, when the animals being examined were waking up, they showed signs of slight hyperreflexia (protective movements even when touched only lightly). However, these mild signs could not be distinguished with certainty from the hyperreflexia that often occurs during recovery from Pentothal anaesthesia in animals whose general condition is good or is only slightly below normal. There has never been any reason for treating these symptoms. Epileptiform convulsions were never observed, even though the radiographs showed that some of the contrast introduced by cisternal injection in every case had passed into the cranial subarachnoid space and in a couple of cases even into the ventricular system (Figs. 1 and 3).

Owing to the after effects of general anaesthesia, as a rule it was not possible to carry out any neurologic examination of the animals until after recovery, 1 hr. or so after the contrast injection or, in those cases where laminectomy was carried out following myelography, several hours later. Neither immediately after recovery nor later there was any sign of any deterioration in neurological condition. Of the animals that had a lumbar contrast injection or both cisternal and lumbar injections, two had to undergo decompressive laminectomy directly following myelography. This was necessary because of paraplegia with complete motor and sensory paralysis (disc prolapse with extensive compression). Both these animals later regained the ability to walk on their hind legs. The possible significance in the context of the very low level of toxicity of the contrast medium will be dealt with in the discussion.

Comparison of the myelograph quality between Methods I and II

A comparison between the results obtained from myelography with and without any prior withdrawal of liquor (Method I and Method II respectively) shows that both methods yield a diagnostic myelogram. When Method II is used the contrast density anterior to any existing spinal cord compression is greater, and as a result the films are somewhat easier to interpret.

The passage of the contrast from the cisternal puncture site along the spine

A. General observations

For optimum results it is necessary to know the time taken for the contrast to reach and possibly pass a compressive lesion after a cisternal injection.

The following features of the passage of contrast after elevation of the animal's fore-quarters were noted (with both Method I and II):

Where the passage of the medium was not or was only slightly obstructed (Fig. 4), even the first series of exposures showed a good opacification in the cranial cervical, the cranial thoracic, the caudal lumbar and the sacral regions of the subarachnoid space. At the same time there was little or no contrast present in the caudal cervical, the caudal thoracic and the cranial lumbar regions. In the beginning the contrast solution did not mix completely with the CSF and that may simulate — on the lateral projections — a central position of the contrast medium, especially in the lumbar region (Fig. 4 b). During approx. the first 10 min. the contrast would gradually increase in the caudal lumbar and sacral region without during its passage having produced a good opacification in the caudal thoracic and cranial lumbar regions (Fig. 4 a). However, after turning the dog on its back for ventro-dorsal projection or particularly after elevation of the hind-quarters even these not sufficiently opacified regions could be well filled with contrast (Fig. 4 c).

B. Obstruction to the passage of contrast medium in the cervical subarachnoid space

In the five animals with cervical spinal cord compression the first exposure, taken within a minute or two after the injection (Method I) or after elevation of the fore-quarters (Method II),

Table 2. Findings at subarachnoid myelography with cisternal injection correlated to the clinical signs and to the localization, extent and degree of the pathological-anatomical changes assessed at surgery (laminectomy), necropsy or following subarachnoid myelography with lumbar injection.

Animal no.	Clinical signs			Extent of compression			
	type	location	duration at time of suboccipital myelography	acc. to suboccipital myelography (anterior limit given first)	acc. to lumbar myelography*	as revealed by operation*	as revealed by post-mortem examination*
1	pain only	cervical region	5 days	posterior edge C_3 anterior edge C_4	—	—	—
2	„ „	„ „	2 weeks	posterior edge C_2 anterior edge C_3	—	—	—
3	„ „	„ „	7 days	neg.	—	—	—
4	„ „	„ „	4 months	neg.	—	root compression†	—
5	„ „	thoraco-lumbar region	2 days	posterior edge T_{10}	—	—	—
6	„ „	„ „	5 days	posterior edge T_{13} anterior edge L_1	—	—	—
7	„ „	„ „	7 days	middle of T_{12}	posterior edge T_{12} anterior edge T_{13} (5 days)	—	—
8	„ „	„ „	10 days	anterior edge T_{11} posterior edge T_{12}	posterior edge T_{10} anterior edge T_{11} (2 days)	—	—
9	„ „	„ „	12 days	posterior edge T_{11}	posterior edge T_{11} anterior edge T_{12} (4 hrs.)	—	—
10	„ „	„ „	2 weeks	posterior edge T_{13} anterior edge L_1	posterior edge T_{13} anterior edge L_1 (1 day)	—	—
11	„ „	„ „	2 weeks	anterior edge L_4	—	—	—
12	„ „	„ „	3 weeks	posterior edge T_{13} anterior edge L_1	posterior edge T_{13} anterior edge L_1 (1 day)	—	—
13	„ „	„ „	2 months	neg.	—	—	—
14	quadriparesis	cervical region	< 24 hrs.	posterior edge C_4 anterior edge C_5	—	herniation of disc C_4—C_5 (30 min.)	—

15	„	„	„	7 days	posterior edge C_5 anterior edge C_6	—	spinal cord compressed from ventral over disc C_5—C_6 (1 day)	—
16	„	„	„	6 days	posterior edge C_6 anterior edge T_1	—	extradural neurinoma over C_7 (30 min.)	—
17	„	„	„	½ year	neg.	—	—	vertebral canal neg. (2 days)††
18	paraparesis posterior	thoraco-lumbar region		7 days	anterior edge T_{11}	—	—	—
19	„	„	„	1½ months	anterior edge T_4 posterior edge T_4	—	intramedullary tumour over T_4	—
20	„	„	„	1 month	neg.	—	—	vertebral canal neg. (9 days)††
21	paraplegia posterior	thoraco-lumbar region		< 24 hrs.	—	middle of T_{11} middle of L_2	discmasses spread out over ½ T_{11}—½ L_2 (30 min.)	—
22	„	„	„	1 day	posterior edge T_{10}	posterior edge T_{11} anterior edge T_{12} (30 min.)	herniation of disc T_{11}—T_{12} (60 min.)	—
23	„	„	„	2 days	middle of T_{11}	—	—	herniation disc T_{11}—T_{12} (2 days)
24	„	„	„	2 days	posterior edge T_{12}	posterior edge T_{11} anterior edge L_4 (5 hrs.)	—	discmasses spread out over T_{12}—I/4 L_4 (7 days)
25	„**	„	„	10 days	posterior edge L_2	—	—	—
26	„	„	„	10 days	posterior edge T_{13} anterior edge L_1	—	—	herniation disc T_{13}—L_4 (30 min.)
27	„	„	„	2 weeks	neg.	—	—	vertebral canal neg. (30 min.)††
28	„	„	„	7 days	neg.	—	—	vertebral canal neg. (3 days)††

