ASCENDING COCCYGEAL VENOGRAPHY IN EVALUATION OF PARAPLEGIA IN DOGS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Veterinary Science

Faculty of Veterinary and Animal Sciences
Kerala Agricultural University

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COLLEGE OF VETERINARY AND ANIMAL SCIENCES
MANNUTHY, THRISSUR - 680651
KERALA, INDIA

2002

DECLARATION

I hereby declare that the thesis, entitled **"ASCENDING COCCYGEAL VENOGRAPHY IN EVALUATION OF PARAPLEGIA IN DOGS"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled **"ASCENDING COCCYGEAL VENOGRAPHY IN EVALUATION OF PARAPLEGIA IN DOGS"** is a record of research work done independently by **Sri. Joshi George**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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ACKNOWLEDGEMENT

Research work is a collective effort. It is an effort, armed with the knowledge gained by the previous and contemporary related researches, for quest for seeking further knowledge and truth. Hence I pay my respect to all those researchers whose references I have quoted and those authors unknown to me, in whose writings, I gained knowledge.

With great devotion, I fondly acknowledge my major advisor and Chairperson of the Advisory committee, Dr. T. Sarada Amma, Associate Professor and Head, Department of Surgery for her expert planning and meticulous guidance. The incessant help rendered by her in all possible ways throughout the period of this study has resulted in this thesis.

This work would not have been possible, but for my teacher Dr. K.N. Muraleedharan Nayar, Professor and Head (Retd.), Department of Surgery. It is indeed, a chance of a lifetime to be under the tutelage of Dr. K.N. Muraleedharan Nayar and I consider myself very fortunate in this regard. I looked upon him in the times my trouble, when things were not going quite right and he always had the right answers. With his vast knowledge and expertise, he guided me in the right direction throughout my research work, inspite of his busy schedule.

I am much obliged to Dr. C.B. Devanand, Assistant Professor (Sr. Scale), Department of Surgery and Dr. Usha Narayanan Pillai, Assistant Professor, Department of Clinical Medicine (members) for having given the expertise and personal attention during each phase of this research work and also for the timely correction of my thesis.

I express my great sense of gratitude to the Dean, College of Veterinary and Animal Sciences, Mannuthy for providing me the necessary facilities for carrying out this work.

I am indebted to my teachers, Dr. K. Rajankutty, Associate Professor, Dr. K.D. John Martin, Dr. Syam K. Venugopal, and Dr. M.K. Narayanan, Assistant

Professors, Department of Surgery, for all their advises and suggestions given to me, that helped me to complete my research work and thesis.

Being a researcher in the formative stage, I remember with gratitude my course teachers, Dr. P.G. Baby, Professor and Head, Department of Clinical medicine, Dr. P.C. Alex, Associate Professor, Department of Clinical Medicine, Dr. S. Ajithkumar, Assistant Professor, Department of Clinical Medicine, Dr. V. Jayaprakasan, Associate Professor and Head, Department of Microbiology, Dr. K. Venugopal, Dr. Zacharias Cherian, Associate Professors, Department of Pharmacology, Dr. T. Sreekumar, Professor, Department of Pathology, Dr. K.V. Athman, Associate Professor, Department of Animal Reproduction and Dr. Santa E. George, Associate Professor (Retd.), Veterinary Hospital, Mannuthy, whose classes and lectures helped me, mould my mind into a fact oriented one.

Since this research work was clinical case oriented, it had been tough and difficult, at times, especially the wait for want of clinical cases and the necessity of timely assistance during the work. Hence apart from the technical help, physical assistance as well as moral support was also equally important for completion of this work. In this regard, I would like to specially mention the name of N.J. Jayesh, attendant and Smt. A. Mary, Labourer, Department of Surgery for physical assistance rendered. It would not have been possible without them, and literally speaking they were at my disposal.

I similarly acknowledge Mrs. Indira Devi, Radiographer, Department of Surgery for her help extended in taking radiographs.

I express my sincere gratitude to Dr. P.T. Dinesh, Teaching Assistant, Department of Surgery, Dr. Shejo Jose, Dr. S. Sooryadas, Dr. S. Anoop, Dr. S. Senthilkumar, my senior colleagues and Dr. D. Prasanna, Dr. Divya Balan, Dr. Sachin J. Shenoy, Dr. Ashalatha, my junior colleagues, Department of Surgery, for their whole-hearted support and cooperation during the entire period of my research work.

Friends are ones who stick with you till the last. I am lucky because my friends saw me through. I sincerely thank Dr. K. Jitheshkumar, Dr. Soja Sagar, Dr. R. Renjith, Dr. T. Sajeevkumar, Dr. K.S. Ajith, Dr. Bibin Becha, Dr. Sunil Wilson, Dr. S. Biju, Dr. Harikumar, Dr. Arun, P., Dr. Suresh, Dr. Arun George, Dr. Nigil Mathew, Dr. Murali, Dr. Chinthu Ravisankar, Dr. K.C. Bipin, and Dr. J.B. Rajesh.

I hereby record my sincere thanks to all those final year students for their help and cooperation extended during my research work.

I am thankful to Kerala Agricultural University for awarding me the KAU Fellowship for the period of study.

My thanks to the staff of the University and college libraries for their help rendered in scanning the literature.

I appreciate M/s Peagles, Mannuthy for the prompt and meticulous typing of the manuscript.

Last but not the least, I am indebted to the Almighty for His Blessings and I am also fortunate for the love and devotion that has been showered upon me by my parents, sisters and my brother-in-law.

JOSHI GEORGE

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INTRODUCTION

Paraplegia due to spinal lesions requiresan accurate confirmation of the site and type of abnormality, in order to adopt appropriate treatment measures. Clinical and neurological examination alone may not be helpful in locating the lesions. The current techniques viz. Myelography, Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI) are by and large, successful in locating the spinal lesions, either used singly or in combination. But these techniques are either difficult and pose risk to the animal as in myelography, or requires sophisticated equipments and skill as in cases of CT and MRI and hence may not be practically possible under field conditions. Radiography being more simple and economical, the studies on radiological changes of the vertebral canal will be of much practical use, especially in field conditions.

The longitudinal vertebral venous sinuses of the spinal cord in dog, their radioopacification by contrast radiography and their diagnostic feasibility were explored long back by Worthman (1956 a&b). Due to the segmental nature of the drainage of these sinuses into the vena cava, radioopacification of the whole course of these sinuses is difficult. But since these sinuses are extremely thin walled and valveless, they are extremely sensitive to the compressive changes of the cord and get collapsed easily (Hoerlein, 1978a), and hence changes in them are good indicators of a spinal damage. Several techniques for opacification of the venous sinuses have, therefore, been evolved. The techniques like experimental ligation of the vena cava (Worthman, 1956 a&b),

internal compression and occlusion of the vena cava by techniques like inflation of the bladder (Blevins, 1986), use of balloon catheter (Hathcock *et al.*, 1988) and external abdominal compression of the vena cava can be used, so that retrograde flow of the contrast into the venous sinuses is possible from the vena cava, when the contrast material is being injected from a peripheral vein. Another method for opacification of the venous sinuses is intraosseous/vertebral venography, wherein the contrast medium is injected into the cortex of the L5 or L6 vertebral body. The contrast medium drains into the venous sinuses and thereby gets opacified. But the technique is difficult to perform and causes distress to the animal (Ramirez and Thrall, 1998).

