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THE LOCALIZATION OF SPINAL CORD COMPRESSION USING
TRANSOSSEOUS VERTEBRAL VENOGRAPHY IN CANIS FAMILIARIS

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by

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INTRODUCTION

Spinal cord compressions, the majority of which are caused by herniated intervertebral discs, can be difficult to localize using conventional radiography in the dog. Studies indicate that only 37% of the herniated intervertebral disc lesions can be demonstrated on a plain radiograph. By injecting a radiopaque medium in the subarachnoid space (myelography) most lesions can be localized; however, this is rather dangerous without the aid of fluoroscopy. If the contrast medium is allowed to come in contact with the medulla oblongata, respiratory paralysis can result. The purpose of this study was to develop a technique that was less difficult and dangerous to perform than myelography and to determine its accuracy in localizing compression lesions of the spinal cord.

The utilization of the venous system of the spinal canal to localize intervertebral disc lesions was first suggested by investigators of human medicine based on the hypothesis that, if a herniated intervertebral disc is present, the blood flow in these venous systems should be occluded. Intraosseous injection of a radiopaque medium into the dorsal spine of one of the lumbar vertebrae was found to provide adequate contrast of these vessels so herniated intervertebral .

discs could be localized.

Attempts at using the sinus vertebrales longitudinalis (vertebral venous sinuses) to localize herniated discs in the dog have been performed. Retrograde filling of the venous sinuses by injecting a contrast medium intravenously while compressing the abdomen has been tried. Although some filling of the venous sinuses was observed, the technique was not adequate for localizing herniated discs.

The purposes of this investigation were to determine a site for intraosseous injection of a contrast medium that would radiographically opacify the vertebral venous sinuses and to determine the validity of this technique for localizing spinal cord compression in the dog.

REVIEW OF LITERATURE

Transosseous vertebral venography is a technique in which the vertebral venous sinuses are utilized in localizing spinal cord compressions. It is generally accepted that one should be well versed in the anatomy of the area before utilizing such a procedure. Likewise, it is important to know what results can be expected from this procedure as well as complications that might be anticipated. For these reasons, the literature review concerns both anatomical and technical aspects of this procedure.

Anatomical Considerations

It is interesting to note that the existence of the vertebral venous sinuses were recorded in the literature as early as the sixteenth century. Harris (30) gave a very complete bibliographical and historical sketch of their early description in man. More recent accounts have been recorded (19, 29, 36, 48).

Batson (5) in 1940 was the first to demonstrate the clinical significance of the vertebral venous system in man. Prior to this study, the mystery of paradoxical metastases to the brain and spinal cord without lung lesions was unsolved. Some thought that a patent foramen ovale was the cause.

However, Batson's original work has now been verified by other studies (3, 6, 7, 8).

Worthman (57) has conducted a very complete anatomical and physiological study of the vertebral venous sinuses in the dog. According to his work the vertebral venous sinuses were paired and located within the epidural space along the entire length of the floor of the vertebral canal. The posterior course started with the ventral occipital sinuses at the postero-lateral wall of the cranial cavity and continued within the spinal canal as the right and left vertebral sinuses. At the foramen magnum and throughout the atlas, each vertebral sinus appeared ampullated and large. Within the third cervical vertebra, the sinuses were slightly smaller, but remained uniformly large throughout the cervical region. A definite decrease in caliber of the vertebral sinuses was evident at the thoracic inlet. After this reduction the diameters remained quite constant throughout the thoracic and anterior lumbar regions. At the level of the fifth lumbar segment, a marked reduction in the caliber of the sinuses began and progressed from one segment to the next. They diminished to two fine threads at the fifth or sixth coccygeal vertebra beyond which they could no longer be traced (Figure 1).

Figure 1. Plan of the systemic veins of the head, neck, and trunk of the male dog.
(Printed by permission of Worthman).

1. Left angularis oculi vein.
2. Superior sagittal sinus.
3. Straight sinus.
4. Confluent sinus.
5. Left transverse sinus.
6. Left dorsal cerebral vein.
7. Left basilar sinus.
8. Inercavernous sinus.
9. Left cavernous sinus.
10. Emissary vein.
11. Left condyloid sinus.
12. Left condyloid vein.
13. Left ventral occipital sinus.
14. Interoccipital sinus.
15. Left occipital vein.
16. Left ventral cerebral vein.
17. Pharyngeal plexus.
18. Left internal maxillary vein.
19. Left cranial laryngeal vein.
20. Left external maxillary vein.
21. Hyoid arch vein.
22. Left lingual vein.
23. Left sublingual vein.
24. Left facial vein.
25. Caudal laryngeal arc vein.
26. Left cranial thyroid vein.
27. Left caudal thyroid vein.
28. Left internal jugular vein.
29. Thyoidima vein.
30. Left external jugular vein.
31. Right external jugular vein (cut).
32. Right axillary vein.
33. Left internal thoracic vein.
34. Right and left costocervical - vertebral trunks.
35. Left vertebral vein.
36. Left costocervical vein.
37. Left supreme intercostal vein.
38. Left deep cervical vein.
39. Left longitudinal vertebral sinus.
40. Deep ventral transverse anastomosis.
41. Superficial ventral transverse anastomosis.
42. Dorsal anastomosis.
43. Intervertebral branch of occipital vein.
44. Azygos vein.
45. Bronchoesophageal vein.

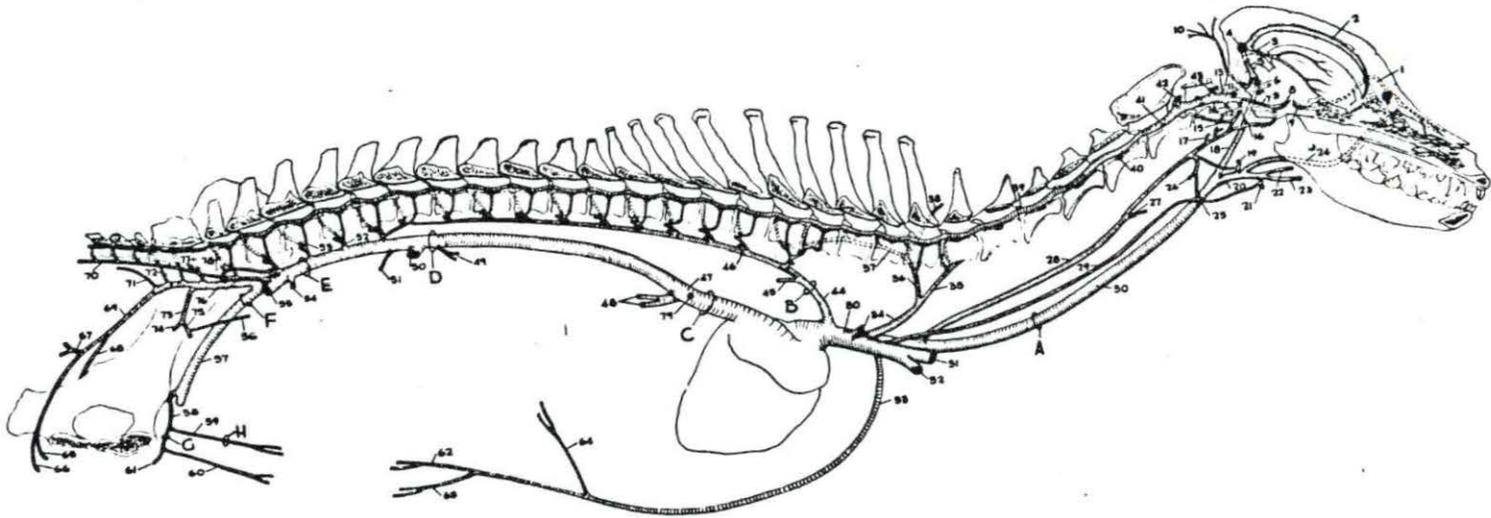


Figure 1 (continued)

46. Right and left sixth intercostal veins.
47. Posterior vena cava.
48. Hepatic veins.
49. Right phrenico-abdominal veins.
50. Right renal vein.

51. Right (internal) spermatic vein.
52. Fourth lumbar vein.
53. Basivertebral vein.
54. Right deep circumflex iliac vein.
55. Right common iliac vein (cut).

56. Left ureteral vein.
57. Left external iliac vein.
58. Left pudendo-epigastric trunk.
59. Left caudal deep epigastric vein.
60. Left caudal superficial epigastric vein.

61. Scrotal branches of left external pudendal vein.
62. Left cranial deep epigastric vein.
63. Left cranial superficial epigastric vein.
64. Left musculophrenic vein.
65. Left dorsal vein of penis.

66. Left deep vein of penis.
67. Left perineal-caudal hemorrhoidal trunk.
68. Left caudal gluteal vein.
69. Left internal pudendal vein.
70. Middle sacral vein.

71. Left lateral superficial coccygeal vein.
72. Left third sacral intervertebral vein.
73. Left urogenital vein.
74. Left ureteral vein.
75. Left prostatic-caudal vesical trunk.

76. Left internal iliac vein.
77. First sacral branch from cranial gluteal vein.
78. Intervertebral branch from ilio-lumbar and seventh lumbar veins to lumbo-sacral junction.
79. Right phrenic vein.
80. Anterior vena cava.

Within the atlas and between the atlas and axis, the larger sinuses were positioned against the sides of the vertebral arches so that the spinal cord passed between the two sinuses and was in contact with the dorsal surface of the dens of the axis. Because of this lateral displacement, the first cervical nerve invariably penetrated the sinus of either side in emerging from the spinal canal. Posterior to the axis, the sinuses were more medially located and were positioned on the floor of the vertebral canal in contact with the dorsal longitudinal ligament.

The vertebral sinuses were characterized by their segmentally arranged arcs with the right and left convexities converging in the middle of each vertebral segment. The curvatures of these two arcades varied. The greatest arcs were in the lumbar and sacral regions while the arcades in the coccygeal and anterior half of the thoracic regions had a lesser curvature. At each intervertebral foramen, where one arcade joined the next arcade, intervertebral veins connected the sinus of that side with veins outside the vertebral canal. Small radicles from the plexus of veins along the spinal cord followed the dorsal and ventral roots of the spinal nerves and joined the intervertebral veins at each foramen.

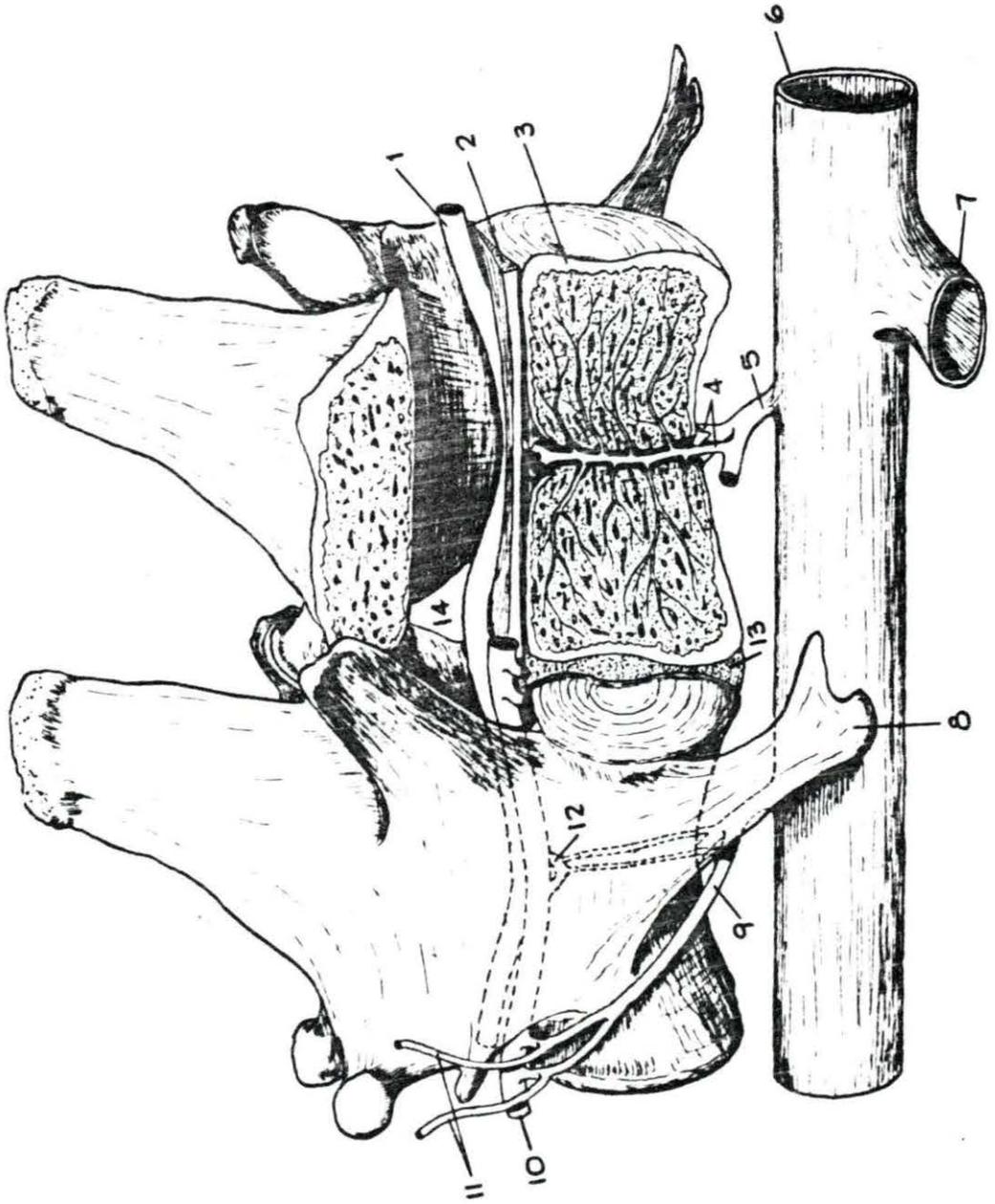
In the middle of each vertebra, the convexities of the right and left sinuses were connected across the midline beneath the dorsal longitudinal ligament. These deep transverse anastomoses passed either beneath the ligament or through a bone channel under the ligament. Basivertebral veins made connections with these deep anastomoses. By passing through canals within the vertebral bodies, these basivertebral veins emerged through venous foramina on the ventral side of the bodies of the vertebrae and joined extravertebral veins (Figure 2).

Crock (11) described the veins within the vertebrae more completely. He stated that the tributaries of the basivertebral vein within the centrum were arranged predominately at right angles to its long axis. The basivertebral vein essentially was a center of a rosette. The branches of the basivertebral vein originated within a short distance of the metaphyseal zones of the vertebrae, from whence they coursed centrally towards the basivertebral vein. The veins draining the epiphyses of the vertebrae were characterized by fine arborizing veins that were bilaterally symmetrical and drained via slender stems directly into the vertebral venous sinus.

The extravertebral drainage that will be of importance in this thesis is the drainage of the thoracic, lumbar, sacral

Figure 2. Plan of the emissaries of the sinus vertebralis in the third and fourth lumbar segments. The third lumbar vertebra is cut sagittally to the right of the midline. (Printed by permission of Worthman).