* The approximate time elapsing after the cisternal injection (dog no. 21 after lumbar injection) is given in parenthesis.
** Pain sensitivity returned after total sensory motory paralysis.
† Compression of cervical nerve root outside vertebral canal.
†† Vertebral canal including spinal cord and spinal cord membrane without macroscopic changes.

showed that the contrast had reached maximum concentration immediately in front of the compression (Fig. 5 a). In the two animals exhibiting slight clinical signs contrast was also found immediately caudal of the compression in sufficient quantities to enable accurate determination of the extent of the compression (Fig. 5 b). In the three cases exhibiting severe signs (of quadriparesis) no diagnostic amount deposit of contrast immediately behind the compression was obtained initially, but after the forequarters had been elevated for between 5 and 10 min. the contrast was visible in the caudal lumbar region. After elevation of the hind-quarters sufficient contrast flowed forward (within above 5 min.) to enable determination of the caudal limit of the compression.

C. Obstruction to the passage of contrast medium in the thoracic and lumbar subarachnoid space

Even in animals with compression in the thoraco-lumbar region the first series of exposures showed that a diagnostic amount of contrast had gathered immediately in front of existing compression (Figs. 6 a and 7 a). There was a good opacification of the cervical and thoracic subarachnoid space as far as the compression. In some cases it was possible to determinate the cranial limit of the compression more certainly in the ventro-dorsal projection than in the lateral projection because of a better opacification immediately cranial to the compression.

In four of the ten cases examined with slight and acute* compression signs the first series of exposures showed that the contrast had passed by the compressed area. In two dogs only faint traces of contrast passed caudal to the compression (observed in the sacral region, Fig. 7 c), whereas in the other two animals a fairly large quantity of contrast gathered in the caudal lumbar region. In all four cases, the amount of contrast was sufficient to determine the caudal limit of the compression following the elevation of the hind-quarters (Fig. 7 b). In the remaining six cases with slight acute signs contrast had not passed the compression after the first series of exposures. In four of these six, later series

* The term "acute" is used when pain was obviously felt by the animal and it was likely that continued irritation of the spinal cord was to be expected.

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A COMPARISON BETWEEN CISTERNAL AND LUMBAR INJECTIONS OF METRIZAMIDE "AMIPAQUE" IN DIAGNOSING AND LOCATING SPINAL CORD COMPRESSION

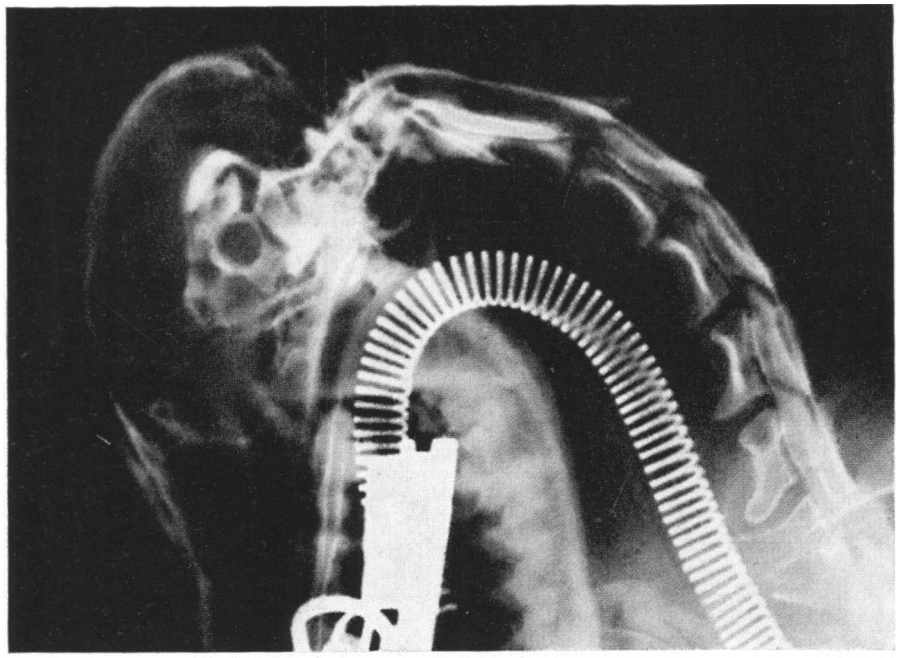

Figure 1. Metrizamide myelogram with cisternal injection of contrast in dog no. 22 (see Table 2).

Myelogram (lateral projection) with fore-quarters elevated, immediately after completion of injection. Contrast has passed into the ventricular system of the brain.

Note the "spiral" that shows up clearly is the steel-wire-reinforced endotracheal tube.

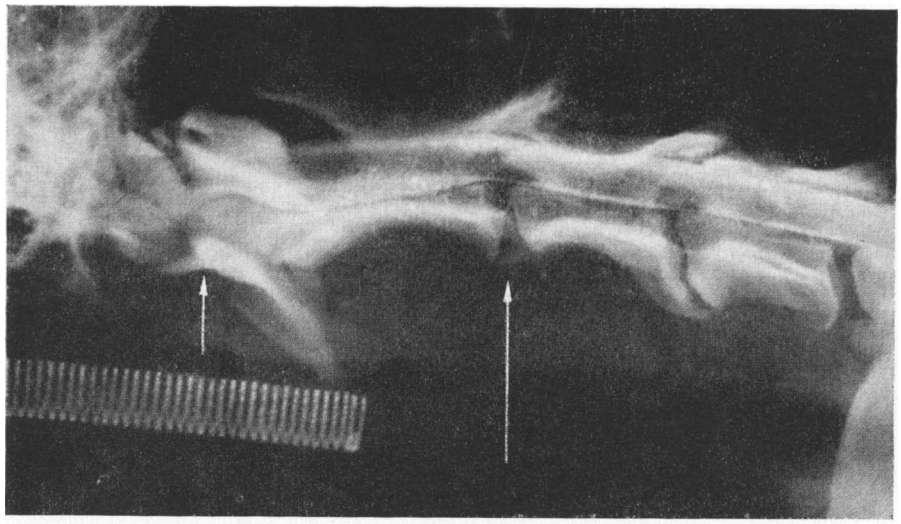

Figure 2. Metrizamide myelogram with cisternal injection of contrast in dog no. 19.