In the present study, ascending coccygeal venography has been undertaken with an aim of evolving a simple, safe and economic technique for locating spinal lesions in dogs suffering from paraplegia.

The present study has been conducted with the objective of studying the comparative efficacy and reliability of ascending coccygeal venography and epidurography in diagnosing the site and type of lesions in cases of posterior paralysis in dogs.

An effort thus has been made to critically evaluate and compare the efficacy of both the procedures, in combination with neurological examination and survey radiography.

Review of Literature

REVIEW OF LITERATURE

Anatomy

Vertebral column

The vertebral formula in the dog is $C_7T_{13}L_7S_3Cy_{20}$. Each segment of the cord gives rise to a pair of spinal nerves, that come out via the intervertebral foramina and in all, there are 35-36 pairs of spinal nerves. The spinal segments do not necessarily correspond numerically with the vertebral segments except in the first cervical segment, the last two thoracic segments and the first two or three lumbar segments. The remaining cord segments are positioned cranial to the corresponding vertebrae. (Hoerlein, 1978a)

Longitudinal vertebral venous sinuses

Worthman (1956a) in a study on the anatomy of the longitudinal vertebral sinuses of the dog reported that the longitudinal vertebral sinuses traversed along the entire length of the epidural space on the floor of the vertebral canal. These sinuses were the direct continuations of ventral occipital sinuses posterior to the foramen magnum. The ventral occipital sinuses on each side of the basilar part of the occipital bone was formed by the confluence of condyloid sinus and the basillar sinus and coursed posterolaterally without interruption, as right and left vertebral sinuses within the spinal canal. At the foramen magnum and the atlas, the sinus was ampullated and was largest in diameter. Posterior to the axis the sinuses were more medially located and lay upon the floor of the vertebral canal against the dorsal longitudinal ligament. The longitudinal vertebral sinuses were characterized by their segmentally arranged arcs, the right and left convexities of which approached each other in the middle of each vertebral segment. The curvature of these arcades was greatest in the lumbar and sacral regions and least arched in the coccygeal and anterior half of the thoracic region. The size and diameter of these sinuses also varied at different regions. At the thoracic inlet, there was a definite decrease in the caliber of longitudinal vertebral sinuses and from here the diameter remained quite constant throughout the thoracic and the anterior lumbar region. At the level of the fifth lumbar segment, a marked reduction in the caliber of the sinuses was noticed which was progressive from one segment to the next. At the level of sixth coccygeal segments, they were reduced to the size of two fine threads and beyond that they could not be traced.

In the middle of each vertebrae, the convexities of the right and left sinuses were connected across the midline beneath the dorsal longitudinal ligament. Basivertebral veins made connections with these deep anastamoses after passing through canals within the vertebral bodies and emerged on the ventral side through the venous foramina to join with extravertebral veins. At each intervertebral foramen, the sinus of each side made connection by intervertebral veins outside the spinal canal. In the cervical region, the anterior and posterior veins of each pair passed through the intervertebral foramina by the way of posterior and anterior notches of the contiguous vertebrae and drained into the costocervical vertebral trunk vein. In the thoracic region ,the azygos vein received the right and left intercostal veins to where the segmental drainage from the thoracic vertebra was observed. In the lumbar region, the sinuses drained into the right and left lumbar veins and then emptied into the azygos, posterior vena cava, common iliac, the iliolumbar or the middle sacral vein. The longitudinal vertebral sinuses of the sacral region were drained by way of anterior gluteal or internal pudendal veins to the right and left internal iliac veins. The sinuses in the coccygeal region drained exclusively into the coccygeal veins. The vertebral sinuses along its entire course were found to be valveless.

Worthman (1956b) in an experimental work studied the venous drainage of the vertebral canal in 22 dogs after ligating the large venous trunks at eight different sites. Forty-five radiographs were obtained, of which 11 were photographically reproduced. After caval occlusion, the contrast media was injected through various peripheral veins including the superficial lateral coccygeal vein, femoral vein and saphenous vein. Study was also undertaken in animals without caval occlusion, but by tight abdominal compression, to determine the flow in the venous sinuses. It was hence observed that the longitudinal vertebral sinuses appeared to be the largest and most immediately available of the collateral routes of the venous return after caval occlusion and under such conditions, the sinuses were capable of enlarging their caliber as their tributaries.

Parker (1974) in an experimental study on the traumatic occlusion of segmental spinal veins in dogs described the anatomy of vertebral sinuses similar to that of Worthman (1956). He stated that each pair of thoraco lumbar spinal column had a pair of segmental veins that drained into azygos vein, pelvic veins, external or common iliac veins, cranial gluteal or the internal pudendal or the caudal venacava directly. Individual variations in the venous drainage pattern of the lumbar vertebrae were also observed. The venous drainage after applying lumbar trauma was studied, and it was observed that despite extensive trauma and extensive loss of lumbar intervertebral veins, rapid collateral drainage occurred and though the sinuses were rendered nonfunctional by clots or fragments, collateral routes involving the intervertebral veins, pelvic veins and the azygos vein aided in preventing stagnation of blood in the lumbar spinal cord.

Hoerlein (1978a) stated that the longitudinal vertebral venous sinuses that lie within the spinal canal were paired, thin walled, flattened and valveless vessels that extended from the skull to coccygeal vertebrae. These paired trunks approached each other at the vertebral segment and diverged at the intervertebral foramina. There were frequent anastomoses between the right and left sinuses which involved the basivertebral, intervertebral and the arcuate veins. The arterial supply to the spinal cord was segmental with branches from the spinal arteries.

Spinal Diseases

Hoerlein (1978b) has classified clinical spinal disorders into degenerative, congenital, and traumatic disorders. The general clinical signs of cord compression were pain, paresis or weakness and rigid or flaccid paralysis. The signs varied according to the site and were segmental. A local damage in thoracic and lumbar areas caused pain,, posterior paralysis, paraplegia, urinary and faecal retention, exaggerated or depressed tendon reflexes, diminished postural and placing reactions for hindlimbs. The author further stated that Dachshund and members of the chondrodystrophoid breeds of dogs were most frequently affected with the disc disease, with higher incidence between three and six year range.

Oliver Jr. *et al.* (1978) studied in detail, the cauda equina compression due to lumbosacral malformations and malarticulations in dog. The clinical signs observed were pain, difficulty in rising, paresis/paralysis of the hindlimbs, tail paresis and faecal and urinary incontinence.