1. Left longitudinal vertebral sinus.
2. Dorsal longitudinal ligament.
3. Body of third lumbar vertebra (cut sagittally).
4. Paired basivertebral veins.
5. Third lumbar vein. (The second lumbar vein usually drains into the third but is not shown).
6. Posterior vena cava.
7. Right renal vein.
8. Transverse process of fourth lumbar vertebra.
9. Right fourth lumbar intervertebral vein.
10. Right longitudinal vertebral sinus.
11. Epaxial branches.
12. Deep ventral transverse anastomosis.
13. Intervertebral disc.
14. Left third lumbar intervertebral foramen.



and coccygeal vertebrae. As reported by Worthman (57) the azygos vein received right and left intercostal veins of most of the thoracic vertebrae. Single intervertebral branches connected the vertebral venous sinuses to each of these intercostal veins at the highest point in the intercostal spaces of each side. A vein of small caliber joined the azygos to the first lumbar vein. This posterior extension of the azygos vein coursed along the midline beneath the bodies of the last thoracic and first lumbar vertebrae.

Each intervertebral vein of the lumbar region emerged from its foramen as a double vessel which quickly united to form a single lumbar vein on each side. Right and left lumbar veins then passed downward and forward on either side of the bodies of the vertebrae and emptied into the azygos, the posterior vena cava, the common iliac, the iliolumbar, or the middle sacral veins. The right and left veins of all but the first and last lumbar segments joined each other beneath the vertebral bodies to form a common trunk which then emptied into the extravertebral veins.

The vertebral venous sinuses of the sacral region drained by way of the anterior gluteal or internal pudendal veins into the right and left internal iliac veins.

The sinuses in the coccygeal region drained almost

exclusively into the middle coccygeal vein which was the posterior continuation of the middle sacral vein.

Worthman (57) found no valves within the cavities of the sinuses themselves. However, one or more valves in the veins that connected the intervertebral vessels with their major extravertebral vein were found. Each lumbar vein possessed a valve at its entrance into the posterior vena cava. The free edges of these valves were directed toward the major extravertebral vein and away from the sinuses. This finding is compatible with the findings of other investigators (6, 8, 11) and explains why Batson (6) described the vertebral venous system as being constantly subject to arrests and reversals in direction of blood flow.

Technical Considerations

According to Hoerlein, (33) spinal cord compression in the dog was usually caused by herniated intervertebral discs. Of all cases in which spinal symptoms were observed, 50% resulted from disc herniation. Dexler (13) in 1896 was the first to describe a form of paraplegia in the dog which was caused by compression of the spinal cord by cartilaginous excrescences of the intervertebral disc. The condition was called enchondrosis intervertebralis. There is little doubt that he was referring to intervertebral disc protrusion.

Since Dexler's early description, many investigators have studied this disease primarily in the 1950's and early 1960's.

Intervertebral disc herniation has been described (23) as occurring in three different types:

Type 1: Sharply defined "button-shaped" protrusion over one disc and parts of adjacent vertebrae.

Type 2: Protrusion as in 1, combined with extension of disc substance like a carpet over adjacent vertebrae.

Type 3: Extension of disc substance like a carpet over several vertebrae.

Type 3 disc herniation was the most common type observed. Type 1 had the second highest incidence. Type 2 was rather rare in occurrence according to this report.

Hoerlein (32) in another study reported that the disc most frequently affected was $T_{13}-L_1$. The midthoracic segment was not usually affected. This phenomenon was explained by the presence of the ligamentum conjugale costorum in this region (54).

The diagnosis of herniated intervertebral disc disease should be based on the clinical history, clinical examination, and radiographic examination of the patient.

The treatment of intervertebral disc herniation is either conservative or surgical. If the clinician chooses to use the conservative approach, then the exact location of the herniated disc need not be demonstrated. If surgery is contemplated, then it becomes very important to know where the herniation has occurred.

Funkquist (24, 25) has compared the results of conservative and surgical treatment. He divided his patients into three groups.

Group I. The animals were incapable of walking with their hind legs; some voluntary movements were observed in one or both of the hind legs.

Group II. The animals had completely lost the ability to voluntarily move the hind legs, but some tonus of the muscles was present.

Group III. The animals completely lacked ability to voluntarily move the hind legs; the muscles were without tonus.

Surgery (decompression laminectomy) was a better treatment in each group than was conservative treatment. As the severity of the spinal attack increased, the difference

between the results of the two treatments increased. For example, the rate of recovery with or without disturbance of movements with surgical treatment compared to conservative treatment was 87.5% and 81.8% respectively in group I. In group II the difference was 78.6% compared to 39.1%. Of the animals that regained their ability to walk, more in the surgery group regained complete control of the hind legs than in the conservative group. In group I 75% of the dogs in the surgery group returned to normal while only 33% treated conservatively returned to normal. The percent difference between surgical and conservative therapy increased as the severity increased.

It becomes obvious that surgery (decompression laminectomy) is the "treatment of choice." However, another factor that must be considered is the speed of development of the compression. It was reported (23) that the faster a herniation occurred the less time one had to institute therapy. This was an important factor to be considered if surgery was contemplated. The speed of development and critical time for surgery have been reported (23). A sudden, powerful compression of the spinal cord, even of short duration, could cause irreversible changes so that any method of treatment would be futile (45).

The localization of the herniated disc can be accomplished by using two different radiographic techniques -- plain radiography (normal contrast) and myelography. The radiographic criteria for diagnosing a herniated disc on a plain radiograph have been described in the literature (34, 55). The most frequently observed roentgen sign used in diagnosing the condition of herniated intervertebral disc on a plain radiograph was that of observing calcified disc material in the intervertebral foramen. Narrowing of the intervertebral space was also indicative of a herniated disc. Using these criteria, however, only 37% of the positive lesions could be recognized, and 6% were diagnosed abnormal and found to be normal on necropsy. Plain radiographs were often of questionable value in the proper diagnosis and location of myelopathy caused by dorsal herniation of intervertebral discs, the most common cause of traumatic spinal cord injury in dogs.

Myelograms have shown highly satisfactory agreement with changes in the epidural space observed by laminectomy or necropsy (22). The percent accuracy with this method has been reported as being 70% (16) and 90% (20). False positives have been reported as constituting less than 3% of the lesions observed on the radiograph (2). Severe myelomalacia could be

indicated by contrast medium replacing the spinal cord (10) and was indicative of a grave prognosis. No other diagnostic method could yield this information. Another major advantage of myelography was that the contrast medium would pass beyond the site of the compression allowing for the diagnosis of multiple disc hernias (22).

Myelography was not without complications and contraindications. The major disadvantage of the water soluble mediums was their irritating qualities, occasionally producing hypotension and sometimes death (10, 26). Edema and some necrosis of the spinal cord have been observed on histopathological examination. Myelography has caused aggravation of the symptoms of compression by producing an increase in volume of the spinal cord by osmosis; however, this change was usually transient (21). The most damage was usually on the side that the dog was lying on during recovery from anesthesia (26). If the myelogram was not satisfactory following the first injection, a second injection was not attempted because of reported danger of causing spinal cord damage (10, 21). The oily products used for myelography have caused foreign body reactions and granulomas in the leptomeninges. Thus, repeated studies were not attempted (34). Frequently the oily products would stop flowing about one

vertebra from the actual protrusion (34). This was a cause of diagnostic error.

Myelography of the spinal cord has been carried out with a mixture of water soluble contrast medium and xylocaine. The blood pressure was continuously checked and if necessary, was corrected during the procedure (27). The dog's head was kept elevated to keep the contrast medium from entering the cranial subarachnoid space (10). The animal was turned during recovery to avoid concentration of the medium on one side (26). When a radiopaque medium was accidentally injected into the epidural space, no abnormal nervous manifestations were observed (10).

Despite the proclaimed safety of myelography many still adopt a reluctant attitude towards indiscriminant and repeated employment of the procedure or condemn it as a screening procedure. The basis for this hesitancy is reported occasional adverse reactions of the leptomeninges with early or late sequelae in the spinal canal. A method without the disadvantages associated with the introduction of a potentially irritating substance into the subarachnoid space but with comparable accuracy would indeed constitute a valuable addition to our diagnostic armamentarium.

It has been reported in both the man and the dog that

when the posterior vena cava was occluded, retrograde filling of the vertebral venous system could be accomplished (3, 58). Helander (31) using a technique similar to that used by Anderson (3) stated that venography of the vertebral venous system may be used to differentiate between anatomical and pathological variations where myelography cannot. Varices of the epidural veins had been reported as a cause of low back pain (17). The history and clinical signs, as well as the appearance of the myelogram, were similar to those of herniated intervertebral disc. Venography of the vertebral venous sinuses was used to differentiate between the two diseases.

In the early 1960's publications describing intraosseous vertebral venography began to appear on its use in human medicine. Most authors were quite satisfied with the results of the technique saying that it compared favorably with myelography (1, 28, 31, 38, 50, 51, 52). Others questioned the adequacy of the technique in diagnosing herniated intervertebral disc lesions (14, 18, 39).

With dilution of isotopes injected into the medullary canal and clearing of radiopaque contrast medium similarly deposited the circulation of the hemopoietic bone marrow was found to be dynamic and in direct communication with the extraosseous venous system (47). Medullary pressure curves

indicated the presence of a pulse wave as well as respiratory fluctuations and response to vasoactive drugs (46). Contrast media injected into the marrow cavity were cleared more rapidly than from muscles or soft tissue. The ease and rapidity with which large quantities of fluids could be introduced into the marrow space and cleared reflected the capacity of the venous outflow of the system. It was this property of the marrow circulation which made intraosseous venography practical (56).

The technique consisted of injecting a water soluble contrast medium into the marrow cavity of the dorsal spine of either the fourth or fifth lumbar vertebra while the patient was lying on an inflated bladder that occluded the blood flow in the posterior vena cava. The radiograph was taken as the last two to three cubic centimeters of contrast medium were being injected. The medium was cleared quickly from the marrow cavity via the vertebral venous sinuses. If a herniated disc was present, the filling of the vertebral sinuses was incomplete in the area of the compression.

If aseptic technique was used, venography as well as intraosseous vertebral venography was found to be an innocuous procedure. If some of the contrast medium spilled into the epidural space or soft tissue, no complications were observed

(12, 15, 49, 50, 52). No changes in subarachnoid pressure have been observed (51).

However, some contraindications and complications have been reported. If an infection was present in the injection area, the procedure was not performed. Coagulation dyscrasias and idiosyncrasy to the contrast agent were relative contraindications. Patients with these disorders were not exposed to the technique (56).

The most frequently reported complication was mild discomfort and pain of short duration after the procedure (37, 40, 56) but this was of little concern quoad vitam. Marrow cells, bone spicules, and fat have been reported to be embolized to the pulmonary vessels during the course of intraosseous contrast studies (9, 37, 43). One author (53) stated that although some fat was conceivably displaced into the blood stream, there was little ground for fearing any such complication as fat embolism. The injection site had a relatively low fat content even in the adult. Other complications that have been rarely reported are thrombophlebitis (40), thrombosis (35), and osteomyelitis (56).

The only attempts at using the vertebral venous system to localize spinal cord compression reported in the literature have been by Olsson (44) and Lindblad (42). Dogs were laid

on their side with their backs towards a metal plate and the abdomen was compressed with a wooden instrument. A water soluble contrast medium was injected into the saphenous vein immediately after compression of the vena cava was started. Two radiographs were taken 15 and 20 seconds after the injection. Compression was removed slowly to avoid too high a concentration of the medium in the brain.

Opacification of the vertebral venous sinuses was observed up to the level of the eleventh or twelfth thoracic vertebra. By using venography, it seemed possible to demonstrate even slighter spatial changes in the spinal canal than with myelography, but venography could not be used as a method of localizing spinal cord compression. However, spinal cord compression, at least below the level of the eleventh or twelfth thoracic vertebra, could be ruled out in cases where compression was suspected.

Lewis (41) has used intraosseous vertebral venography in the dog with disappointing results. Using a lateral approach, Lewis tried to place the tip of a needle into the body of the sixth lumbar vertebra. The dog was in lateral, horizontal recumbency while the injection was made. The radiograph was taken as the last cubic centimeter of contrast medium was injected. In the normal spine the venous sinuses

were filled up to the level of the thirteenth thoracic vertebra. Occasionally these vessels were filled up to the eighth thoracic vertebra. When using this procedure, it was extremely difficult to consistently place the needle into the body of the vertebra. The needle would slip off the ventral side of the body of the vertebra.

Working together, Lewis and Botta performed some compression studies using this technique. Botta surgically placed an intramedullary pin across the floor of the spinal canal under the spinal cord from the left intervertebral foramen to the right intervertebral foramen of a particular vertebral junction. Using intraosseous vertebral venograms, no obstruction was found immediately after the surgery. After 24 hours, obstruction was demonstrated with a vertebral venogram apparently caused by edema and swelling in the area. After an extended period of time, venous flow as well as function returned. One or two clinical cases of herniated intervertebral discs were successfully localized using this technique, but difficulty in consistently placing the needle in the marrow cavity of the vertebra lead to the abandonment of the procedure.

In view of the results of intraosseous vertebral venography in the human subject, this project was undertaken with

the expectation of obtaining similar results in the dog. However, a new approach to placing a needle in the marrow cavity of one of the lumbar vertebrae must be devised.

This author prefers to name the procedure transosseous vertebral venography. The prefix intra implies that the vessels being studied are within the bone and this is not the case. The bone is merely an injection site. The contrast medium travels across the marrow cavity into the extra-osseous vessels.

MATERIALS AND METHODS

Thirty-three dogs of various breeds were used in this study. Their weight varied from 2.3 kilograms to 36.4 kilograms and averaged about 11.4 kilograms. No attempt was made to record sex differences.

Development of the Technique

A procedure for performing transosseous vertebral venography should meet the following criteria.

1. The procedure should be simple to perform.
2. The procedure should be relatively safe.
3. Maximum radiographic opacification of the vertebral venous sinuses should be obtained.

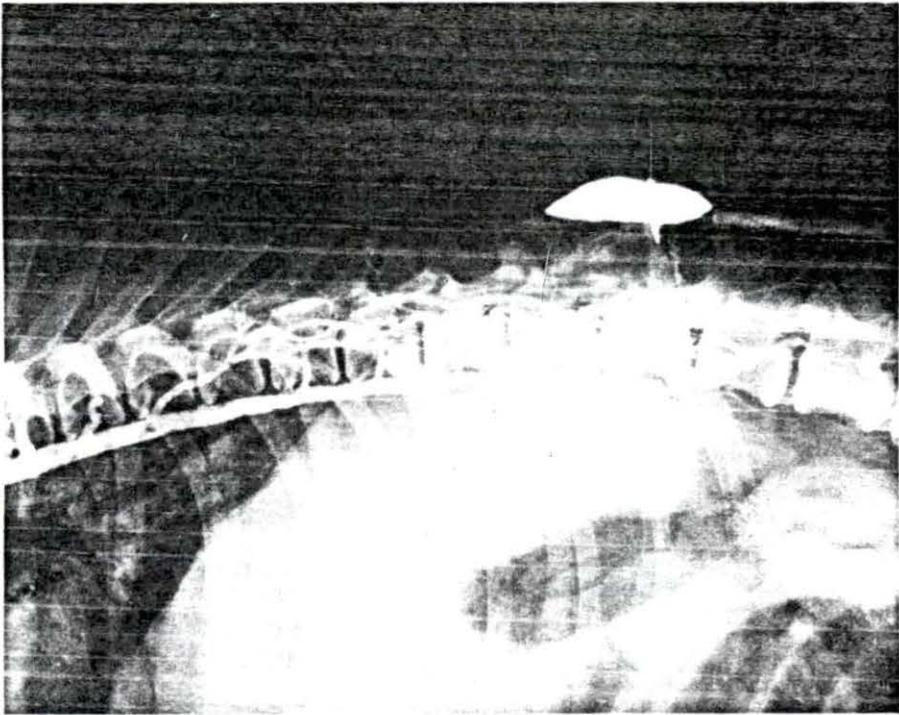
Using these criteria, the first attempt at radiographic opacification of the vertebral venous sinuses was made by drilling a bone marrow biopsy needle into the marrow cavity of the iliac crest. With the dog in lateral recumbency, ten cubic centimeters of sodium diatrizoate (Hypaque¹) were infused. As the last cubic centimeter of contrast medium was injected, the radiograph was taken. None of the contrast medium entered the venous sinuses; consequently, the technique was abandoned.