Myelogram (lateral projection) with fore-quarters elevated about 1 min. after completion of injection. Good filling with contrast in the cranial cervical region. Note the dorsal deviation of the ventral contrast line over the top of the dental process of epistropheus (short arrow) and on the first disc (C_2/C_3) (long arrow). At necropsy, the cervical vertebral canal was normal.

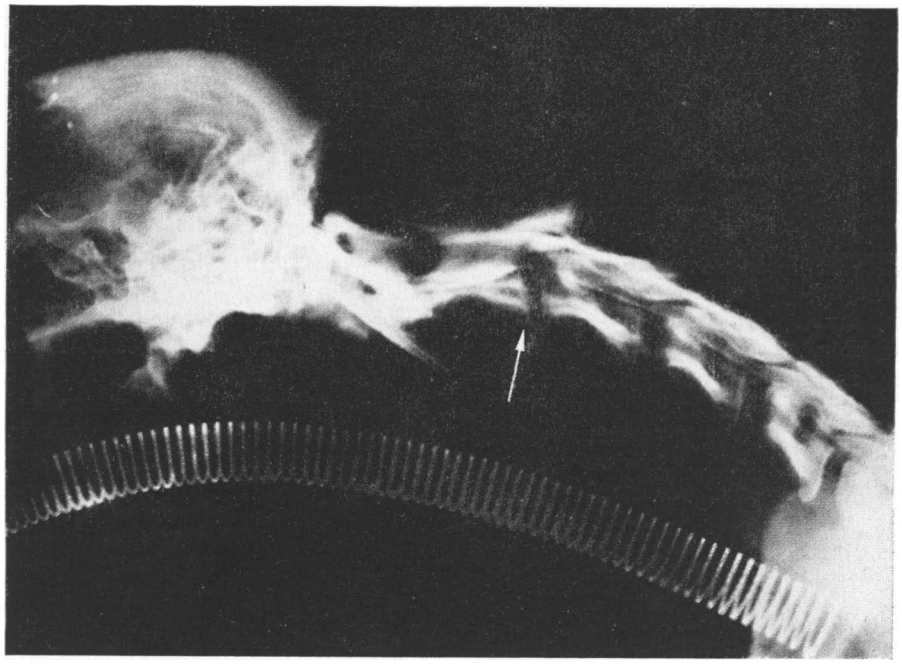

Figure 3. Metrizamide myelogram with cisternal injection of contrast in dog no. 24.

Myelogram (lateral projection) with fore-quarters elevated about 1 min. after completion of injection. Good filling with contrast in the cervical region. Note the dorsal deviation of the ventral contrast line over the first disc (arrow). At necropsy, the cervical vertebral canal was normal.

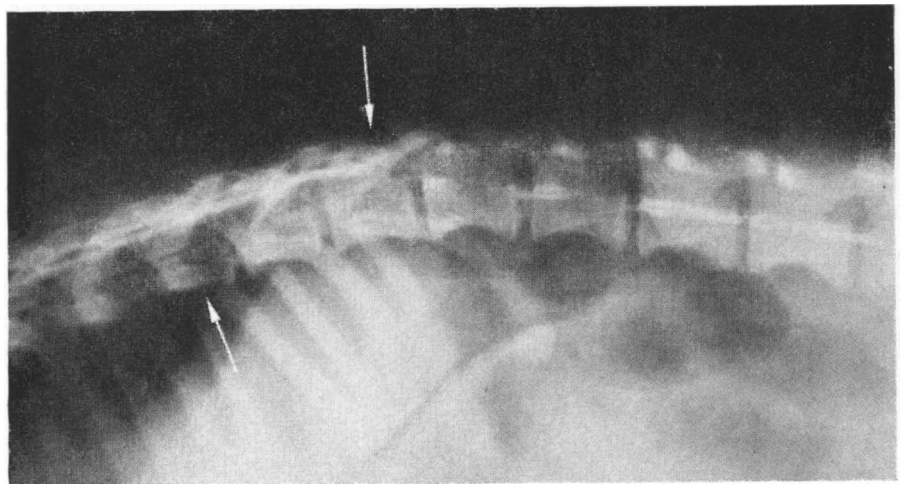

Figure 4a.

Figure 4. Metrizamide myelogram with cisternal injection of contrast in dog no. 6.

a) myelogram (lateral projection) with fore-quarters elevated, about 2 min. after completion of injection. The dorsal line of contrast medium is broken at the posterior end of T_{13} (arrow), while the ventral line gradually fades away over T_{11}. Only traces of contrast over the anterior lumbar vertebrae are seen.

b) myelogram (lateral projection) with fore-quarters elevated, just over 2 min. after completion of injection. Total filling of region over L_7 and sacrum. A line of contrast, which seems located centrally in the vertebral canal is present in the lumbar region.

c) myelogram (lateral projection) with hind-quarters elevated, about 14 min. after completion of injection. The contrast medium in the lumbar region has now concentrated further forward thus revealing a slight spinal cord compression by the elevation of the ventral line of contrast medium over the anterior part of L_1 and disc T_{13}/L_1 (arrow), changes which could not with certainty have been demonstrated by previous myelograms with the fore-quarters elevated.