Tarvin and Prata (1980) discussed in detail the occurrence, etiology, and pathophysiology of lumbosacral stenosis in dogs. They stated that the stenosis of the spinal canal could be any type of narrowing of the spinal canal or intervertebral foramen or both and this could be categorized into acquired (degenerative) and congenital (developmental) forms. The clinical signs of lumbosacral stenosis were difficulty in rising, stiff gait, intermittent nature of the paraparesis, exacerbation of the symptoms after exercise, paresthesia or self mutilation of the tail and the hind digits, hyperpathia at the lumbosacral junction and atony of the bladder along with faecal incontinence.

Denny *et al.* (1982) stated that other than stenosis of the neural canal, cauda equina syndrome was also seen in animals with traumatic lesions at the lumbosacral junction.

Griffiths (1982) described the conditions causing acute as well as chronic onset of paraplegia. According to the author, majority of the conditions with acute onset was associated with trauma viz. vertebral fractures, dislocation, traumatic disc protrusion and concussion.

Braund *et al.* (1990) stated that the progressive pathologic changes that followed acute traumatic injuries of vertebral column included varying degrees of tissue necrosis and neurologic dysfunction, petechial haemorrhages, progressing to haemorrhagic necrosis over a 24 hour period. These changes might be seen as early as two hours after a traumatic injury. Trauma caused histopathological as well as metabolic changes of the nerves, supportive glial elements and the affected spinal cord segments.

Brawner Jr. *et al.* (1990) described in detail the etiology, pathology and pathophysiology of acute spinal trauma. Automobile accidents, gunshot wounds and fighting caused acute trauma. Other than external causes, acute injury arose from internal factors like disc disease, congenital factors such as atlantoaxial subluxation and spinal cord infarction associated with fibrocartilagenous embolization. External traumatic injuries were classified into ventral compartment injuries involving vertebral body, intervertebral disc, dorsal and ventral longitudinal ligaments and intertransverse ligaments. Dorsal compartment injuries involved the lamina pedicle, dorsal spinal processes, articular processes, supraspinous and interspinous and interarcuate ligaments.

McKee (1992) stated that in thoracolumbar disc protrusion in dogs, the age range of occurrence was two to eleven years with a mean range of five to eight years. The most commonly affected breed was Dachshund and the incidence was more in males.

Thilagar *et al.* (1993) in a retrospective analysis of thoracolumbar disc prolapse in 12 dogs reported that 66.7% of the animals showed occurrence of the disease between four to seven years range. They also reported a higher incidence in Dachshunds.

Yovich *et al.* (1994) recorded the clinical details of 61 dogs with thoracolumbar disc protrusion. They observed that Dachshund comprised 51% of the cases and the age ranged from 1-11 years with 56% in the 5-7 year range. The symptoms mentioned were back pain, varying degrees of interference in ambulation from ataxia to paresis in the initial stages followed by complete paraplegia, bladder dysfunction and absence of deep pain perception.

Shell (1996b) reviewed the differential diagnosis for acute and progressive onset of paraparesis. The etiology for acute onset were commonly intervertebral disc herniation, trauma and fibrocartilagenous embolism and less commonly discospondylitis, neoplasia, distemper myelitis, rickettsial meningeomyelitis, mycosis, parasitic migration and rabies myelitis. Type-I degenerative disc disease was more common in chondrodystrophoid breeds of dogs.

The author further opined that trauma was commonly caused by motorized vehicles, heavy falling objects, gunshot and bites during dog fights. Trauma caused rapid deformation of the cord, vascular damage, petechial haemorrhages and necrosis of grey mater, progressive reduction of the blood flow and release of chemical mediators and free radicals.

Shell (1996c) described the differential diagnosis of progressive onset paralysis. The causes of progressive onset were Type II intervertebral disc herniation, degenerative myelopathy, discospondylitis, degenerative lumbosacral stenosis, neoplasia affecting the spinal cord, and meningomyelitis. Type-II intervertebral disc herniation usually affects middle aged to older breeds of non-chondrodystrophoid breeds.

Shell (1996d) described the diagnosis for six cases of posterior paralysis. The complete blood cell count taken in all six animals at the time of clinical examination were found to be in the normal range.

Ramirez and Thrall (1998) in a review of the imaging techniques for the cauda equina syndrome have given the etiology, incidence and symptoms in detail. It was more common in larger breeds of dogs, more so in males than in females and has been reported to occur between the ages of three to nine years. The symptoms of cauda equina syndrome described were unwillingness to jump or climb stairs, reluctance or inability of the animal to rise from a sitting or lying position, lumbosacral pain, hyperesthesia, pelvic limb lameness, unilateral or bilateral paraparesis, muscle atrophy, tail paresis and in severely affected dogs urinary or faecal incontinence.

Fenner (2000) stated that in majority of nervous system diseases, there were minimal haematological changes. Haematological changes occurred primarily during systemic diseases with secondary involvement of the nervous system.

McKee (2000) described in detail the pathophysiology and diagnosis of intervertebral disc disease, the disc anatomy and function as well as injury to the spinal cord caused by its extrusion. The author observed that any breed might be affected with degenerative intervertebral disc disease and the age of occurrence was usually above two years. The signs seen in acute cases were paraplegia, urinary and faecal incontinence, tail paresis and loss of deep pain perception.

Neurological examination

Mentation

Shell (1996a) stated that paraparetic dogs with changes in mentation or cranial nerves were more likely to have a multifocal or diffuse disease rather than disc herniation. In the absence of cranial nerve signs, the lesions could be located below the foramen magnum.

Gait and posture

Griffiths (1972) stated that supporting a paraplegic animal by its tail could reveal any previously unseen defects to the legs, especially hip flexion.

Griffiths (1982) stated that if the animal could not move of its own, it should be aided to adopt its normal walking position to reveal voluntary movements which would have otherwise been masked.

Braund *et al.* (1990) reported that pelvic limb functions were usually absent in animals suffering from lumbosacral or thoracolumbar syndrome.

Shell (1996a) considered weakness of voluntary movements of pelvic limbs as paraparesis where as paraplegia was defined as complete absence of voluntary movements.

Postural reactions

Tarvin and Prata (1980) reported bilateral conscious proprioceptive defects in the hindlimbs of all the 15 animals affected with lumbosacral stenosis.

Griffiths (1982) stated that if the animal was paralyzed in any limb, proprioceptive tests were ineffective. Individual reactions did not specifically localize a lesion, however when combined with other reactions, they were of diagnostic value.

Braund *et al.* (1990) reported that postural reactions were seen depressed or absent in animals showing thoracolumbar or lumbosacral syndrome. The wheel barrowing reactions were particularly useful in testing thoracic limb function. The wheel barrowing reactions were normal in animals with thoracolumbar or lumbosacral syndromes whereas they remained depressed or absent in animals with cervicothoracic or cervical syndromes.