¹Winthrop Laboratories, New York, N. Y.

In view of the results obtained by Lewis, (41) the body of the seventh lumbar vertebra was the next injection site investigated. Lewis was continually plagued by the needle slipping off the vertebra on the ventral aspect. In this experiment, the needle was drilled through the wing of the ilium to stabilize the needle as it was drilled into the body of the seventh lumbar vertebra. Some filling of the venous sinuses was obtained from L₇ to L₁; however, it was extremely difficult to drill the needle through the ilium and maintain control of the needle tip as it entered the seventh lumbar vertebra. For this reason the procedure was abandoned.

The dorsal spinous process was investigated as an injection site in two experiments. In one experiment, the dorsal spinous process of the first lumbar vertebra was drilled with an 18 gauge hypodermic needle, and 10 cubic centimeters of sodium diatrizoate were infused with the dog in lateral recumbency. The radiograph was exposed as the last cubic centimeter was injected. Opacification of the venous sinuses was obtained from L₂-T₉ (Figure 3). In the second experiment the same procedure was followed except the dorsal spinous process of the fourth lumbar vertebra was drilled. As a result opacification of the venous sinuses

Figure 3. Transosseous vertebral venogram performed by injecting the dorsal spinous process of L₁. Note opacification of the vertebral venous sinuses from L₂ to T₉.



from L₄ to T₁₀ was obtained (Figure 4).

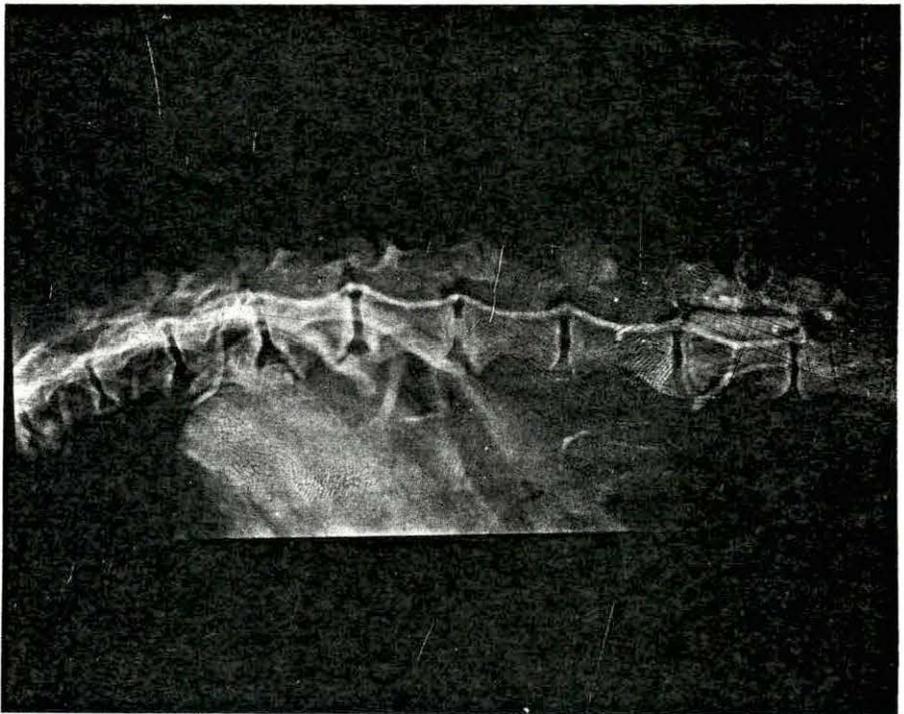
These experiments indicated that opacification of the vertebral sinuses was feasible using the dorsal spinous process; however, in the author's opinion the procedure would be limited to large dogs because of the difficulty encountered in drilling this slender process.

Another attempt at drilling the marrow cavity of the seventh lumbar vertebra was made using a ventral approach. The necessity of post caval compression was also investigated in this experiment. A femoral vein was surgically exposed and a balloon catheter inserted until the balloon was situated just posterior to the renal veins. Using the crest of the ilium as a landmark, a Lundy-Irvin caudal needle¹ was inserted beneath the ileum into the psoas muscle and then drilled into the seventh lumbar vertebra. After inflating the balloon, ten cubic centimeters of sodium diatrizoate were infused with the dog in horizontal, lateral recumbency. The radiographic exposure was made as the last cubic centimeter was infused. The procedure was repeated without inflating the balloon.

With the balloon inflated, the vertebral venous sinuses were opacified from the first coccygeal vertebra to the sixth thoracic vertebra. Many of the small radicles of veins

¹Becton, Dickinson, and Company, Rutherford, New Jersey.

Figure 4. Transosseous vertebral venogram performed by injecting the dorsal spinous process of L₄. Note opacification of the vertebral venous sinuses from L₄ to T₁₀.



that join the vertebral sinuses were also opacified, especially in the lumbar region (Figure 5). Without inflation of the balloon, the venous sinuses were opacified from the first coccygeal vertebra to the seventh thoracic vertebra. The small radicles were not opacified (Figure 6).

Since catheterization of the posterior vena cava with a balloon catheter added to the complexity of the procedure and did not significantly increase the opacification of the vertebral venous sinuses, this portion of the procedure was abandoned. However, the intraosseous injection of a contrast medium in the seventh lumbar vertebra using the ventral approach produced the desired opacification of the vertebral venous sinuses.

As dogs with clinically normal spinal columns were studied to determine the anterior limit of opacification using this technique, it was noticed that occasionally the medium would stop near the thoraco-lumbar area (Figure 7). Since this phenomenon would introduce some diagnostic error, the technique was revised. The dogs were placed in lateral recumbency on a 35° incline with the head lower than the tail. Theoretically, this would increase the blood flow in the venous sinuses. It was found that in dogs with poor blood flow in the venous sinuses, this procedure improved blood flow.

Figure 5. Transosseous vertebral venogram performed by injecting the body of L₇. A balloon catheter was used to block blood flow in the posterior vena cava.

Figure 6. Transosseous vertebral venogram performed by injecting the body of L₇. The balloon catheter was not inflated in this procedure.

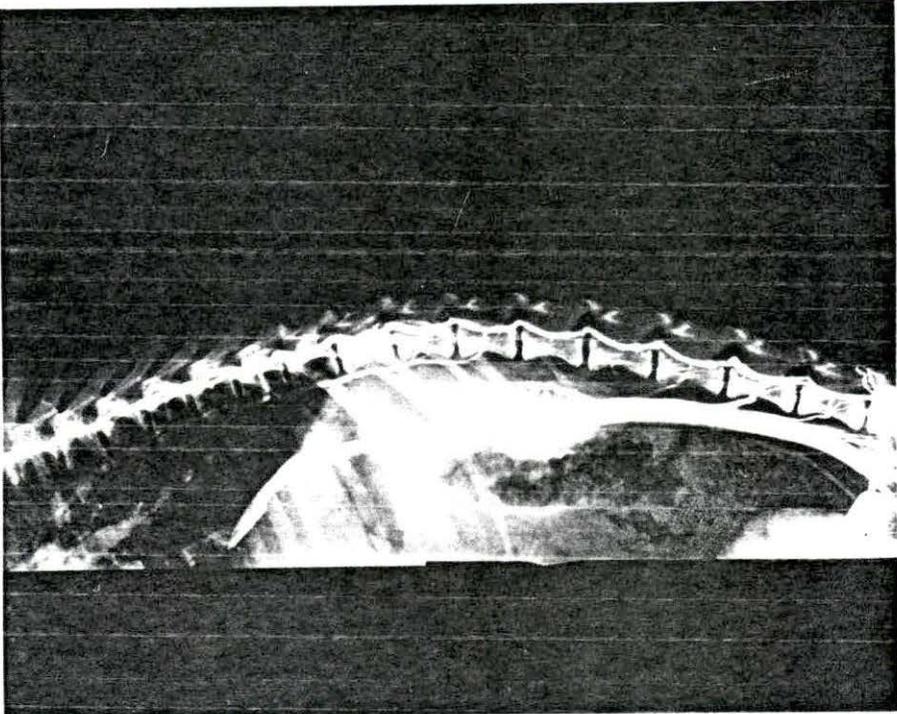
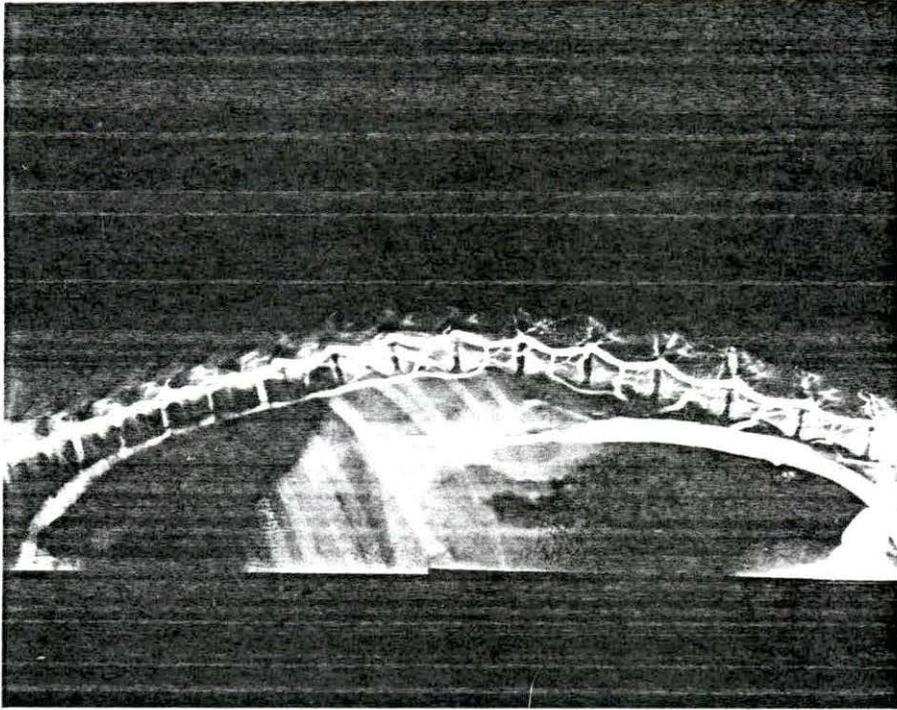
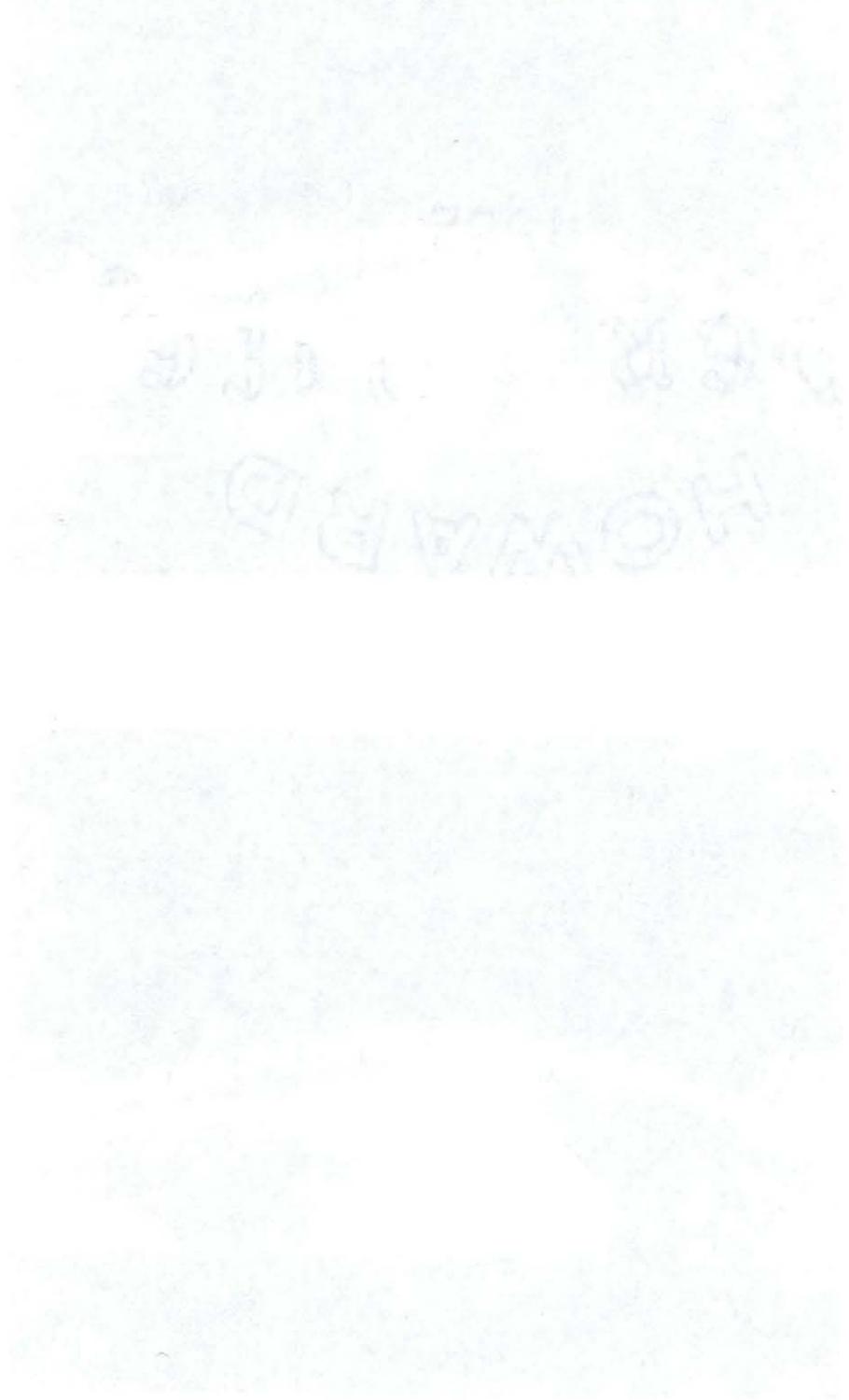
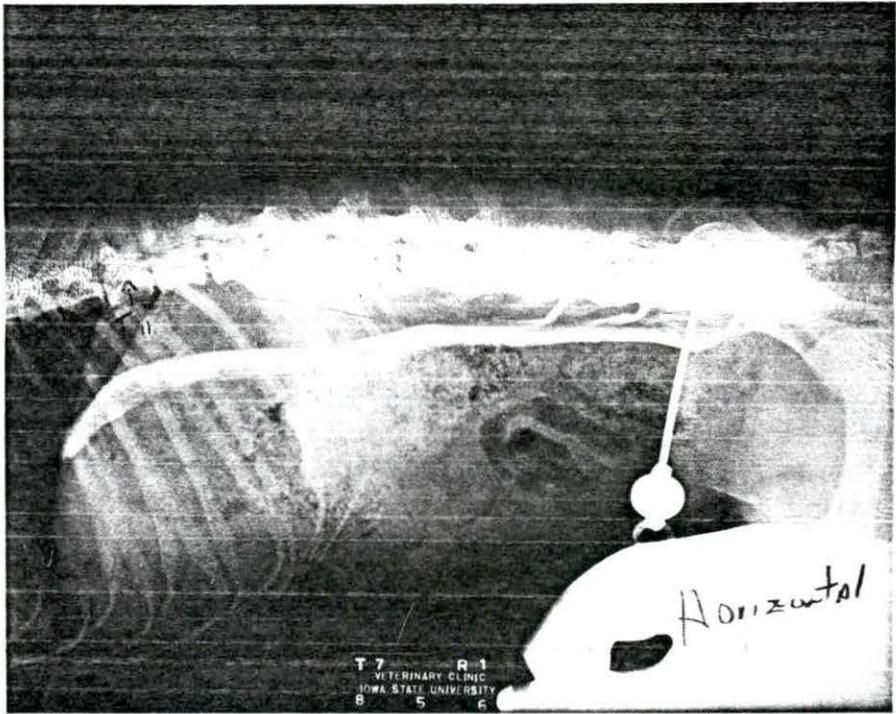


Figure 7. Transosseous vertebral venogram performed with dog in horizontal, lateral recumbency. Opacification of the vertebral venous sinuses stops at T₁₁.