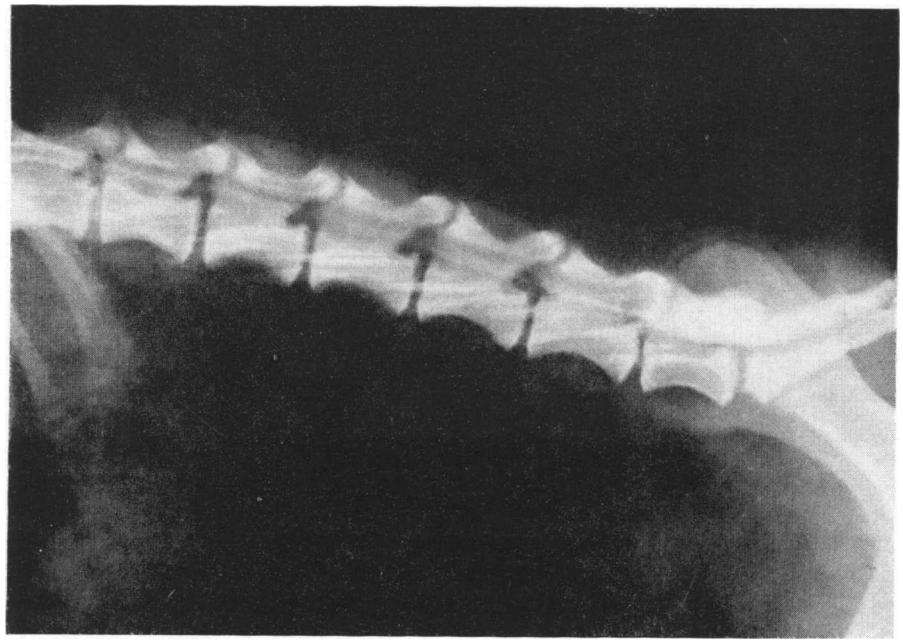

Figure 4b.

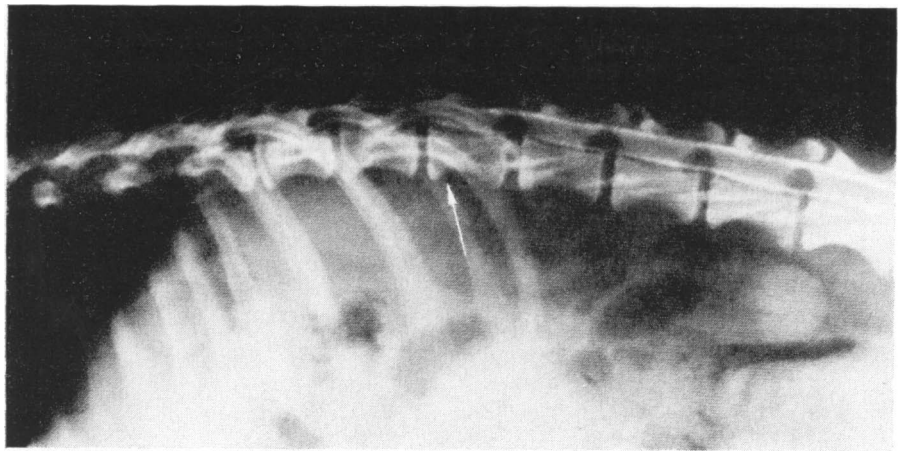

Figure 4c.

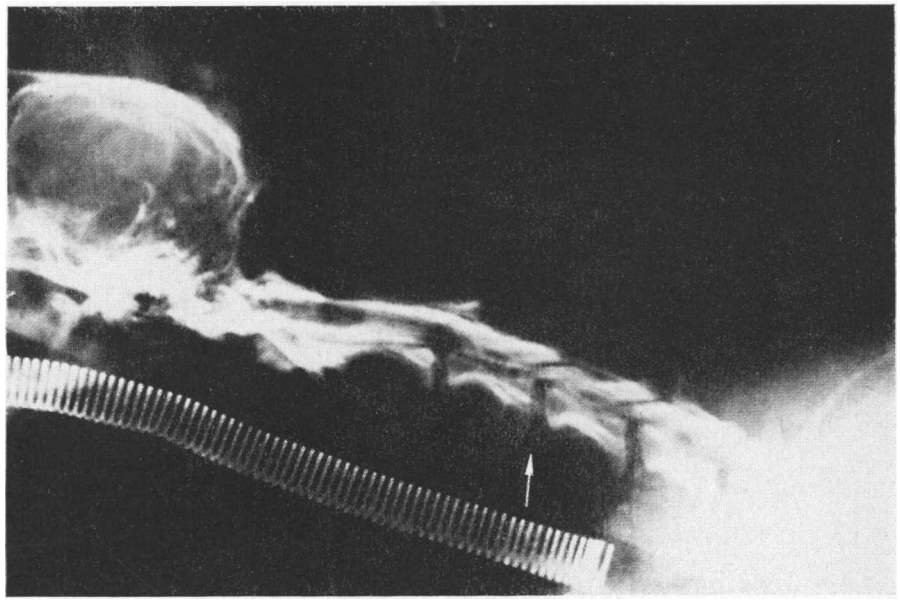

Figure 5a.

Figure 5. Metrizamide myelogram with cisternal injection of contrast in dog no. 1.

a) Myelogram (lateral projection) with fore-quarters elevated, about ½ min. after completion of injection. The ventral line of contrast is raised above disc C_3/C_4 (arrow). Quite large amounts of contrast caudal to the compression are visible.

b) Myelogram (lateral projection) with hind-quarters elevated, about 12 min. after completion of injection. The contrast, which passed the compression caudally while the fore-quarters were elevated, has now run cranially and the caudal limit of the compression is indicated more clearly (arrow).

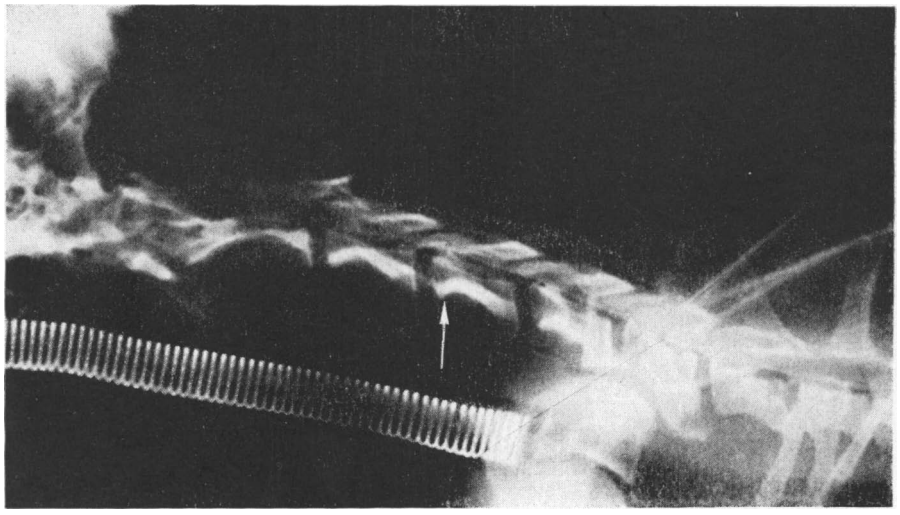

Figure 5b.