Braund (1995) stated that postural reaction such as hopping and placing reactions were absent in pelvic limbs in dogs suffering from thoracolumbar and lumbosacral syndrome. He further stated that the wheel barrowing reaction, though particularly useful, is manipulative and should not be performed in animals with vertebral column injuries.

Shell (1996a) stated that if the postural reaction and spinal reflexes were normal for the thoracic limb, the abnormality could be below T2 or T3 spinal cord segments.

Shell (1996c) stated that in Type-II intervertebral disc herniation, spinal compression caused ataxia, loss of postural reactions, followed by progressive weakness of limbs and paralysis.

CNS examination

Oliver Jr. (1978) stated clinical signs related possibly with CNS origin were convulsions, altered mental status (stupor or coma) and behaviour, paresis, paralysis, proprioceptive deficits, ataxia, head tilt, nystagmus, intention tremors, dysmetria, hyperesthesia, analgesia, syncope, blindness, hearing deficits, anorexia and visual dysfunction.

Braund *et al.* (1990) described in detail the syndromes of brain namely pontomedullary syndrome, cerebellar syndrome, vestibular syndrome, midbrain syndrome, hypothalamic syndrome and cerebral syndrome.

The absence of cranial nerve deficits and cranial syndromes in a case of paraplegia indicated that the lesion was of spinal origin. (Shell, 1996d)

Spinal nerve examination

Oliver Jr. (1978) stated that lesions of the lower motor neuron (LMN) produced - a) paralysis of muscles innervated, b) arreflexia. c) severe neurogenic atrophy and d) flaccidity of muscle and loss of tone. A lesion of the LMN disease was specifically significant in localizing a lesion and differentiation of a lesion of the cell body or nerve root or of the axon was made on the basis of distribution of signs. The upper motor neuron (UMN) were motor systems of the brain that controlled the LMN and this system was responsible for initiation and maintenance of normal movements and for the maintenance of tone in the extensor muscles.

Redding and Braund (1978) stated that spinal reflexes formed the basic unit of CNS integration and function and these reflexes tested the cord segments in which the reflexes were involved. The spinal nervous system was arranged in a segmental fashion with each spinal segment demarcated by a pair of spinal nerves and each nerve having a dorsal root (sensory) and a ventral (motor) root.

Tarvin and Prata (1980) in a study on the lumbosacral stenosis in dogs observed that due to compression of cauda equina, irritation of pudendal nerves occurred that increased the sphincter tone and made urination difficult, and it was exhibited in the form of incontinence or bladder stasis. Atrophy of muscles of sciatic innervation, hyperpathia of the lumbosacral region and paresthesia were the other prominent features of cauda equina syndrome.

Griffiths (1982) stated that by judging a UMN or LMN lesion in the limbs, it was possible to identify the appropriate level of spinal lesion. Normal foreleg reflexes and UMN lesion in the hindlimbs indicated the site of lesion in thoracic or upper lumbar cord, whereas normal foreleg reflexes and LMN lesion in the hindlimbs implicated the level of lesions between L4 and S2 spinal cord segments. In further localization of a spinal lesion, the author categorized the segmental reactions. Lesions of L4/L5/L6 cord segments showed loss of patellar reflexes, whereas affections of L7 and sacral segments showed loss of pedal reflex, anal reflex and lower motor neuron of bladder dysfunction.

The author further graded the increasing severity of cord damage in terms of prognosis as a) paresis b) paraplegic, intact bladder control and pain sensation c) paraplegic and loss of bladder control and pain sensation; the last indicating grave prognosis. Failure to improve within a two-week period usually indicated that the recovery at the least would be incomplete.

Braund *et al.* (1990) described in detail, the procedures for conducting neurological examination, including the method for conducting spinal reflexes. The spinal lesions were localized in the cord based on the syndromes elicited. Lumbosacral syndrome was seen in affections between L4 and S3 cord segments and they included flaccid weakness or paralysis of pelvic limbs and tail, urinary incontinence (flaccid bladder), reduced or absent reflexes and muscle tone with atrophy, absence of anal/bulbocavernosus reflex, faecal incontinence, reduced or absent pain perception in pelvic limbs and tail and depressed or absent postural reactions of hindlimbs. Clinical signs of thoracolumbar syndrome were seen in affections between T3 and L3 cord segments and the symptoms shown were spastic weakness or paralysis in the pelvic limbs with normal thoracic limb functions, normal to increased spinal reflexes and muscle tone without neurogenic atrophy, reduced or absent pain perception caudal to the site of lesion, increased sensitivity at the site of lesion, urinary incontinence (spastic bladder with intermittent spurting of urine) and depressed or absent postural reactions in the pelvic limb

A spinal cord lesion between the cervical and lumbar enlargements (i.e. between T3 and L3 cord segments) produced the thoracolumbar syndrome. It was characterized by spastic weakness or paralysis of pelvic limbs, increased or normal pelvic limb reflexes, incontinent and spastic bladder with hypertonia of external urethral sphincter and depressed or absent pain perception caudal to the site of lesion. Segmental muscle atrophy was not a feature of thoracolumbar syndrome, though generalized disuse muscle atrophy occurred in long term patients (Shores and Braund, 1993).

Braund (1995) reviewed the effectiveness of the assessment of neurological syndromes to localize the lesions in the spinal cord. The lumbosacral syndrome was produced by lesions involving a) spinal cord segments L4 and L5 through S1 to S3 cord segments or b) Lumbosacral nerve roots that formed the cauda equina. Clinical signs ranged from flaccid weakness to paralysis of pelvic limbs and tail. Patellar, gastrocnemius and cranial tibial as well as perineal reflexes were observed to be depressed or absent. Within one or two weeks, segmental atrophy could be seen in iliopsoas, quadriceps and sartorius muscles following an injury to L4-L6 cord segments. Pain perception in perineum, hindlimbs and tail remained reduced or absent. Paralyzed bladder with passive overflow incontinence as well as faecal incontinence was typical of this syndrome. In certain instances, a combination of signs termed as root signature, associated with nerve root compression or entrapment by fragments of extruded disc material was exhibited as partial flexion of one hindlimb, repetitive stamping motion of hindlimbs and other signs of lumbosacral syndrome.