The anterior limit of opacification was extended into the midthoracic area (Figure 8). The dogs thereafter were placed on an incline as part of the standard procedure.

The only other technical difficulty encountered was that repeated drilling of bone with the Lundy-Irvin needle was difficult. Since the needle was not designed for this purpose, it was damaged with each procedure. Barrett (Athens, Georgia, private communication, 1969) suggested that an Ackerman vertebral bone marrow biopsy needle¹, Kirschner wire, and a hand held chuck be used.

An anesthetized dog was placed on the radiographic table in horizontal, lateral recumbency. An area 6 inches by 6 inches was clipped, scrubbed, and draped in the standard surgical manner. The instruments autoclaved in the vertebral venography pack were a perforator, guide, tapered stylet, trephine, blunt stylet, Kirschner wire, and hand chuck (Figure 9).

The drilling depth was gauged by adjusting the Kirschner wire in the hand chuck while the wire was inserted in the guide (Figures 10, 11). By extending the hip joint and placing the thumb of the left hand on the ventral margin of the iliac crest, a depression was palpated between the anterior margin of the sartorius muscle and the musculature

¹Becton, Dickinson, and Company, Rutherford, New Jersey.

Figure 8. Transosseous vertebral venogram performed with dog in lateral recumbency on a 35° incline. Note that opacification of the vertebral venous sinuses is extended to T₇.

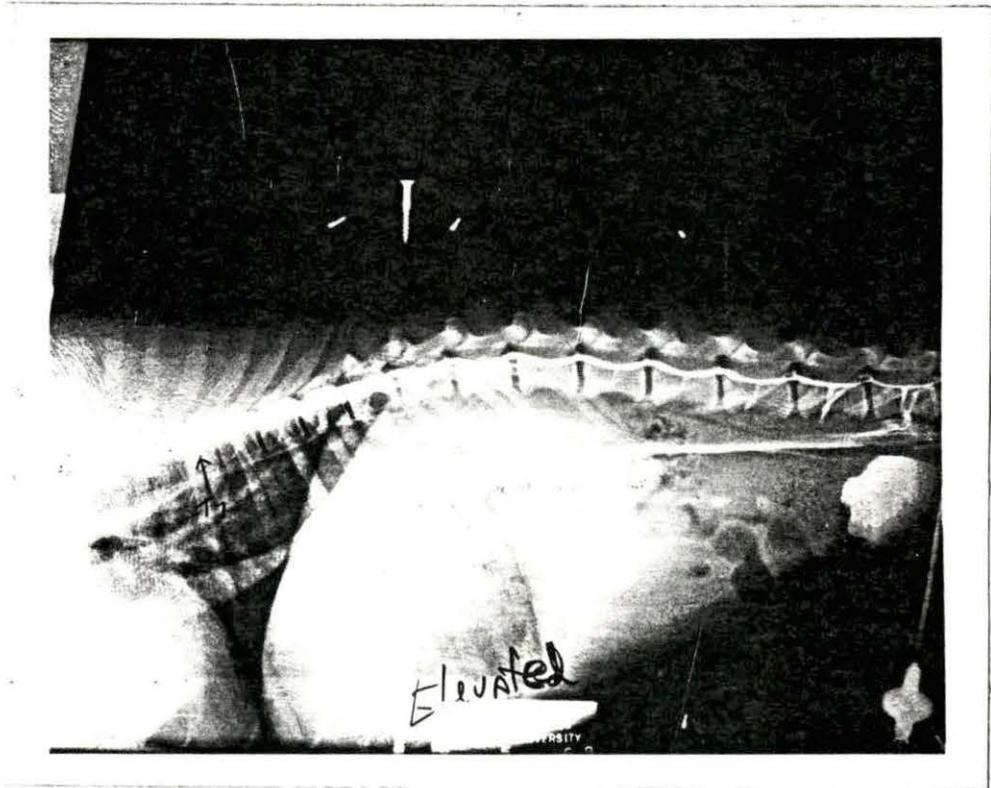


Figure 9. Photograph of instruments used to perform transosseous vertebral venography.

1. Trephine with blunt stylet
2. Hand chuck
3. Kirschner wire
4. Tapered stylet
5. Guide
6. Perforator

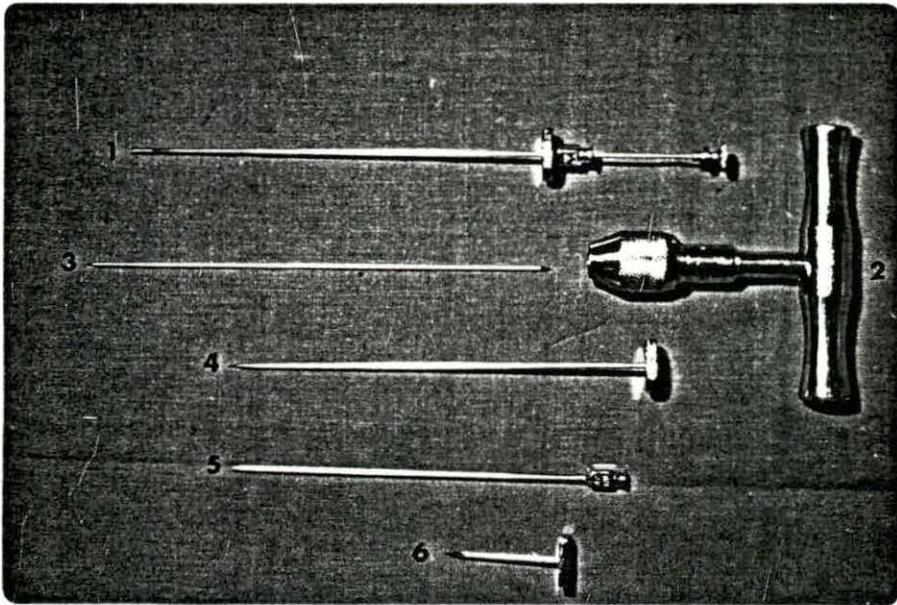
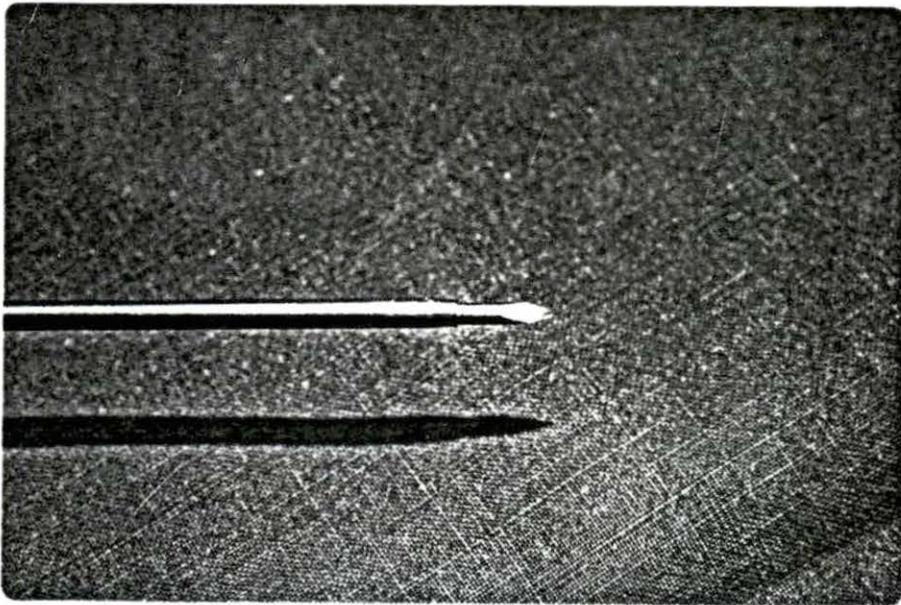
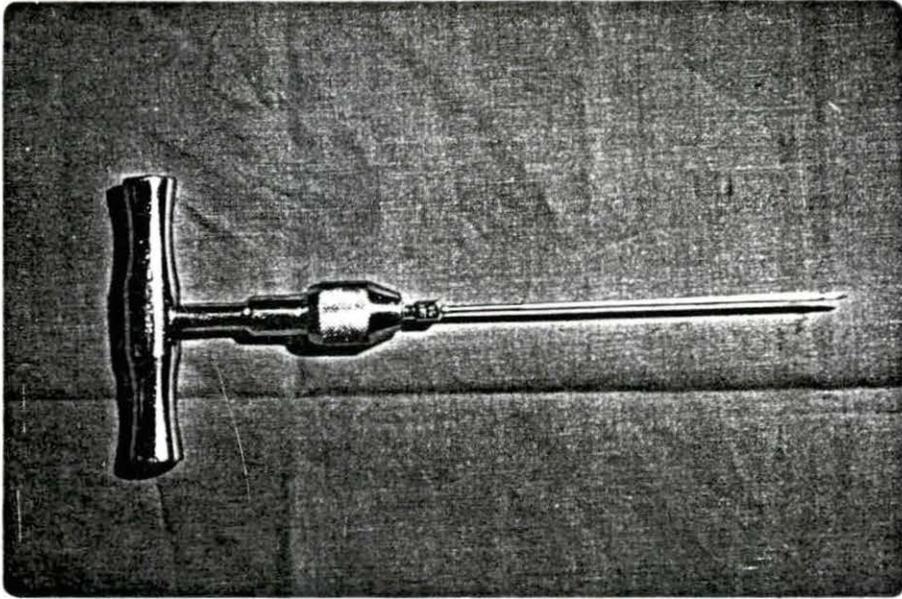


Figure 10. Photograph of the assembled Kirschner wire, hand chuck, and guide.

Figure 11. Close-up of the above photograph. By adjusting the length of Kirschner wire allowed to protrude past the guide, the drilling depth is determined.



of the abdominal wall (Figure 12). A hole was made in the skin by placing the perforator in this depression (Figure 13).

The guide with the tapered stylet in place was placed in this hole and inserted through the psoas muscle. If the needle touched the femoral nerve or sixth lumbar nerve, the needle was redirected. The bone could be differentiated from the disc by the resistance felt. The center of the body was determined by palpating the concavity of the bone with the needle (Figures 14, 15).

Once the site for drilling was located, the guide was slid down the stylet to the bone and held firmly (Figure 16) while the stylet was removed and the Kirschner wire inserted for drilling (Figure 17).

With the drilling completed to the predetermined depth, the Kirschner wire was removed and the trephine inserted. With a rotary motion a plug of bony tissue was removed from the drilled hole. After using a blunt stylet to clear the trephine (Figure 18), the trephine was re-inserted through the guide into the hole in the seventh lumbar vertebra.

A 6 cubic centimeter syringe filled with heparinized saline was attached to the trephine. Blood from the marrow cavity was aspirated into the barrel (Figure 19) to determine if the needle was correctly placed. If blood flowed easily

Figure 12. Palpating the depression between the anterior margin of the sartorius muscle and the musculature of the abdominal wall.

Figure 13. Making hole in skin by placing perforator in the depression palpated.

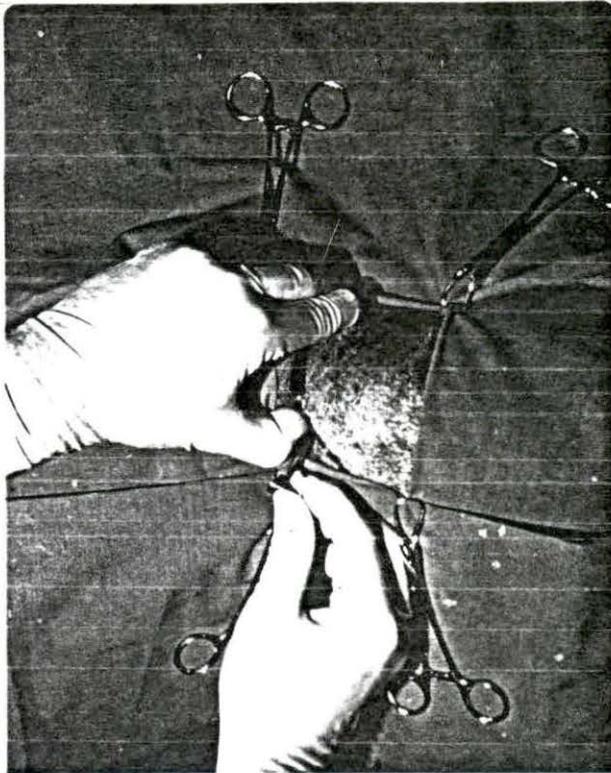
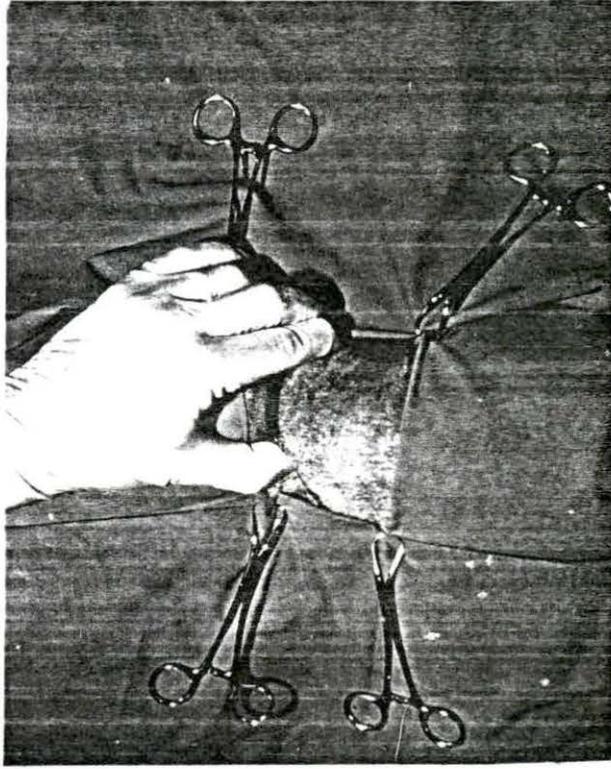


Figure 14. Palpating the body of L₇ with the tapered stylet in the guide.