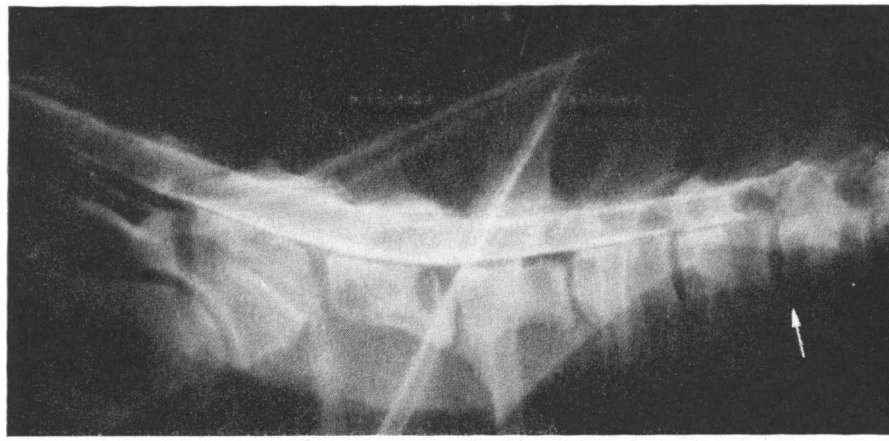

Figure 6a.

Figure 6. Metrizamide myelogram with cisternal injection of contrast in dog no. 19.

a) Myelogram (lateral projection) with fore-quarters elevated, about 2 min. after completion of injection. The column of contrast medium reaches down to the anterior edge of T_4 (arrow) vertebra.

b) Myelogram (lateral projection) with hind-quarters elevated, about 15 min. after completion of injection. The contrast, which passed the compression caudally while the fore-quarters were elevated, has now run back cranially. Widening of the column of contrast medium over the posterior part of T_4 is seen. No filling with contrast present cranial to this part (arrow). (Path. anat.: Glioma).

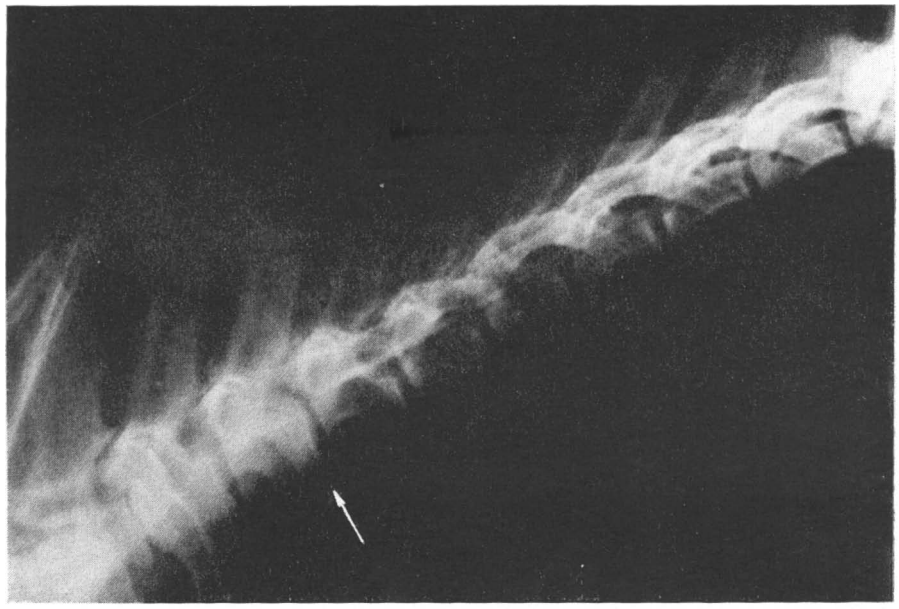

Figure 6b.

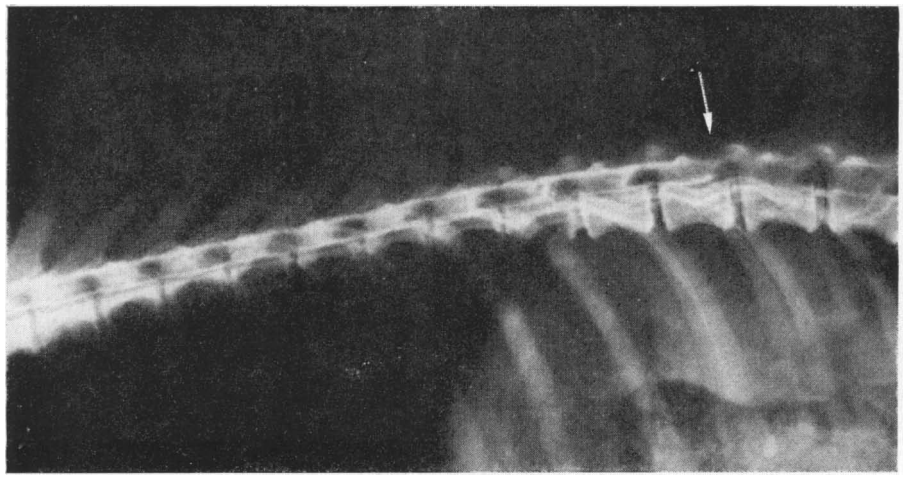

Figure 7a.

Figure 7. Metrizamide myelogram with cisternal injection of contrast in dog no. 12.

a) Myelogram (lateral projection) with fore-quarters elevated, about 1 min. after completion of injection. The ventral line of contrast medium bulges over disc T_{13}/L_1 (arrow). No filling is present caudal to this.

b) Myelogram (lateral projection) with hind-quarters elevated, 18 min. after completion of injection. The small amounts of contrast medium, that passed the compression while the fore-quarters were elevated, have now concentrated further ahead and are located over L_1, which enables also the posterior limit of the compression to be seen (arrow).

c) Myelogram (ventrodorsal projection) with fore-quarters elevated, about 2½ min. after completion of injection. Widening of the column of contrast medium over posterior part of T_{13} (arrow) and filling defect total behind this part. Caudal to this region contrast appears only as traces down in the sacral region (arrow).