Shell (1996a) in a review of the basics of pelvic limb weakness described that limb weakness could be caused by a problem in upper or lower motor neuron system. The UMN's and their axons had an inhibitory effect on the lower motor neurons that maintained the normal muscle tone and spinal reflexes. Hence in the occurrence of a UMN spinal lesion, the spinal reflexes for the limbs could no longer be controlled and therefore the exaggerated response. According to the author, the patellar reflex was the most reliable spinal reflex, which was mediated by the femoral nerve with cell bodies of origin at the spinal cord segments, L4 through L6 located in level with L3 and L4 vertebrae. An exaggerated patellar reflex indicated a lower motor neuron disease above the L4 cord segments, where as a depressed or absent reflex indicated a lower motor neuron lesion in the quadriceps muscle, femoral nerve or nerve roots or cell bodies located in cord segments L4 through L6. The sciatic nerve and its branches mediated the cranial tibial muscle, gastrocnemius muscle, sciatic and flexor reflexes with the cell bodies of this nerve located at L6 through S1 cord segments near the L4 and L5 vertebrae. The most reliable sign of a sciatic nerve damage was a reduced or absent flexor response. Cutaneous trunci reflex was another sign that could be used to localize the site of lesion especially in animals with thoracolumbar syndrome. The superficial pain perception and the cutaneous trunci reflex were reduced distal to the site of the lesion.

Lack of patellar reflex and lack of deep pain perception in the medial toe of the hindlimb suggested damage to the femoral nerve or the spinal cord segments L4-L6 (Shell, 1996d).

Fenner (2000) stated that cerebral recognition of pain perception was essential for a positive response to the tests aimed at evaluating the nociceptive pathways.

Radiography

Survey radiography

Plain radiography allows diagnosis of majority of conditions involving vertebrae and intervertebral veins. Tumors not involving bone, inflammatory and degenerative diseases, cord concussion and some cases of disc protrusions are some of the conditions that could not be identified on plain radiography (Griffiths, 1982).

Routine radiography was diagnostic only in conditions which involve the bony components of the vertebrae like fracture, luxation, disc protrusion and other degenerative changes (Hathcock *et al.*, 1988).

Lang (1988) described that because of its complex anatomy, radiographic examination of lumbar spine was difficult. Early advanced degenerative changes at the level of intervertebral foramen, intervertebral disc disease, hypertrophic changes of dorsal longitudinal ligament and certain types of lumbosacral stenosis could not be studied well on plain radiography due to superimposed pelvic structures.

Brawner Jr. *et al.* (1990) observed that the structures and conditions that were visible on survey radiographs were vertebrae, mineralized intervertebral discs, radioopaque foreign bodies, fractures, luxation, displacement of bone elements and indirect evidences of intervertebral disc prolapse and cord compression. Spinal cord, nerve roots and meninges, ligaments, nonmineralized intervertebral discs, haemorrhage and haematomas, radiolucent foreign bodies, instability of bone elements and cord compression were not usually noticeable in plain radiographs. They opined that radiographic findings should be correlated with the results of neurological examination and other clinical tests to arrive at a diagnosis.

Plain radiographs of the lumbosacral junction even with prominent degenerative changes of instability did not always indicate cauda equina compression (Schmid and Lang, 1993).

Barthez *et al.* (1994) stated that in diagnosing cauda equina syndrome in dogs, the plain radiographs could be used for examining lumbosacral disc space collapse, congenital stenosis of the vertebral canal, transitional vertebral segments, osteochondroses and discospondylitis.

Fenner (2000) opined that plain radiography was more useful in identifying lesions involving the bony components of the vertebral column.

McKee (2000) used survey radiography to localize vertebral lesions in diagnosing intervertebral disc disease and to evaluate the status after surgical correction. This was correlated with myelography for confirmation of the lesions.

Contrast radiographic procedures

Contrast medium

Funquist (1962 a&b) used the contrast medium Kontrast U^R 20 per cent at the rate of 0.3ml/kg body weight. The side effects and complications due to the contrast medium have been described which included hyperreflexia, aggravation of the neurological symptoms, convulsions, respiratory embarrassment and mortality.

Wheeler and Davies (1985) reported that Iohexol at a concentration of 300 mgI/ml provided adequate radioopacity and it was extremely suitable and safe for myelography in dog and cat.

Puglisi *et al.* (1986) after conducting myelographic studies in dog with Iohexol stated that it had good diagnostic quality and had minimal complications.

Herrtage and Dennis (1987) stated that Iohexol being a low osmolar, nonionic compound, had half the number of particles for the same amount of iodine as the conventional media, and more over due to the presence of an electrical charge, it was least neurotoxic of all the compounds used.

Allan and Wood (1988) performed myelography with Iohexol in 100 dogs. A single injection of Iohexol at a dose rate of 45 mg I/kg body weight, adequately opacified the subarachnoid space. A radiographic diagnosis, either of the disease involving the spinal cord or of a normal myelogram, was made in 96per cent of the dogs. Iohexol had an increased safety as a myelographic contrast medium in comparison with metrizamide.

Lewis (1991) stated that Iohexol and Iopamidol were the ideal agents of choice for contrast radiography of the spinal cord. The radiographic detail provided by these products were comparable and the risk of neurotoxicity was low. Iohexol was concluded to be less toxic and could be used without any real prospect of serious hazard.

Butterworth and Gibbs (1992) opined that Iopamidol caused a higher incidence of side effects than Iohexol but that the scale of difference could not be quantified and the newer nonionic contrast media caused fewer side effects than metrizamide.

Widmer *et al.* (1992) recommended using nonionic contrast media at 200 to 240mgI/ml for canine myelography because contrast pooling occurred at higher concentrations. They further opined that Iohexol and Iopamidol were safer than previous myelographic contrast media because they lacked a glucosamine moiety, were more hydrophilic and had improved shielding of Iodine atoms. The dose rate of the contrast recommended for myelography used was 0.3 to 0.45ml/kg body weight.

Olby *et al.* (1994) opined that Iohexol has consistently been found to be superior to other two non- ionic water-soluble iodine contrast media, metrizamide and iopamidol, both in incidence of side effects and radiographic quality.

Thilagar *et al.* (1994) opined that myelograms with Iohexol at 45 mgI/kg body weight were not of any diagnostic value, where as excellent density and morphology with Iohexol was observed at a dose rate of 75 mgI/kg for all regions of the spinal column.

Yovich *et al.* (1994) performed positive contrast myelography using Iohexol administered by cisternal and or lumbar punctures in 56 dogs with good results.

McKee (2000) mentioned that Iohexol was satisfactory as contrast medium in performing myelography in dogs.

Myelography

Blevins (1980) stated that myelography was not helpful in diagnosing lesions of lumbosacral area because the subarachnoid space usually ended cranial to this area.

Feeny and Wise (1981) stated that due to the obvious limitations of myelography in delineating the lumbosacral area, epidurography and interosseus vertebral venography must be used as alternative techniques.

In a comparison of the three radiographic contrast procedures namely myelography, epidurography and venography in evaluation of the canine lumbosacral vertebral canal, myelography was least successful (Hathcock *et al.*, 1988).