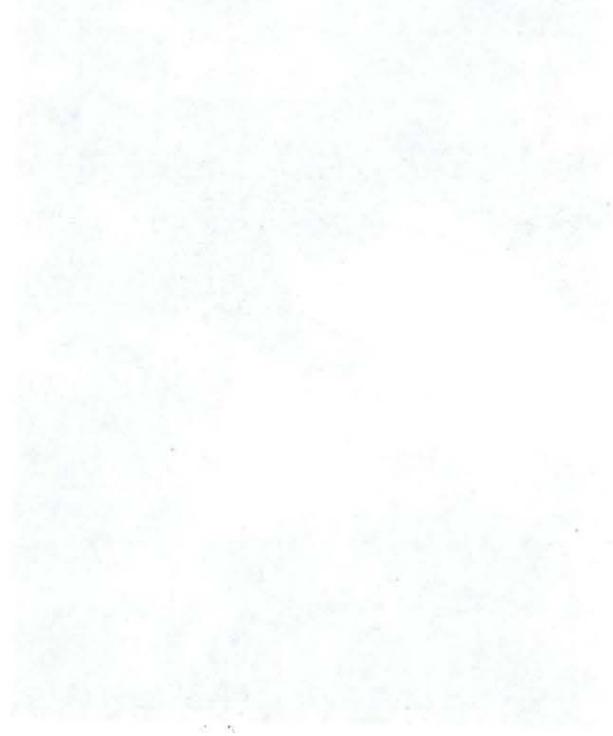
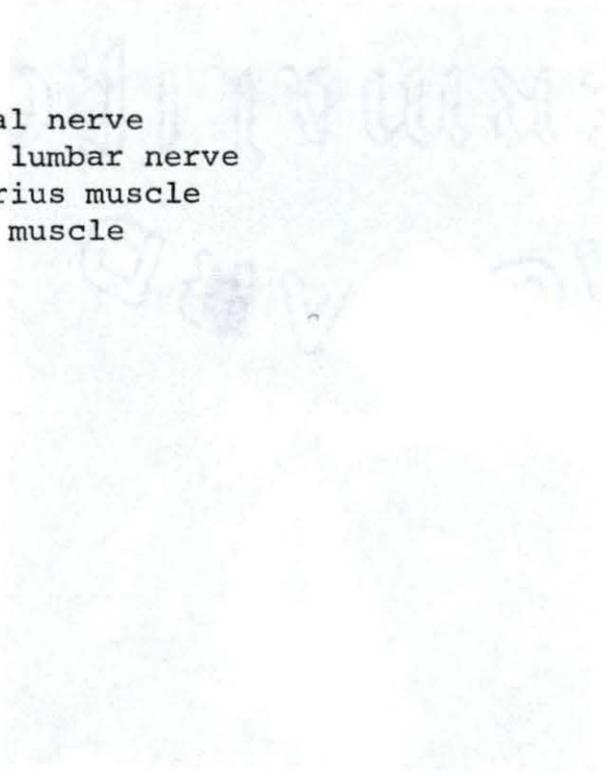


Figure 15. Cross-section of the injection area illustrating the anatomical structures.

1. Ilium
2. Femoral nerve
3. Sixth lumbar nerve
4. Sartorius muscle
5. Psoas muscle



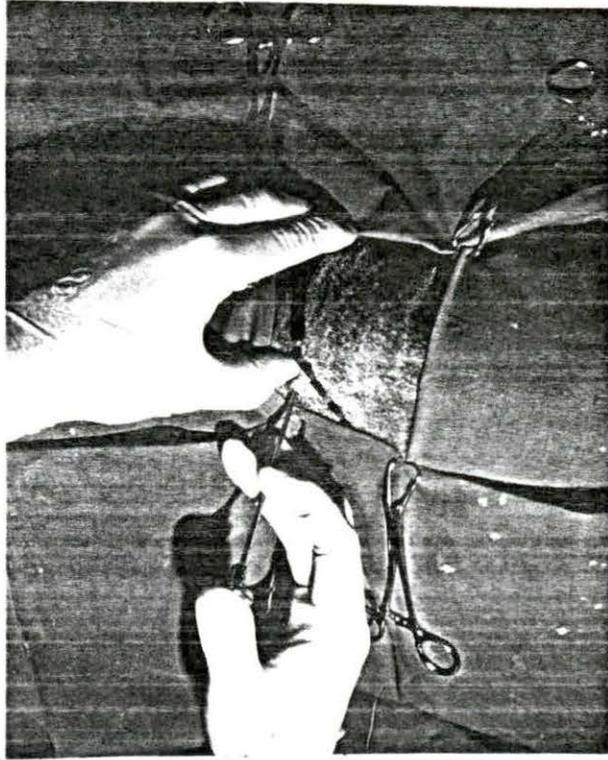


Figure 16. Holding guide in place.

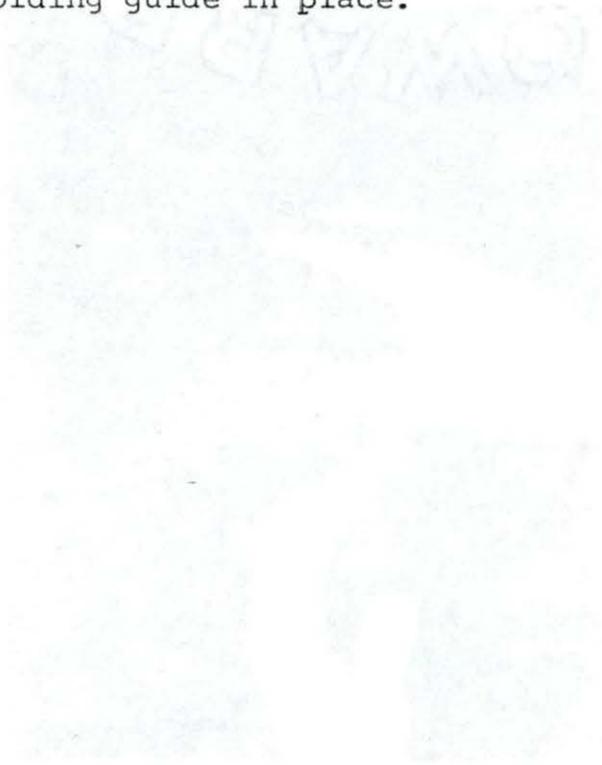
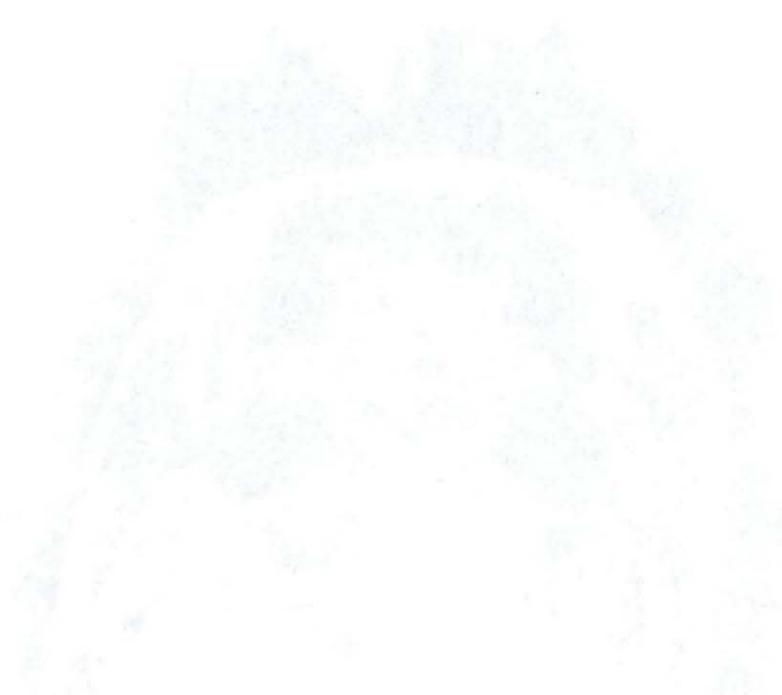


Figure 17. Drilling the marrow cavity.



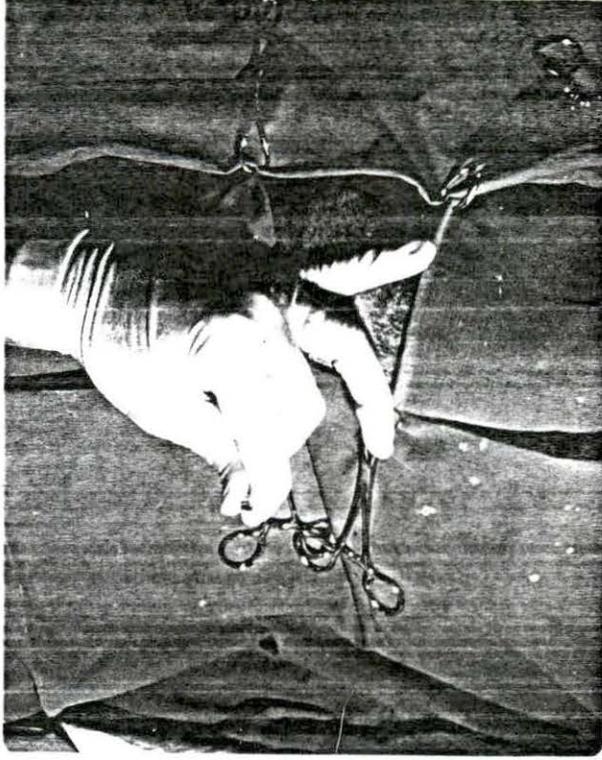


Figure 18. The plug of bony tissue removed from the trephine.

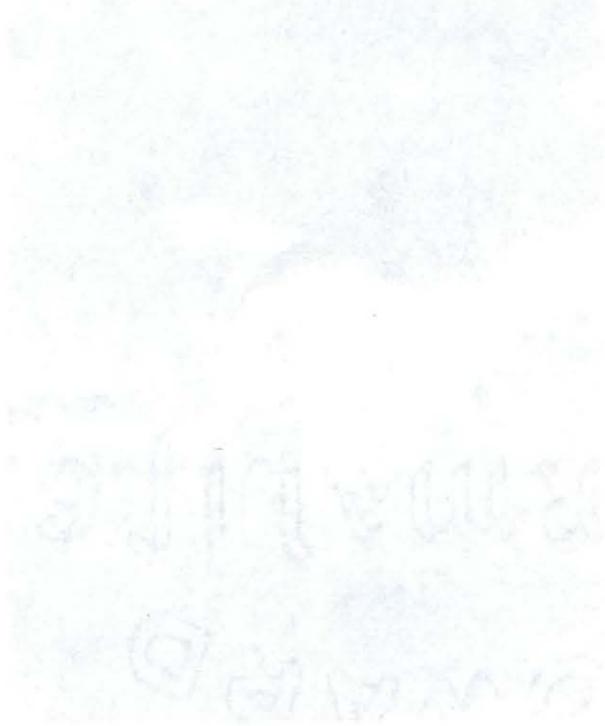
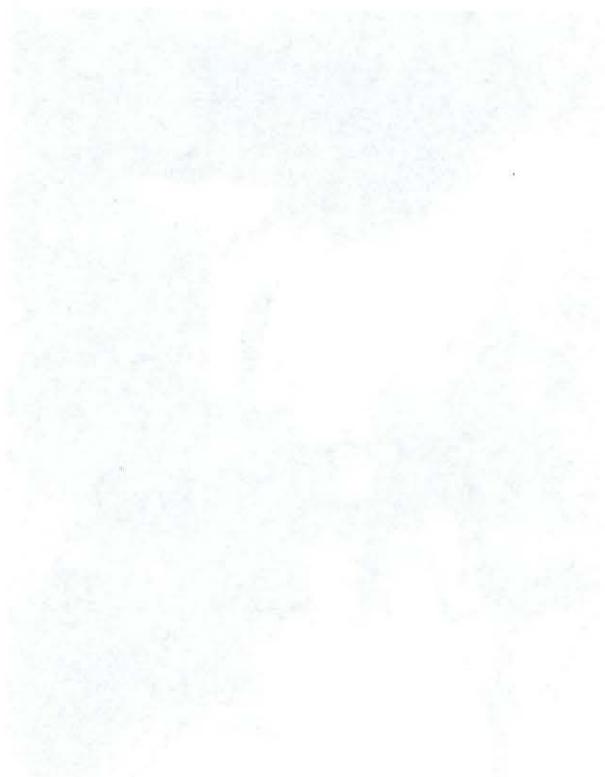
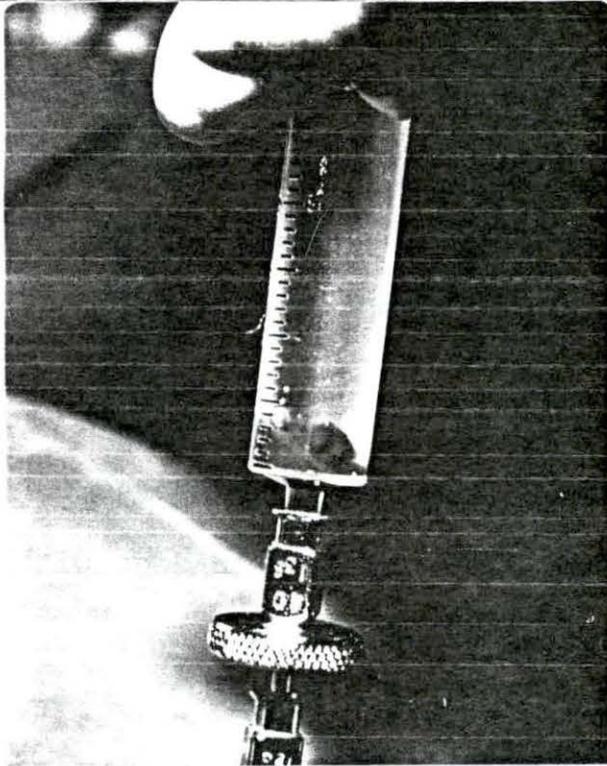
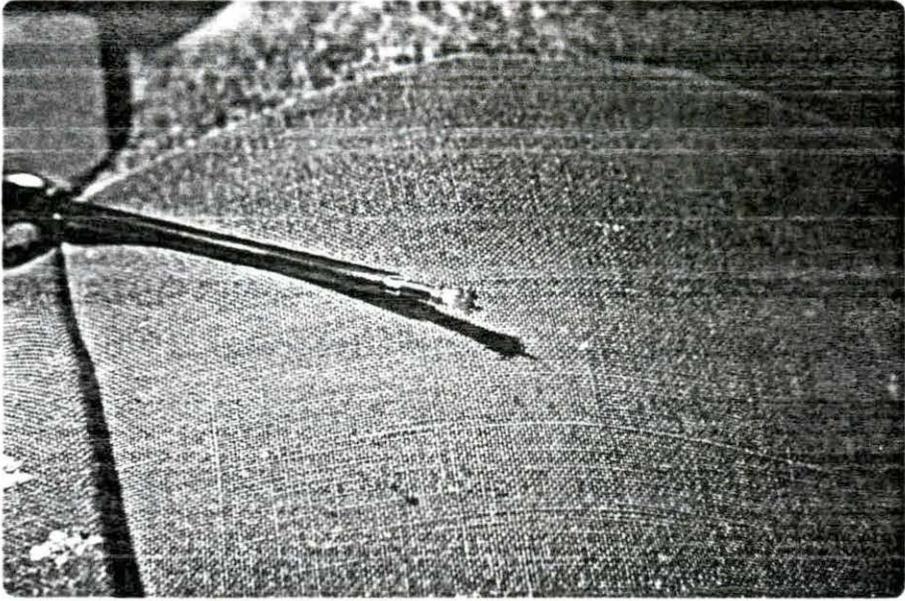


Figure 19. Aspirating blood from the marrow cavity of L₇.





into the syringe, the drilling was probably too deep and penetrated the spinal canal. Although with correct placement blood readily flowed into the syringe, some resistance was encountered. The heparinized saline was injected to dilate vascular channels in the marrow cavity so injection of the contrast medium could be done more easily. At this point aseptic technique was broken; however, care was taken not to contaminate the tip of the syringe or the hub or the needle.