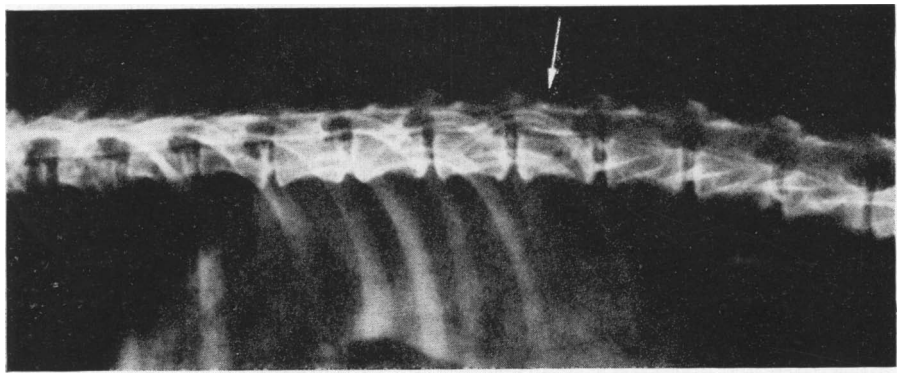

Figure 7b.

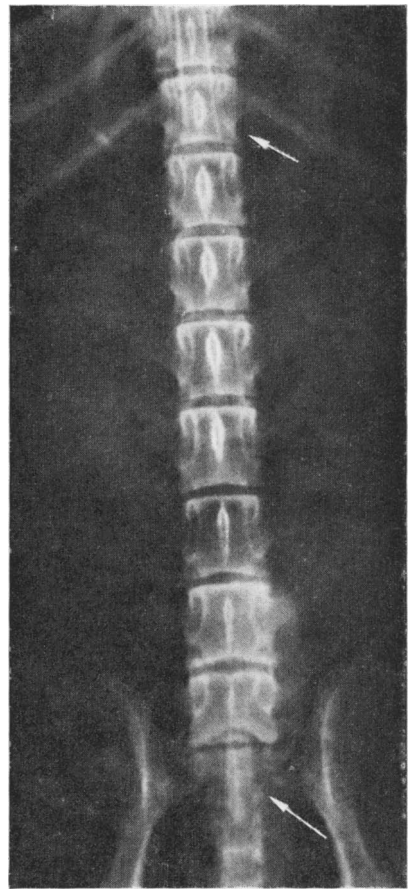

Figure 7c.

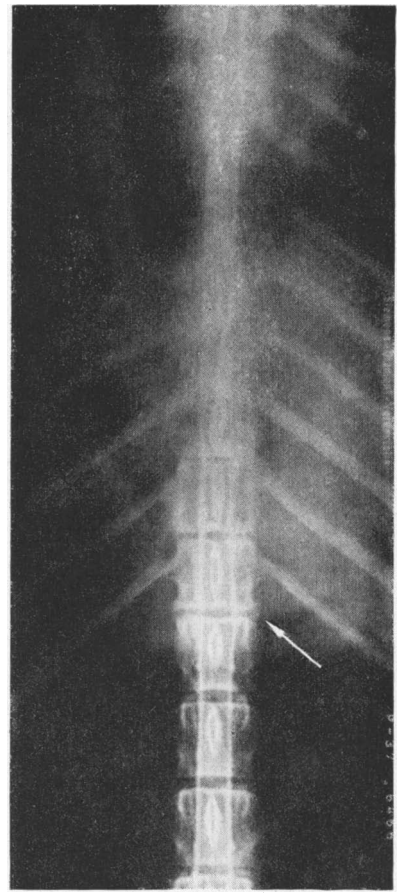

Figure 8a. Same dog as in Fig. 7. Metrizamide myelogram with lumbar injection of contrast carried out the day after the cisternal injection.

a) Myelogram (ventrodorsal projection) on completion of the injection. Moderate widening of the column of contrast medium between T_{13}/L_1 (arrow). The good filling of the thoraco-lumbar subarachnoid space in other areas means that no space occupying lesions are suspected at other levels.

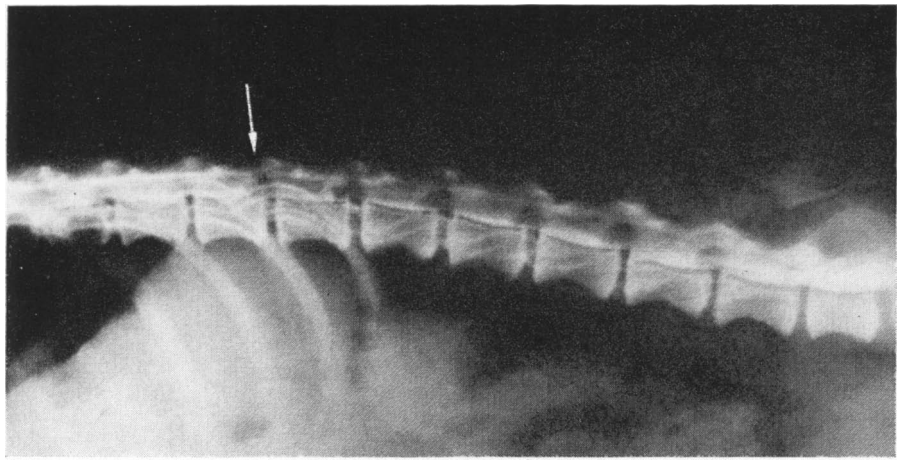

Figure 8b.

b) Myelogram (lateral projection) ½ min. after completion of injection. Good filling of thoraco-lumbar subarachnoid space. Filling defects dorsally and ventrally over posterior part of T_{13} (arrow) and disc Th_{13}/L_1.

of exposures (made more than 20 min. after the injection) indicated only faint traces of contrast behind the compression, and in only one of these cases was the quantity of contrast sufficient to determinate the caudal limit of the compression after elevation of the hind-quarters. To sum up, in the animals with mild signs, tilting the dog to elevate the fore-quarters (even with the dog in vertical position) for more than 10 min. did not improve the amount of contrast caudal to the compression. Centrifuging these animals was ineffective.

In the three cases examined with acute, severe motor disturbances (paraplegia lasting a maximum of 48 hrs.), it was not possible to demonstrate at any time the passage of contrast beyond the compression. Of the two dogs with severe motor disturbances of long duration (paraplegia for 10 days) contrast did not pass beyond the compression in one dog, while in the other, contrast in the lumbar region was demonstrated about 15 min. after the injection.