To overcome the disadvantage of myelography in establishing lesions at lumbosacral area, the radiographic appearance of canine dural end sac and its behaviour during extension and flexion of the spine was studied by Lang (1998). He reported that the shape, length, position and diameter of the dural end sac at the level of lumbosacral articulation was extremely constant during extension and flexion. Out of the 21 dogs with cauda-equina compression, myelographic diagnosis was possible only in seven dogs and in the other 14 dogs, overextension of the spine followed by imaging in lateral and dorsal recumbency was necessary to establish a diagnosis.

Ramirez and Thrall (1998) compared the efficacy of imaging modalities available for cauda equina syndrome. Myelography was of little value in evaluating the cauda equina syndrome because the dural sac remained elevated from the vertebral canal floor and terminated before the lumbosacral junction.

Epidurography

Feeny and Wise (1981) described techniques and radiographic findings of epidurography in normal dogs. Epidurography was found to be more advantageous in delineating the lumbosacral area. The procedure was technically easy and entailed a minimal amount of trauma when compared with myelography and venography. The contrast medium was deposited in the ventral epidural space at the sacrococcygeal junction or the cranial coccygeal region. The peripheral margins of the contrast medium on lateral radiographs were smoothly undulating and varied considerably in radioopacity due to somewhat irregular pooling of the contrast medium in the epidural fat. The authors advocated the use of additional injections of the contrast for every succeeding radiograph for consistent visualization. In normal epidurograms, the contrast medium gradually narrowed from the cranial part of L7 vertebra to the caudal part of the S1 vertebra and from this point the tapering was more dramatic. On the dorsoventral radiograph the contrast medium had a tubular shape, but less caudal tapering was seen than on the lateral radiograph. The authors were of the opinion that the sequence of a recumbent right lateral radiograph followed by a dorsoventral radiographic projection was most useful, however most consistent visualization of the lumbosacral area (dorsal and ventral aspects) was in the right lateral radiograph. The other advantages noticed in lateral position were a) easy positioning, b) better radiographic quality as bucky grid could be used and c) easier interpretation.

Hathcock *et al.* (1988) performed lumbosacral epidurography in 12 dogs before and after introduction of silicone mass into the epidural space and lateral radiographic projections were taken as the last 1-2 ml of the contrast remained to be injected. Epidurography was stated to be the technically easiest procedure to perform when compared to myelography and intraosseus vertebral venography. Lumbosacral epidurography had greater potential to give consistently good quality radiographs and thereby a greater probability of detecting an abnormality.

Based on observations by previous workers, Lang (1988) opined that in epidurography, interpretation was difficult because of multiple filling defects caused by the epidural fat.

Sisson *et al.* (1992) stated that epidurograms showed a 20 per cent error in diagnosing cauda equina abnormalities.

Barthez *et al.* (1994) undertook discography and epidurography as contrast radiographic procedures for evaluation of lumbosacral junction in dogs with cauda equina syndrome. The epidurograms so obtained were diagnostic in all the 18 cases of cauda equina syndrome. The abnormal findings that denoted a lesion were narrowing, elevation, deviation or obstruction of contrast medium column. The authors stated that the combination of discography along with lumbosacral epidurography was superior to the conventional sacrococcygeal epidurography as it reduced technical artifacts and was easier to perform. The disadvantages mentioned were that there was difficulty in identifying an artifact and a true filling defect. Epidurography, though successful in identifying the site of lesion at the lumbosacral region, was not a satisfactory procedure for detecting mass lesion within the canal.

Epidurography along with myelography and computed tomography aided in diagnosis of epidural lipomatosis in a six year old Dachshund (Meij *et al.*, 1996).

Ramirez and Thrall (1998) in a review of various works relating to imaging modalities in the diagnosis of cauda equina syndrome mentioned that injecting contrast medium into the lumbosacral epidural space and taking radiographs just as the last millilitre remained to be injected, was technically easier than injections at the sacrococcygeal junction, but the needle at the site of the interest in the previous method complicated the interpretation. Epidurograms were considered normal, when the contrast medium filled the epidural space and the contrast medium was visible on the floor of the vertebral canal, where as poor epidural filling caused negative results. Radiographic signs of elevation, deviation/obstruction of the contrast column, narrowing greater than 50% of the canal diameter were reported to be consistent with significant neural compression.

Venography

Worthman (1956b) conducted venographic studies to demonstrate the pattern of venous drainage by the longitudinal vertebral venous sinuses and to investigate the clinical significance of these vessels. In 16 dogs, a number of large venous trunks were ligated at eight different sites. Occlusion of the venacava prior to the kidneys resulted in collateral circulation through the vertebral veins, which was studied radiographically using Diodrast 70 per cent. The effect of abdominal compression on venous return was also demonstrated radiographically.

Parker (1974) used lumbar venograms to identify changes in the venous drainage of the vertebral column after applying trauma in dogs. The venous drainage pattern was segmental in nature and even after extensive loss of the venous sinuses due to trauma, collateral circulation occurred and were identified venographically.

Oliver Jr. *et al.* (1978) performed transosseous vertebral venography in eight cases of lumbosacral stenosis in dogs and abnormal findings in the venograms like blockage of the contrast flow or deviation of the sinuses were reported in all the cases.

Blevins (1980) reported that transosseus vertebral venography provided adequate radiographic contrast for seeing the lumbar and sacral vertebral venous sinuses and hence was a diagnostic aid for lumbosacral diseases. Venograms were taken just as the last millilitre of the contrast medium remained to be injected. The author further observed that since the venous sinuses were extremely thin walled and easily collapsed, a mass lesion or stenosis of the spinal canal, with or without vertebral subluxation, would cause an obstruction to contrast medium flow in the sinuses, narrowing of the sinuses or deviation of the sinuses. Technical errors encountered were extravassation of the contrast into the perivertebral tissues and lack of abdominal compression. The author after reviewing the previous works of other authors, has opined that venography could not be used as a definite method of localizing spinal cord compression, however in the presence of a normal venogram, spinal cord compression could be ruled out.

Intraosseus venography was performed in a dog with lumbosacral stenosis demonstrating attenuation at the L7-S1 spinal segments (Tarvin and Prata, 1980).

Feeny and Wise (1981) reported that intraosseous venography provided false positive diagnoses and epidurography had a distinct advantage over venography.

Hathcock *et al.* (1988) conducted intraosseous vertebral venography at the caudal vertebrae with abdominal compression cranial to the iliac crests to facilitate flow of the contrast medium into the vertebral sinus and lateral radiographic projections were taken as last 2-3 ml of the contrast remained to be injected. Good quality venogram was described as one in which the contrast medium outlined the lumbar and sacral venous sinuses, where as non diagnostic radiograph was one, where non filling of the sinus or filling of the sinus upto the level of the lumbosacral region occurred, even when there were no technical errors. The possibility of technical errors were more in venography and some of them were inaccurate placement of the needle, inadequate abdominal compression and anatomic variation among dogs.