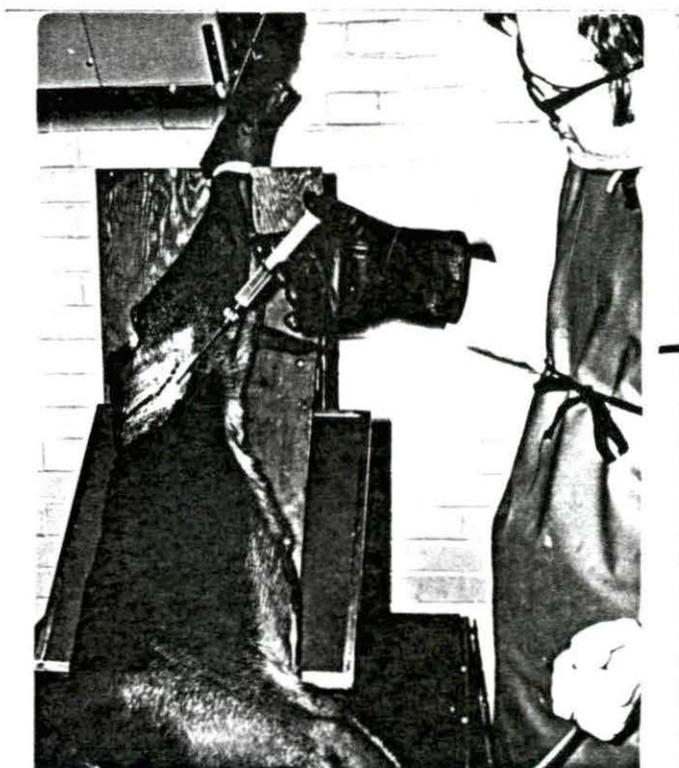
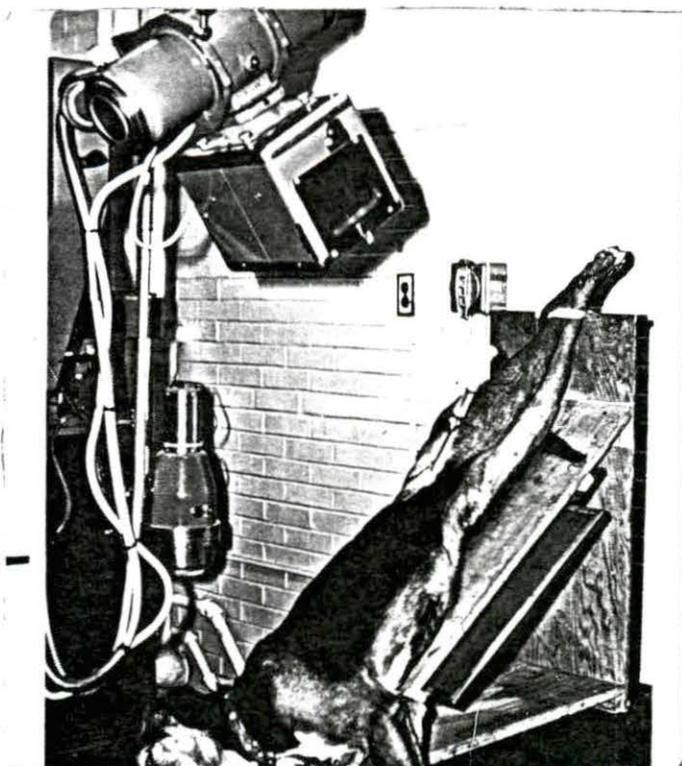
The dog was placed on the 35° incline in either lateral or ventrodorsal recumbency. For the ventrodorsal view the dog was obliqued 15° to its right so the opacified posterior vena cava would not be superimposed over the spinal column. A syringe filled with 10 cubic centimeters of contrast medium was attached to the trephine (Figure 20). As the last cubic centimeter of the contrast medium was infused the radiograph was taken (Figure 21). This technique was performed 31 times on 18 dogs with clinically normal spinal columns.

Accuracy of the Technique

Using the procedure described, transosseous vertebral venography was performed 25 times on 16 dogs with either experimental or spontaneous spinal cord compression. The procedure was performed no later than 5 days after the onset

Figure 20. Photograph of the dog in position for radiographic exposure.

Figure 21. The injection of the contrast medium. As the last cubic centimeter of contrast medium was injected, the exposure was made.



of compression. The spontaneous cases of spinal cord compression included herniated intervertebral discs and fractures of the vertebrae. Experimental spinal cord compression was created in 7 dogs by injecting paraffin wax in the epidural space. Types 1, 2, and 3 herniated discs were simulated by the paraffin wax injections.

By using a quarter inch trephine, a hole was drilled in the dorsal arch between the spinous process and anterior articular process of a particular vertebra. A plug of cold paraffin was cut with the trephine and inserted into the hole. A mandrin was used to press the paraffin into the epidural space beside the spinal cord. This simulated a type 1 disc herniation.

Type 2 and type 3 disc herniations were simulated by injecting hot paraffin wax into the epidural space. With the dog placed in severe kyphosis a caudal needle was placed beside the spinal cord using a dorsal approach. If the paraffin was injected rapidly, it would spread up and down the neural canal simulating a type 3 disc herniation. A type 2 disc herniation was created by injecting hot paraffin wax rapidly during the first half of the dose. The second half was allowed to solidify in the needle and then was pressed into

the epidural space with a stylet. No more than 1 cubic centimeter was injected at any time.

RESULTS

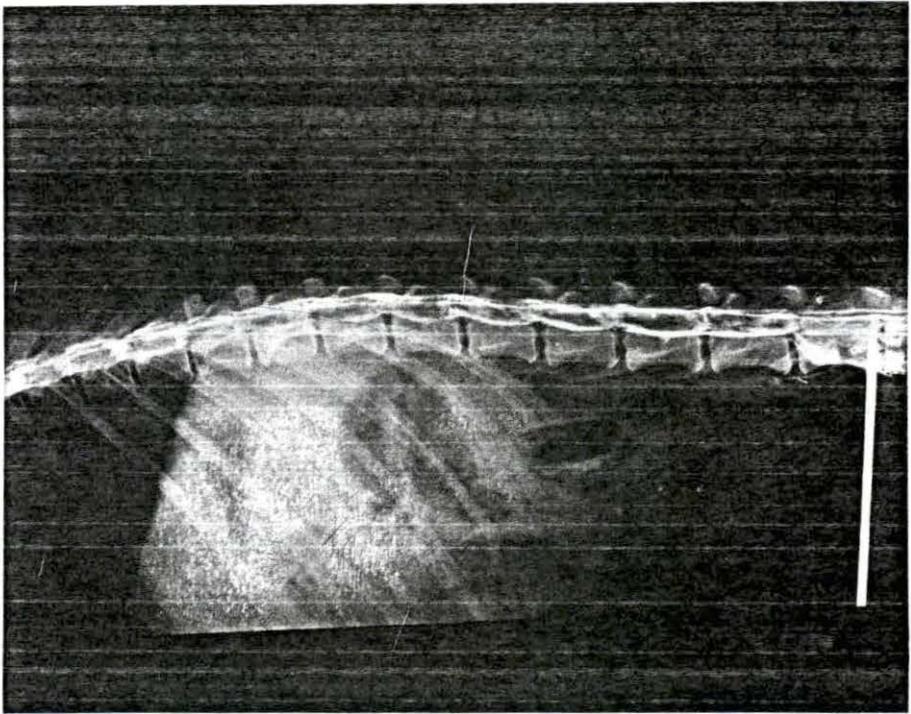
Transosseous vertebral venography in the thoraco-lumbar region was found to be safe and easily performed. None of the complications described in the literature were observed except local pain. Stage III, plane 3 anesthesia was not sufficient to prevent algnesia. Hemorrhage at the injection site was minimal. In one dog a lameness was observed in the rear leg on the same side that the injection was made. Necropsy revealed a contusion of the femoral nerve; however, the nerve was intact. Larger dogs were more easily injected than small dogs. However, if care was taken, small dogs were successfully injected.

Normal Transosseous Vertebral Venogram

Of the 31 procedures performed on 18 dogs, 26 were successful and 5 were not. Success was defined as opacification of the vertebral venous sinuses from the seventh lumbar vertebra to the midthoracic area.

Of the 5 failures, 4 were caused by injecting the contrast medium into the epidural space (Figure 22). One failure was caused by injecting the contrast medium into the intervertebral disc at L₆₋₇ with subsequent spillage into the surrounding soft tissue structures. No adverse reactions were

Figure 22. Contrast medium injected into the epidural space.
This was the most common cause of failure.



noted clinically.

Using the technique previously described, the vertebral venous sinuses were usually (72% of the cases) opacified up to the sixth or seventh thoracic vertebrae (Figure 23). In a few of the cases (14%) the contrast medium stopped at the eighth thoracic vertebra. Occasionally the contrast medium flowed anterior to these sites. In one dog the entire thoracic and lumbar vertebral venous sinuses were opacified (Figure 24).

If the seventh lumbar vertebra was infused, the contrast medium refluxed into the sacral venous sinuses (Figure 25). If the sixth lumbar vertebra was accidentally infused, this phenomenon was not usually observed (Figure 26).

Drainage of the vertebral venous sinuses in every case was via the anastomosing branches with the posterior vena cava and azygos vein. The medium flowed to the heart through these large vessels.

The anterior limit of opacification of the vertebral venous sinuses in the lateral view differed from the ventrodorsal view in most cases. The opacification of the venous sinuses should be farther anterior in the ventrodorsal view. The venous sinuses in this view would be lower than the posterior vena cava and the azygos vein. One would not expect the medium to flow against gravity and leave the

Figure 23. A normal transosseous vertebral venogram (lateral view). Note the opacification of the vertebral venous sinuses up to T₆.

Figure 24. A normal transosseous vertebral venogram (lateral view). Note that the entire lumbar and thoracic vertebral venous sinuses are opacified.

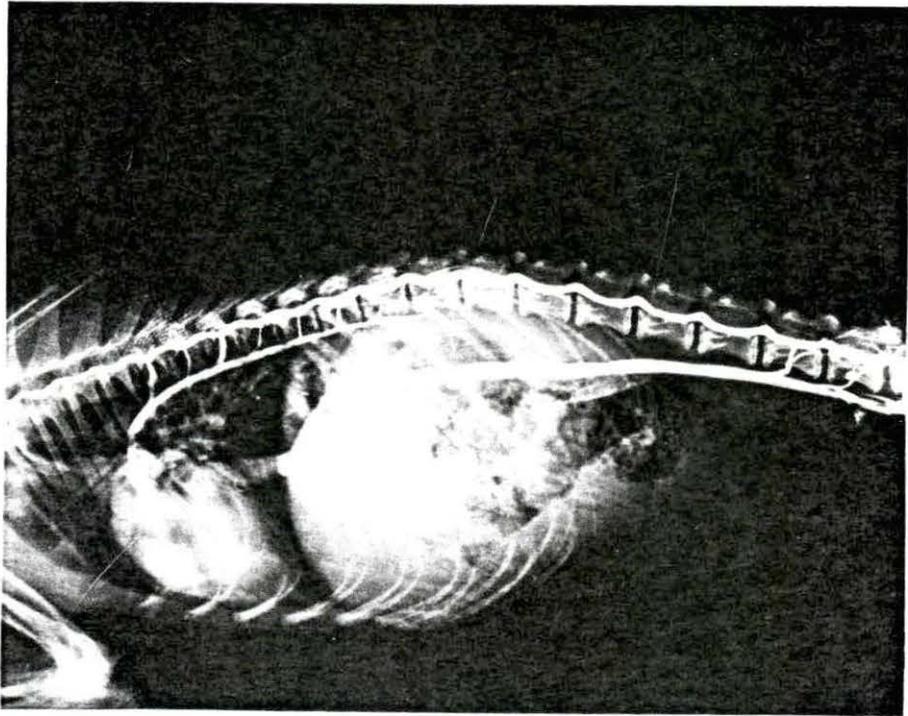
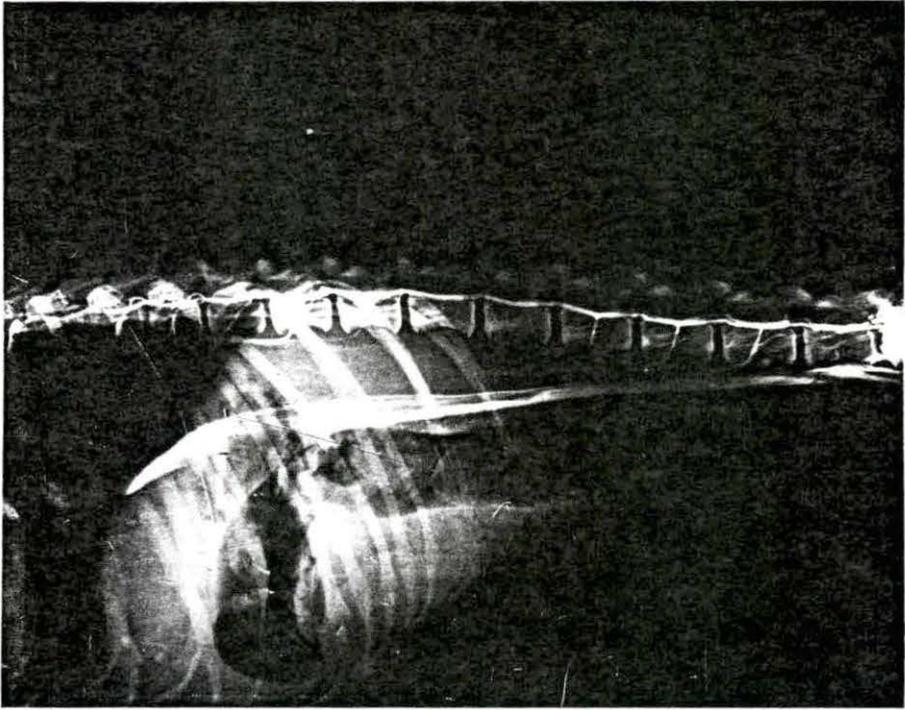
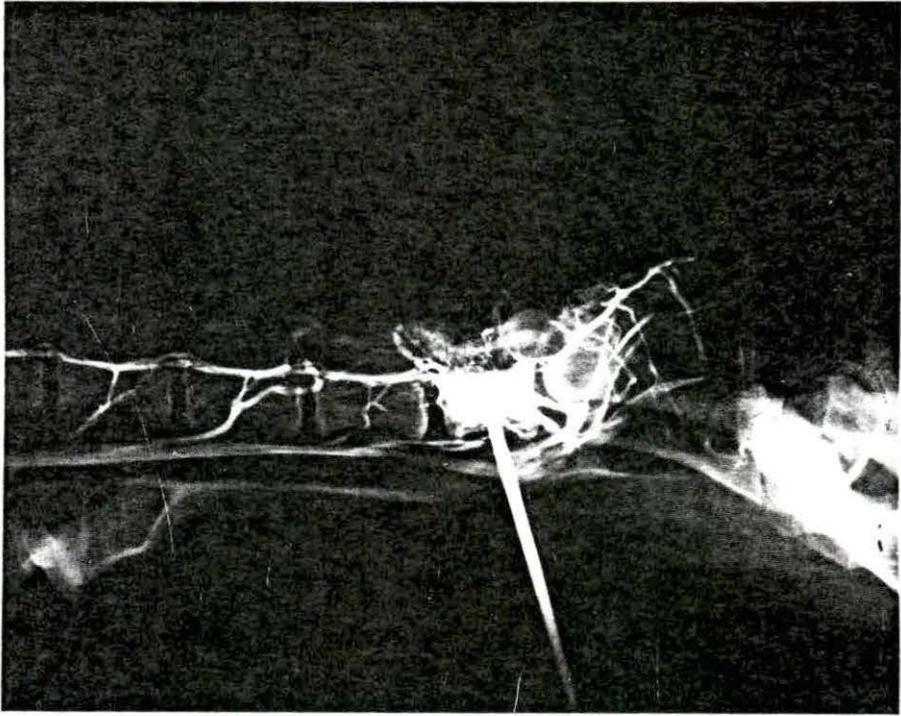


Figure 25. Radiograph of the injection area (L₇). Note the normal filling of the sacral venous sinuses with the contrast medium.