Reliability of the method in diagnosis

In seven cases the cisternal injection gave a negative myelogram. Four of these cases were necropsied and a macroscopic examination of the spinal column, the cord and its membranes also was negative. In one of these seven cases, the signs were sudden neck pain which could be ascribed to compression of a nerve root outside the vertebral canal. The signs disappeared after surgical decompression of the root. In the two remaining dogs the signs that had called for myelography could be explained by damage outside the nervous system.

In every case of cervical cord compression the cisternally injected contrast passed beyond the lesion, making it possible, as mentioned, to outline both the anterior and the posterior limits of the compression in this region. The reliability of these myelographic findings was checked in three of the dogs which underwent decompressive laminectomy, which revealed that the myelographic filling defects corresponded to space occupying lesions (tumour or prolapsed disc).

The assessment of the reliability of metrizamide myelography in the thoraco-lumbar region after a cisternal injection of contrast was based mainly on comparisons with radiographic findings after a supplementary lumbar injection of contrast, carried out the same day or one to two days later (see Table 2). Where

appropriate, the myelographic findings following the cisternal injection of contrast were placed in direct relation to the observations made during an operation (laminectomy) or necropsy. The results of these reliability tests are shown in detail in Table 2. The comparative studies, mentioned above, revealed that there was a good agreement between the two methods of injecting the contrast, cisternal (Fig. 7 c) and lumbar (Fig. 8 a) as regards the anterior limit of the compression, providing that in the event of a discrepancy between lateral and frontal projection the limit of the myelographic changes located furthest away caudally is regarded as the "appropriate" one. When made visible because of contrast passing beyond the area of compression, the myelographic caudal limit also agreed closely with the point observed on surgery or lumbar myelography (Figs. 7 b and 8).

DISCUSSION

Only through the introduction of metrizamide has it become possible to carry out myelography with cisternal injection without running certain risks.

The cisternal puncture in dogs is a relatively simple procedure compared with lumbar puncture. Method II yielded the best myelographic results during examination and offers in addition to its diagnostic superiority the practical advantage that there is no need to change the position of the dog after making the puncture. Thus, there is no danger of the position of the needle being disturbed through a change of the position of the animal. As CSF does not have to be removed there is a considerable saving of time.

When chosing between cisternal and lumbar injection, the following should be taken into consideration:

Where spinal cord compression in the cervical region is suspected, cisternal injection is to be preferred, partly because it is simpler, but also because judging from experience hitherto*, it permits the determination of both the anterior and the posterior limits of the compression, of great value in planning a surgical decompression. In this respect, the method seemed to be better than cervical myelography with a lumbar injection of the contrast medium, a technique which up to now has been the standard one

* No case of extremely severe compression with quadri-plegia, however, in the present material.

in use within this department. It's limitation was that, in cases of severe compression (quadriparesis or quadri-plegia), only the posterior limit of the compression could be determined, because the concentration of contrast cranial to the compression was too low to provide sufficient radiographic density (*Funkquist* 1961a).

When using cisternal injection of contrast for diagnosing spinal cord compression, in the thoraco-lumbar region it is best to be aware of the limitations of the method. This route, as a rule, only provides information as to whether spinal cord compression exists and if so, where the anterior limit is situated. As a rule the extent of the compression cannot be determined. Even a very slight spinal cord compression can be sufficient to completely block the passage of contrast injected cranially. If myelography is used to guide a planned decompression operation in the thoraco-lumbar region, it is preferrable to use a lumbar injection of contrast in such an amount that the pressure becomes high enough to ensure that the solution is forced past the compression, thus enabling the radiographic examination to reveal both the posterior and the anterior limits of the compression (that is the technique described for lumbar injection of the water-soluble contrast medium hitherto used (*Funkquist* 1962a).

A discrepancy concerning filling defects in and deformations of the subarachnoid space sometimes is seen between lateral and ventrodorsal projections (especially in myelographies with a lumbar injection). There sometimes is a severe deformation (elevation) of the ventral line of contrast in the lateral projection in spite of insignificant changes in the ventrodorsal projection (*Funkquist* 1962a), presumably due to the prolapsed disc being located in the middle of the bottom of the vertebral canal. These occurrences serve to underline the importance of always making exposures in both projections. A diffuse filling defect in the ventral line of contrast "upstream" to a compression, which is indicated more exactly by a filling defect in the dorsal line, was observed in the lateral projection in one of the cases (Fig. 4a). The phenomenon, presumably due to slow mixing of the contrast with accumulated CSF, is not peculiar to cisternal injection, but has also been observed, though less obviously, in myelography with a lumbar injection (*Funkquist* 1962a).

In dogs in which the clinical signs are vague and difficulty is experienced in localizing the lesion, injection into the cisterna magna is preferred because the technique is easier and lesions

can be diagnosed by this route in the cervical as well as in the thoraco-lumbar spine.

Concerning the passage of metrizamide through the spinal subarachnoid space after cisternal injection the following general observations should be taken into consideration:

Where the passage of the medium was not, or was only slightly obstructed, the contrast gradually increases in amount caudally under the influence of gravity up to the middle lumbar region, but the thoraco-lumbar region may not be opacified sufficiently. For evaluation of the non-opacified regions and to determine the caudal limit of a compression, the method of tilting the dog to elevate the hind-quarters and move the contrast will have to be employed (Fig. 4c). An alternative is continuous fluoroscopic monitoring of the position of the contrast while tilting the animal at various angles.

The reason for the appearance of contrast in the central part of the lateral projection of the vertebral canal (Fig. 4b) is probably that the heavy contrast medium does diffuse slowly and is lying as a concentrated solution in the lowest part of the subarachnoid space. Supplementary ventrodorsal films with a horizontal beam revealed the contrast lying laterally in the subarachnoid space. This appearance should not be confused with contrast deposited in central necrosis of the cord (*Funkquist* 1962a).

There seems to be a difference in the degree of obstruction caused by compression in the cervical region and thoraco-lumbar areas, when the contrast is injected into the cisterna magna. Even slight signs from the latter region were as a rule associated with complete blockage of the passage of the contrast, whereas in the cervical region, with signs of corresponding severity and duration, it was always observed that the contrast medium passed the compressed part of the subarachnoid space.