Lang (1988) in his review, stated that various methods could be used to visualize the internal venous sinuses in the lumbar area, the important being transosseus vertebral venography and retrograde filling of the sinus by way of the femoral or a peripheral vein. The author opined that stenosis of blood vessels, dorsal deviation of the sinus and total obstruction of the contrast flow were the three types of changes in good venograms, that were suggestive of a lesion. Technical problems were more frequent with venography, which reduced its diagnostic value.

Ramirez and Thrall (1998) stated that venography has been used to diagnose intervertebral disc herniation, traumatic and degenerative lumbosacral instability, lumbosacral vertebral canal stenosis, discospondylitis, neoplasia and ligamentous hypertrophy. Injecting contrast medium into a peripheral vein, or into the vertebral body with adequate compression of the venacava and radiographs taken as the last millilitre of the contrast medium remained to be injected, would result in opacification of the venous sinuses. However the authors were of opinion that this method was very inconsistent, with failure of opacification of venous sinuses anterior to the lumbosacral region as a commonly encountered difficulty and with more scope of technical errors, it was not practical for routine diagnostic use.

Materials and Methods

MATERIALS AND METHODS

The study was conducted in 12 clinical cases of paraplegia in dogs presented at the Surgery unit of the Veterinary College Hospital, Mannuthy. The cases were randomly divided into two groups of six animals each, Group-A and Group-B.

Group A consisted of six cases of dogs serially numbered from A1 to A6. These animals were subjected to epidurography using Iohexol[1], administered into the lumbosacral epidural space at the dose rate of 80 mgI/kg body weight.

Group B consisted of six cases of dogs serially numbered from B1 to B6. These animals were subjected to ascending coccygeal venography using Iohexol at a dose rate of 100 mgI/kg body weight, wherein the contrast media was administered into coccygeal vein after sufficient abdominal compression.

Two normal dogs, one each were subjected for epidurography and ascending coccygeal venography for comparison of radiographic images in the two groups.

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[1]Omnipaque™ - Iohexol 300 mgI/ml, Nycomed Ireland Ltd., Cork.

Radiographic technique

Survey radiography

Ventro-dorsal and/or lateral survey radiograph of the lumbar and sacral region were taken prior to contrast radiography in all the animals to identify any gross abnormalities of the vertebral canal, spinous processes and articulations, in relation to the clinical signs exhibited by the animals.

Contrast radiography

Contrast medium

Iohexol, a water soluble, non-ionic, tri-iodinated compound with an Iodine concentration of 300 mg I/ml was used as the exclusive contrast agent for both epidurography and ascending coccygeal venography.

Anaesthesia

For catheterizing the coccygeal vein and introducing needle into the lumbosacral epidural space, local infiltration with Lignocaine hydrochloride[1] (2%) was used. In animals that were excited, mild sedation was effected with Triflupromazine Hydrochloride[2] at a dose rate of 2 mg/kg body weight or general anaesthesia was induced with Thiopentone Sodium[3] to complete the procedure.

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[1] Xylocaine® 2% - Lignocaine injection I.P., Astra-IDL, Bangalore.
[2] Siquil – Triflupromazine hydrochloride 20 mg/ml, Sarabhai Chemicals, Baroda
[3] Pentothal sodium – Thiopentone sodium injection I.P. – Abbot Laboratories India Ltd., Ankleshwar

Epidurography

Epidurography was conducted by introducing a spinal needle (22G) at the lumbosacral junction, while keeping the hind limbs flexed anteriorly beneath the abdomen. The contrast medium, Iohexol, was used at a dose rate of 80 mgI/kg body weight. Half of the contrast medium was injected at first and the remaining was injected slowly to achieve complete filling in the epidural space. Lateral/ventrodorsal radiographs of the lumbar and sacral region were taken at 0, 3 and at 5 minutes after administration of the contrast medium.

Ascending coccygeal venography

The superficial, lateral coccygeal vein on any one side near the base of the tail was located and catheterized under local anaesthesia with lignocaine hydrochloride (2%). Abdominal compression was brought about by wrapping a folded 15 cm crepe bandage around the mid abdomen with due compression. A radiolucent thermocol wedge was placed beneath the bandage at the ventral region, prior to tightening in fat animals for effective compression of the vena cava. Contrast medium, Iohexol was then injected as an intravenous infusion at a dose rate of 100 mgI/kg body weight. Lateral/ventrodorsal radiographs of the lumbar and sacral region of the vertebral column were taken, as the last millilitre of the solution was being injected. Subsequent radiographs were taken at the third and fifth minute.

All the animals were observed for one week post administration of Iohexol for any adverse effects and complications.

Observations

Clinical examination

All the animals were subjected to detailed clinical examination as given hereunder.

Physiological parameters

Respiration rate (per min), rectal temperature (°C), and pulse rate (per min) were recorded before and 24 hours after each radiographic procedure.

General examination

A thorough physical examination was conducted for each case to determine the type of paralysis and to localize the site of lesion. General condition, age, sex, breed and mentation of the animal were observed and recorded.

Neurological examination

All the animals were examined for postural reactions, cranial nerve reflexes and spinal reflexes to localize the site and type of lesion as mentioned by Braund *et al.* (1990) and Braund (1995) and the observations were correlated with radiography to confirm the diagnosis. The reflexes so observed were graded as 0, 1, 2, and 3 representing absence of reflex, depressed reflex, normal reflex, and hyperreflexia respectively (Shell, 1996d).

Haematological parameters

Blood smears were prepared and venous blood samples were collected in EDTA[1] for estimation of haemoglobin (Hb) concentration, packed cell volume (PCV), total leucocyte count (TLC), total erythrocyte count (TEC), and differential leucocyte count (DC) (Schalm, 1975). Samples were collected just before and 24 hours after the administration of the contrast medium.

Radiographic evaluation

Quantity of the contrast medium injected, duration of administration, radiographic time sequence, the radiographic pattern, and lesions observed were analyzed in detail to study the diagnostic value and accuracy of both the techniques.

Correlation of lesion

The radiographic lesions observed in all the animals were correlated with the clinical and neurological findings to locate the site and type of lesion.

Statistical analysis

The data obtained were analysed and compared using analysis of co-variance test (Snedecor and Cochran, 1994).

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[1]EDTA – EDTA Disodium salt (Nice Laboratory Reagent), New India Chemical Enterprises, Kochi

Results

RESULTS

The study was conducted in twelve clinical cases of dogs suffering from paraplegia, presented at the Surgery Unit of Veterinary College Hospital, Mannuthy. The animals were randomly divided into two groups of six animals each, Group A and Group B.

The animals of Group A were subjected to epidurography and that of Group B were subjected to ascending coccygeal venography after conducting the preliminary clinical and neurological examination and the comparative efficacy of both the procedures in identifying the site and type of lesion were evaluated.

Two normal dogs, one each were subjected to epidurography and ascending coccygeal venography for comparison of radiographic images.

Clinical examination

The observations are presented in Table 1.