Figure 26. Accidental injection of L₆. Note that there is no reflux filling of the sacral venous sinuses with contrast medium.



sinuses earlier than in the lateral view. The medium should stay in the venous sinuses longer and opacify them farther anterior.

When comparing lateral and ventrodorsal radiographs of the same dog, it was found that in some cases the venous sinuses were opacified about one vertebral space farther anterior in the ventrodorsal view. In some cases there was no difference between the two views. In other cases opacification of the venous sinuses was the farthest anterior in the lateral view.

The reason for this phenomenon was not determined. The degree of opacification of the venous sinuses was not affected by exposing the lateral view first or exposing the ventrodorsal view first. Perhaps the difference was caused by the speed of injection. Since the injection was done by hand, it would be difficult to exactly reproduce the injection speed with each procedure.

Transosseous Vertebral Venogram in the Presence of Spinal Cord Compression

Of the 25 procedures performed on 16 dogs with spinal cord compression, 19 were successful and 6 were not. Success was defined as accurately localizing the spinal cord compression. This must be qualified because in cases of type 2

and 3 disc herniations, the contrast medium did not flow to the actual disc where the paraffin wax was injected. However, the posterior limit of simulated disc material was accurately localized. In cases with severe myelopathy caused by fractured vertebrae, the posterior limit of the myelopathy was accurately localized.

Of the 6 failures, one was caused by injecting the contrast medium into the epidural space. However, the compression in this case was successfully demonstrated with the epidurogram. In 2 cases the compression was successfully demonstrated on the lateral views but not on the ventrodorsal views. The reason for the discrepancy between the two views was not determined. In one case with a fractured eighth thoracic vertebra, the compression was successfully demonstrated using the ventrodorsal view but not the lateral view. A repeat venogram using the lateral view yielded the same results. One case was a failure because the paraffin wax was accidentally injected into the vertebral venous sinuses.

When interpreting a transosseous vertebral venogram, one must understand that a compression lesion may be located anywhere between two adjacent basivertebral veins and the venogram will appear the same. Since disc material can migrate up and down the spinal canal (type 2 and 3), this

phenomenon could be a source of diagnostic error. For example, figure 27 is a venogram of a dog that had a type 1 disc herniation at T_{11-12} . Notice that the contrast medium flowed to the basivertebral vein of T_{12} . Figure 28 is a venogram of a dog that had a type 2 disc herniation at L_{2-3} ; however, the contrast medium only flowed to the basivertebral vein of L_4 . Although this seemed to be a diagnostic error of one vertebral space, necropsy revealed that disc material had extended posteriorly to the middle of L_3 . Thus, the contrast medium could not have flowed across L_{3-4} because its exit at the basivertebral vein of L_3 was blocked.

One disadvantage of transosseous vertebral venography that was found was that multiple compression lesions could not be localized. For example, figure 29 is a transosseous vertebral venogram on which a compression lesion at L_{3-4} was indicated. On necropsy a herniated intervertebral disc was found at L_{3-4} ; however, there was also a herniated disc at L_{2-3} .

Occasionally the vertebral venous sinuses were slightly opacified anterior to the site of spinal cord compression (Figure 30). When this did occur, spinal cord compression was ruled out in this area. Filling of the many small radicles that empty into the longitudinal vertebral sinuses

Figure 27. Transosseous vertebral venogram of a dog with a type 1 disc herniation at T₁₁₋₁₂. Notice the opacification of the vertebral venous sinuses up to the basivertebral vein of T₁₂.

Figure 28. Transosseous vertebral venogram of a dog with a type 2 disc herniation at L₂₋₃. The contrast medium only flowed to the basivertebral vein of L₄.

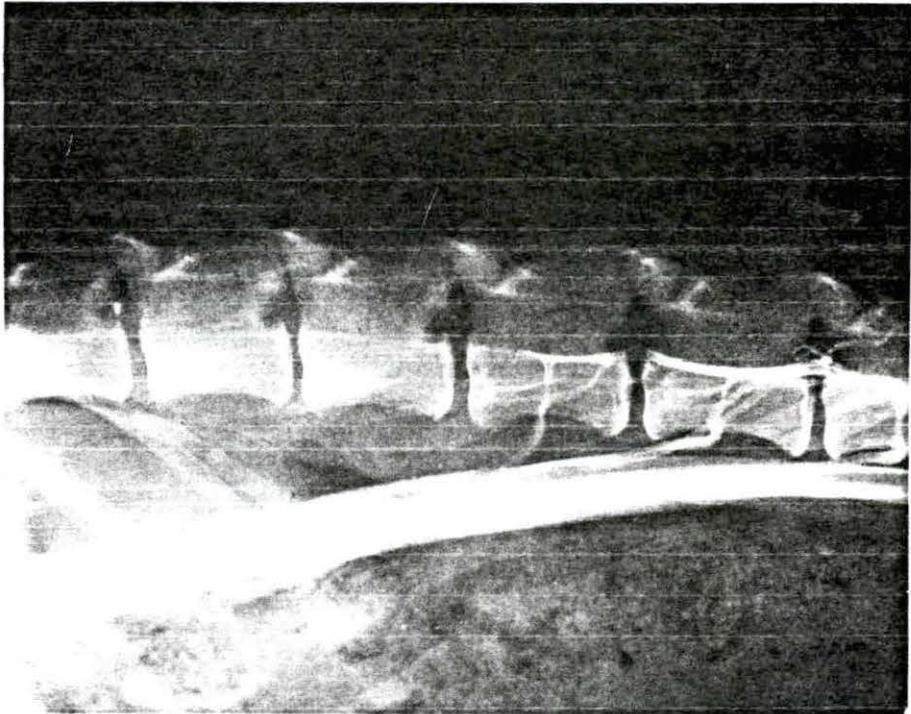
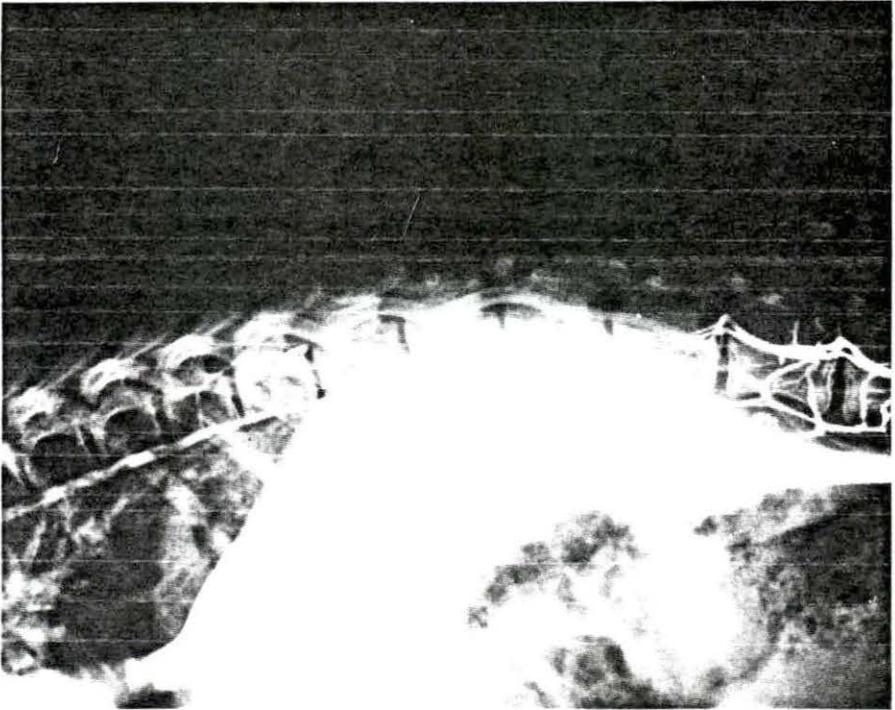
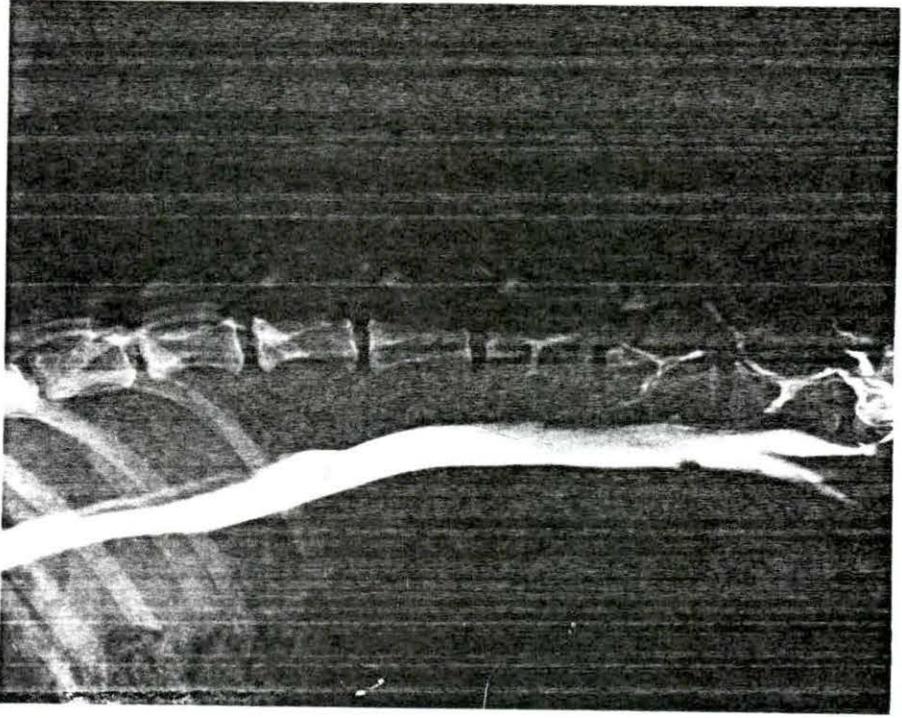


Figure 29. Transosseous vertebral venogram of a dog with a compression lesion indicated at L₃₋₄.

Figure 30. Transosseous vertebral venogram of a dog with slight filling of the venous sinuses anterior to the site of spinal cord compression.



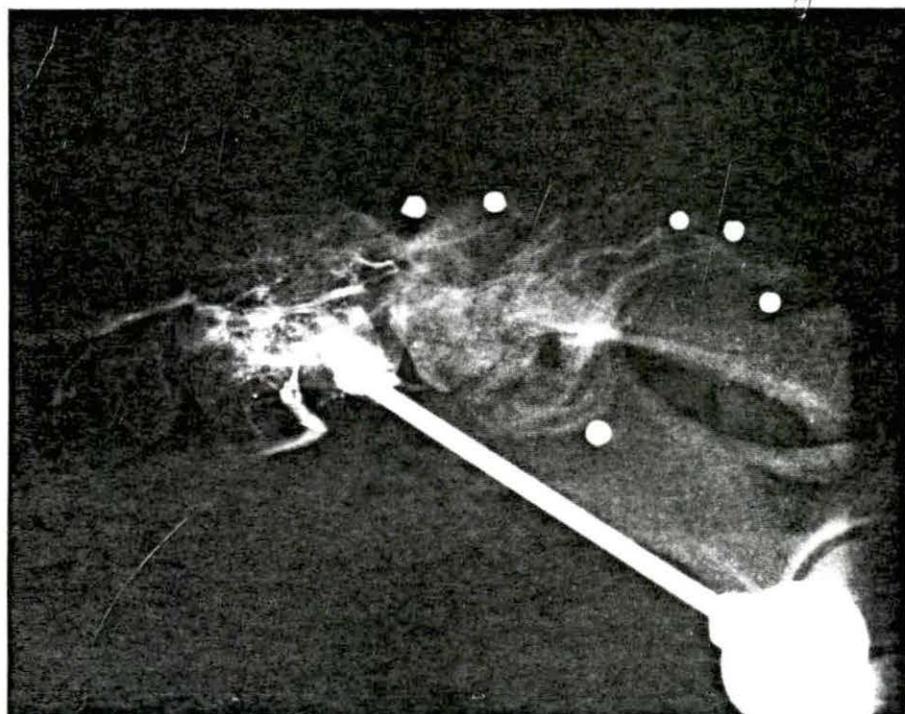
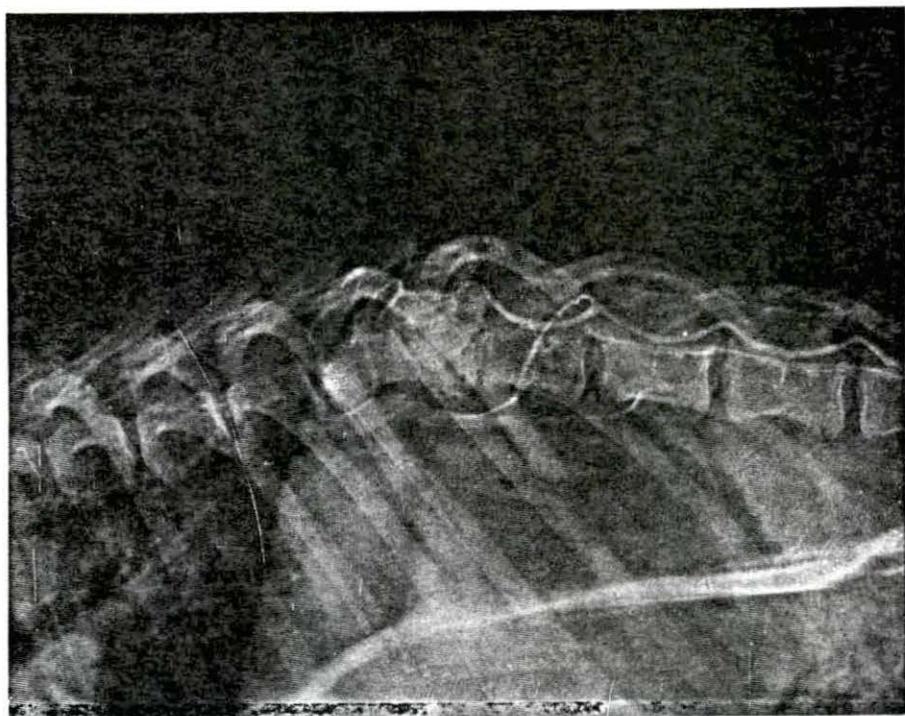
was usually more prominent in the presence of spinal cord compression.