The time available for carrying out the radiographic examination is much longer when using metrizamide than is the case with preparations of the hypertonic compounds. When the latter preparations are used, the contrast density in the subarachnoid space starts to diminish noticeably after no more than 3 or 4 min. (resorption and dilution owing to osmosis (*Funkquist* 1962 a)), whereas with metrizamide good contrast is still obtained between 30 and 50 min. after the injection. This means that by changing the position of the animal during fluoroscopy or when making repeated exposures, there is sufficient time to form a good idea

of the condition of the spinal cord. On the other hand, it does not seem as elevating the fore-quarters for more than 10 min. really improves the contrast filling in the subarachnoid space anterior to a spinal cord compression. Nor does it increase the chances of the contrast penetrating beyond the compression.

Apart from the advantages in simplifying myelographic technique that metrizamide provides, there appear to be advantages in its lack of irritation to the injured spinal cord, in contrast to the sometimes deleterious effects of the hypertonic water-soluble media (*Funkquist* 1961b). In this context it is interesting to note the result of surgical treatment of dogs nos. 21 and 22, which had sudden total paralysis of their hind legs (disc herniation), but which regained their ability to walk after decompressive laminectomy. This good recovery in cases with such a clinical course is not to be expected according to earlier experiences of the same operation performed after myelography with hypertonic contrast medium (*Funkquist* 1962b).

When evaluating the absence of severe complications due to cisternal contrast injection it should be noted that no cases with extremely severe injury of the cervical spinal cord were present in this material; therefore the neurologic effect of cisternal injection of contrast medium in cases with total blockage of the passage could not be studied.

The non-irritant property of metrizamide means that a repeated injection may be made during the same examination, which is contra-indicated with the currently used media (*Funkquist* 1961b, 1962a).

It is likely that the slight spasms, that were observed in the hind legs following a lumbar injection of metrizamide (of dog no. 24 with clinical signs of a total cross-section lesion of the spinal cord), may be explained by the increase in reflex irritability that is usually present in the dog in spinal cord sections caudal to severe damage to the spinal cord.

The radiographic density of metrizamide in the isotonic solution used in this study was quite adequate for the diagnoses being undertaken. If a more concentrated solution is needed for special purposes it is probable, judging from previous experience (*Funkquist* 1962a), that such a hypertonic solution could be used without any great risk, at least in cases where the spinal cord is not made very vulnerable by acute and severe spinal cord compressions.

Disc evacuation immediately following myelography has hitherto been regarded as undesirable because this procedure usually led to at least a temporary aggravation of neurological signs existing before the operation. This aggravation has been interpreted as being a result of the combined effect on the spinal cord of the operation trauma and the contrast medium. This contraindication does not seem to apply to metrizamide.

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REFERENCES

Arnell, S. & P. Lindström: Myelography with Skiodan (Abrodil). Acta Radiol. (Stockh.) 1931, *12*, 287—289.

Brook, G. B.: Experimental and clinical studies of the spine of the dog. Baillière, Tindall & Cox, London 1936.

Funkquist, B.: Lumbar subanachnoid puncture and injection in the dog. Nord. Vet.-Med. 1960, *12*, 805—812.

Funkquist, B.: Cervical myelography with water-soluble contrast medium. Acta Radiol. (Stockh.) 1961a, *56*, 257—274.

Funkquist, B.: Effect on the spinal cord of subarachnoid injection of water-soluble contrast medium. Acta Radiol. (Stockh.) 1961b, *56*, 449—465.

Funkquist, B.: Thoraco-lumbar myelography with water-soluble contrast medium in dogs. J. small Anim. Pract. 1962a, *3*, 53—66, 67—73.

Funkquist, B.: Thoraco-lumbar disc protrusion with severe cord compression in the dog. III. Treatment by decompressive laminectomy. Acta vet. scand. 1962b, *3*, 344—366.

Grepe, A.: Personal communication 1974. (Karolinska sjukhuset, Stockholm, Sweden).

Henkels, P.: Lehrbuch der veterinärmedizinischen Röntgenkunde. Paul Parey, Berlin 1926.

Hoerlein, B. F.: Various contrast medium in canine myelography. J. Amer. vet. med. Ass. 1953, *123*, 311—314.

Irstam, L.: Personal communication 1974. (Sahlgrenska sjukhuset, Göteborg, Sweden).

Metrizamide. A non-ionic water-soluble contrast medium. Experimental and preliminary clinical investigations. Acta Radiol. (Stockh.) Suppl. 335, 1973.

Meyer, F.: Die Röntgenkontrastdarstellung des Wirbelkanals beim Hunde. (Myelographic vizualisation of the vertebral canal in the dog). Thesis, München 1937.

Olsson, S.-E.: On disc protrusion in dog. Acta orthop. scand. Suppl. 8, 1951.

SAMMANFATTNING

Myelografisk lokalisering av ryggmärgskompression på hund.

Metrizamide är ett nytt vattenlösligt kontrastmedel, som har unika egenskaper, bl. a. därigenom, att det har en för myelografiska ändamål tillräcklig röntgentäthet redan i en lösning, som är isoton med blodplasma. Preparatets egenskaper att vara föga vävnadsskadande i nämnd koncentration har gjort det möjligt att i myelografi-syfte injicera kontrastlösningen suboccipitalt, vilket applikationssätt är tekniskt enkelt, medan man vid myelografi med tidigare använda vattenlösliga preparat varit hänvisad till den hos hund tekniskt besvärliga lumbala applikationen. Vid en jämförelse mellan metrizamide-myelografier genom suboccipital respektive lumbal kontrastinjektion med avseende på de diagnostiska möjligheterna har vi funnit följande: Myelografi med suboccipital injektion är att föredraga, dels när det gäller påvisande och lokalisering av cervikala ryggmärgskompressioner, dels i sådana fall, där man önskar en första myelografisk orientering om utrymmesförhållandena i subarachnoidalrummet såväl i cervikalregionen som i thorakal- och lumbalregionen. Om man däremot vill exakt fastställa utbredningen av en thoraco-lumbal kompression (t. ex. vid en myelografi, som ingår i planeringen av en dekomprimerande operation), bör man injicera kontrasten lumbalt i sådan mängd och under sådant tryck, att kontrasten pressas förbi det komprimerade stället. Bortsett från att metrizamide öppnat nya vägar för myelografisk teknik, är det sannolikt, att dess användning vid myelografiska förfaranden, som varit genomförbara även med tidigare preparat, kommer att ge en förbättrad prognos för eventuella efterföljande operationer tack vare preparatets vävnadsvänlighet.

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