Lewis (41) observed that a transosseous vertebral venogram performed immediately after spinal cord compression was normal. This phenomenon was not observed in this study. In one case using a vertebral venogram immediately after creating spinal cord compression, the area was accurately localized. In another case with a fractured eleventh thoracic vertebra, a venogram was performed 5 hours after the fracture occurred. The vertebral sinuses directly above the body of T₁₁ were filled with contrast medium. This extent of opacification was not expected; however, it was not normal in that the medium did not extend up to the mid-thoracic area (Figure 31).

The reflux filling of the sacral venous sinuses was used in one case to illustrate compression in this area. Figure 32 is a vertebral venogram of a dog that was exhibiting posterior ataxia. Notice that there was no filling of the sacral venous sinuses. The fracture callus of the sacrum was the cause of the compression.

Figure 31. Transosseous vertebral venogram of a dog with a fractured T₁₁. The venogram was performed 5 hours after the fracture occurred.

Figure 32. Transosseous vertebral venogram of a dog with a fractured sacrum. Note that there is no reflux filling of the sacral venous sinuses.



DISCUSSION

The use of transosseous vertebral venography in this study proved to be a safe method of localizing spinal cord compressions. Epidural injection of the contrast medium and spillage into the soft tissue structures caused no apparent adverse reactions. Compression lesions caused by herniated intervertebral discs both spontaneous and experimental were accurately localized. In cases of type 2 and 3 disc herniations, the posterior limit of the migration of disc material was localized. Although the actual disc space involved was not indicated, the area for starting decompression surgery was indicated. The laminectomy would be extended forward at the discretion of the surgeon.

Although no complications were observed except local pain and possibly femoral nerve damage in one dog, the threat of complications still existed. Since dogs had to be anesthetized, the risk of anesthetic death was present. Thus, no dog should be exposed to this procedure unless localization of the compression lesion is necessary. If a dog has a herniated intervertebral disc and decompression laminectomy is not contemplated, then the additional risk of a procedure requiring anesthesia is not warranted. Since no prognostic

value was indicated in the presence of herniated intervertebral disc, transosseous vertebral venography cannot be rationalized. With respect to herniated intervertebral discs, the use of transosseous vertebral venography is indicated only to localize a compression lesion for surgery. The clinical history, physical examination, and possibly myelography are better prognostic tools than transosseous vertebral venography.

This procedure was possibly of better prognostic value when evaluating an animal with a fractured vertebra. Since the posterior limit of myelopathy was accurately localized, the extent of spinal cord damage could be determined using this procedure. The time interval between the original insult and the venogram would have to be an important consideration. For example, Lewis (41) observed a normal vertebral venogram immediately after compression was surgically induced. After 24 hours, swelling of the spinal cord was sufficient to cause an abnormal vertebral venogram. If a dog had a fractured vertebra and a transosseous vertebral venogram was performed within a relatively short period of time, a compression indicated several vertebral spaces posterior to the actual fracture may be indicative of a severe hematomyelia and a grave prognosis should be given. If no compression was indicated, then no additional information would have been

gained, since irreversible changes may have already occurred (45) .

In the normal transosseous vertebral venogram, the vertebral venous sinuses were opacified from about the first coccygeal vertebra to the midthoracic area. For this to consistently occur, the injection had to be made in the body of the seventh lumbar vertebra and the dog's body had to be laid on an incline with the head lower than the tail. Since Batson (6) described the vertebral venous sinuses as being constantly subject to arrests and reversals in direction of blood flow, it was hypothesized that the incline was necessary to aid blood flow in the venous sinuses and thus extend their opacification anteriorly. It was found that the use of an incline did extend the anterior limit of opacification, but this gravitational effect was not varified when the ventrodorsal view was compared to the lateral view in the same dog. The vertebral venous sinuses on the ventrodorsal view logically should have been opacified farther anterior than on the lateral view, but this was not always the case. The only variable that could not be accurately controlled was the injection speed. Although no method of controlling the injection speed was available, this variable was incriminated as causing this discrepancy.

Investigators (7, 8, 11, 57) have found no valves in the vertebral venous sinuses but valves were present in the vessels connecting the sinuses with the major extravertebral vessels. The valves were situated so blood could not reflux from the extravertebral vessel into the vertebral sinuses.

Occasionally the vertebral venous sinuses were slightly opacified anterior to the site of spinal cord compression.

When this occurred, three explanations were possible:

1. Occasionally valves are absent between the vertebral venous sinuses and the major extravertebral vein.
2. Valves are always present as reported but are occasionally insufficient.
3. Occasionally sufficient pressure was created in the vertebral venous sinus to force the contrast medium past a compression lesion.

The first explanation is not compatible with reports in the literature. The second explanation is possible but not very probable. The third explanation seems the most probable, but the question of why this occasionally occurs still exists.

Two possible reasons seem apparent:

1. Pressure in the neural canal does not affect the venous sinuses equally; thus, contrast medium is allowed to pass anterior to a compression lesion through one sinus.

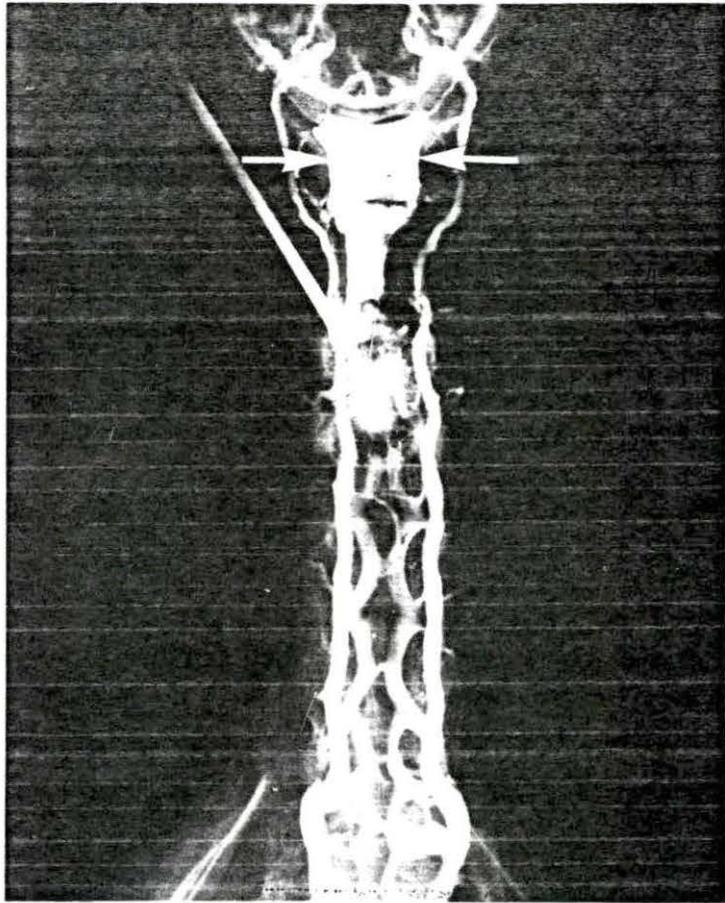
2. A variation in injection speed affects the pressure in the venous sinuses. An increased pressure allows contrast medium to be forced past a compression lesion.

The differentiation of these points will require further study. The second reason seems to be the most probable in view of the variations observed in normal animals between the lateral view and the ventrodorsal view.

The usefulness of the procedure described was limited to the thoracic, lumbar, and sacral areas. A procedure for the cervical region was attempted but not perfected. An intra-osseous injection of contrast medium was made into the body of the third cervical vertebra using a ventral approach. Opacification of the vertebral venous sinuses was observed from the third cervical vertebra through the anterior one third of the thoracic area (Figure 33). Some of the contrast medium spilled into the epidural space and caused a tonic convulsion and death. Since spillage of the contrast medium into the epidural space was the most common complication with the lumbar injection, the procedure would be performed in the cervical area with added risk.

To overcome the complication observed in the one cervical transosseous vertebral venogram, a catheter was inserted into the external jugular vein to the base of the skull via the

Figure 33. Cervical transosseous vertebral venogram. Note the contrast medium that has spilled into the epidural space (arrows).

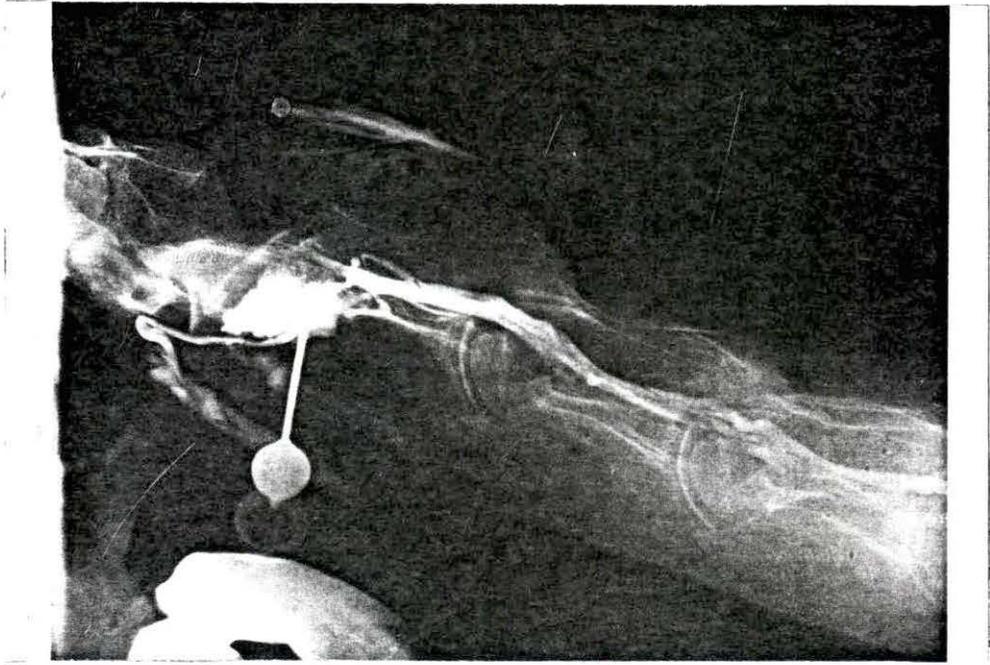
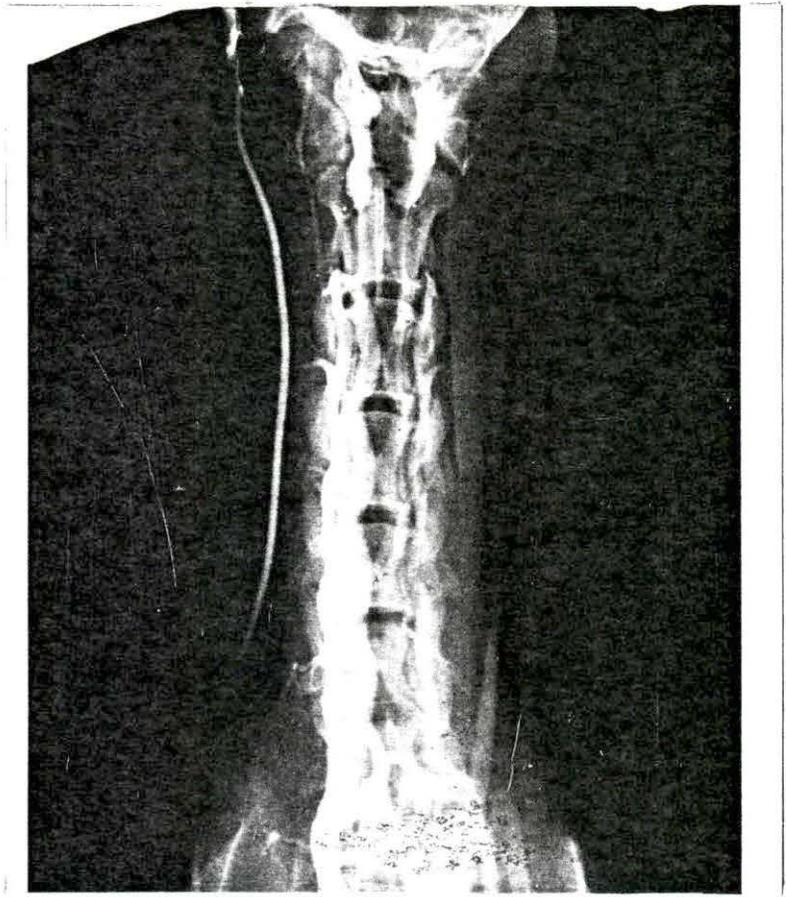


internal maxillary vein. Using this approach, there was no possibility of injecting the contrast medium into the epidural space and opacification of the cervical vertebral venous sinuses was complete (Figure 34).

One cervical transosseous vertebral venogram was performed on a horse (Figure 35). The contrast medium was injected into the body of the axis. This procedure may be of value in studying equine incoordination syndrome.

Figure 34. Cervical vertebral venogram. The tip of the catheter is indicated by an arrow. Note the complete filling of the cervical vertebral venous sinuses.

Figure 35. A cervical transosseous vertebral venogram on a horse. The body of the axis was injected.



SUMMARY AND CONCLUSIONS

1. Thirty-three dogs of various breeds were used in this study to determine a site for intraosseous injection of a contrast medium that would radiographically opacify the vertebral venous sinuses and to determine the validity of this technique for localizing spinal cord compression in the dog. A ventral approach to the body of L₇ was found to be the best for maximum opacification of the longitudinal vertebral venous sinuses. Thirty-one procedures were performed on 18 dogs with clinically normal spinal columns to determine the extent of normal opacification of the vertebral venous sinuses. Twenty-five procedures were performed on 16 dogs with spinal cord compression to determine the validity of the technique for localizing spinal cord compression.

2. Transosseous vertebral venography in the thoracolumbar region was found to be safe and easily performed using the technique described. The only complications to the procedure were local pain at the time of injecting the contrast medium and possibly femoral nerve damage in one case. Stage III, plane 3 anesthesia was not sufficient to prevent algesia.

3. Using this procedure, the longitudinal vertebral

venous sinuses were opacified from the first coccygeal vertebra to the midthoracic area (T_6 to T_7). The degree of opacification in the lateral and ventrodorsal views of the same dog did not always correspond.

4. The most common fault in the injection technique was injection of the contrast medium into the epidural space. Occasionally the medium was spilled into the surrounding soft tissue structures. This caused no adverse clinical reactions.

5. Transosseous vertebral venography can be used to localize spinal cord compression lesions in the dog. The accuracy is limited to the distance between two adjacent basivertebral veins. Multiple compression lesions cannot be identified using this procedure. Herniated intervertebral discs, both spontaneous and experimental, and fractures of the vertebrae were the compressions studied in this work.

6. Transosseous vertebral venography in the cervical region would be done at an increased risk, since epidural injection of the contrast medium in this area caused death.

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