History

Of the twelve cases of posterior paralysis studied, the age of the animals ranged from four months to 11 years, with the maximum number of cases in the age of 4-6 years. Eight animals were non-descript, two were Dachshunds and one German Shepherd and Doberman Pinscher each. Of the 12 cases, nine animals were males and three were females.

In six animals, the onset of paralysis was acute and in the remaining six, the onset of paralysis was slow and progressive. In the animals with progressive onset, the owners could not recall any specific incident or time from which the animal showed paralysis. Of the six animals with acute onset, four animals had history of traumatic injury on the lumbar region.

The general history obtained from all the cases of progressive paralysis were in-coordination and difficulty in walking over long periods of time, reluctance to rise or jump in the initial stages, intermittent nature of ataxia and knuckling and dragging of the hind limbs.

General clinical signs

All the animals presented were alert and reacted normally to visual, auditory and the tactile stimuli.

Four animals had history of traumatic injury on the lumbar region. The onset of paralysis was immediate in these cases. Clinical signs also included swelling and oedema at site of trauma, pain on palpation at the site of injury, distended bladder and absence of micturition and defecation.

Six animals showed clinical signs similar to that of cauda-equina syndrome. Lameness with or without paresthesia, impairment of bladder function, reluctance to rise, unwillingness to jump or climb stairs, faecal incontinence, and paralysis were the main clinical signs observed. The paresis was intermittent and exacerbated after exercise or running. Licking and mutilation of tail was evident in one case. Tail paresis and severe muscular dystrophy was observed in all the cases. All the animals evinced pain on palpation of the lumbosacral area.

The remaining two cases showed an acute onset of paralysis without any history of a specific cause or incident. The animals showed non-ambulatory paraplegia, flaccidity of the hind limbs and tail, pain on manipulation of the lumbar region and urinary incontinence.

Group A

Physiological parameters

The observations are presented in Table 2.

The mean value for the respiration rate (per min) at the time of clinical examination was 30.33±1.80 and 30.17±2.10 at 24 hours after administration of contrast medium. The variations observed were marginal and within the normal range.

The mean value for rectal temperature (°C) was 38.75±0.15 at the time of clinical examination and 38.88±0.13 at 24 hours after injection of the contrast medium. The variations observed were marginal and within the normal range.

The mean value for pulse rate (per min) at the time of clinical examination was 80.50±3.15 and 79.83±5.63 at 24 hours after administration of contrast medium. The variations observed were marginal and within the normal range.

Neurological examination

Mentation

All the animals presented were alert in mentation.

Gait and Posture

All the animals of this group were non ambulatory and could not stand or bear weight on the hindlimbs.

Postural reactions

The postural reactions for both the forelimbs in all the six animals were normal, whereas abnormalities of varying degrees were observed in hind limbs in all the animals.

Wheel barrowing reaction

A normal response of symmetrical forelimb movement was observed in all the six animals.

Hemistanding/hemiwalking reaction

The hemistanding/hemiwalking reaction was absent in all the six animals.

Hopping reaction

A normal response of hopping on the supporting limb in direction of displacement of limb perpendicular to the body was observed in the forelimbs of all the six animals, whereas absence of hopping reactions were observed in the hindlimbs of all the animals due to the inability to support body weight.

Extensor postural thrust reaction

A normal response of extension of hind limbs and an orderly backward stepping was not observed in any of the six animals.

Concious proprioceptive reaction

Proprioceptive deficits of varying degrees were observed in both the hind limbs of all the animals.

Placing reaction

Placing reactions were normal in the forelimbs of all the six animals whereas the response was absent or depressed in case of both the hind limbs of all the animals.

Spinal nerve examination

The results of the spinal nerve examination of the six animals of Group-A are presented in Table 4.

Spinal reflexes of the limbs were then studied in all the animals of Group-A. The forelimb spinal reflexes were normal in all the six animals.

Spinal reflexes of the hind limbs were then examined and have been described individually.

Animal A1: The spinal reflexes for hind limbs were found to be depressed. The patellar reflexes were normal whereas the gastrocnemius, cranial tibial reflex, and pedal reflex were depressed. The anal reflex was normal, but the urinary bladder was flaccid and showed overflow incontinence. The superficial and deep pain perception was present in both the hind limbs. The muscle mass of the hind limb was slightly atrophied and the tone was decreased. The site of lesion was localized between L5 and S1 cord segments.

Animal A2: The spinal reflexes namely the patellar, gastrocnemius and cranial tibial reflexes were exaggerated in the hindlimbs. The pedal reflex was found to be normal; The anal reflex was found to be depressed; The tail was also paretic, the panniculus reflex was absent caudal to L1 vertebral level. The pain perception was absent in both the hindlimbs and the animal showed a spastic bladder i.e. it was firm and difficult to express and there was brief intermittent spurting of urine. Hyperpathia was observed at the L2-L3 vertebral region. Lesion was thus localized between T13 and L3 cord segments.

Animal A3: The patellar reflexes were normal, but the reflexes mediated by the sciatic nerve viz. gastrocnemius, cranial tibial and pedal reflex were depressed. The anal and bulbocavernosus reflexes were normal. The bladder was flaccid with presence of overflow incontinence. The deep pain perception was depressed whereas the superficial pain perception was absent on the lateral and caudal region of the hind limb and toes. Muscle atrophy was severe in the hind limbs; the muscles involved were gastrocnemius and the hamstring that are innervated by the sciatic nerve. Hyperpathia was observed at the lumbosacral junction. The panniculus reflex remained intact till the lumbosacral junction.

Based on the spinal reflexes, the lesions were localized between L5 and S1 cord segments.

Animal A4: All the spinal reflexes were either absent or depressed for hind limbs. The cutaneous trunci reflex was found to be intact along the dorsal midline till the L4 vertebra. The pain perception for both the hind limbs was absent. The paresis of tail and hyperpathia at the L6-L7 regions were also observed. Flaccid bladder and severe muscular atrophy of muscles along the sciatic nerve distribution were observed and thus the lesions were localized between L4 and S2 spinal cord segments.

Animal A5: All the spinal reflexes for hind limbs including the patellar, gastrocnemius, cranial tibial, pedal and anal reflexes were absent. Paresis of the tail, flaccid and incontinent bladder, flaccid muscle tone and hyperpathia at the L5 vertebral region were the other spinal nerve changes observed. The lesion was thus localized between L4 and S2 cord segments.

Animal A6: All the spinal reflexes for hind limbs namely patellar, gastrocnemius, and pedal were exaggerated. The anal tone was normal. However the bladder remained spastic and tense. There was increased tone and spasticity of the muscle mass indicating that it was a thoracolumbar syndrome and the lesion was localized between T13 and L3 vertebral cord segments.

Haematological parameters

The data for the haematological parameters of animals in Group-A are presented in Table 3.

The mean value for total red blood count (10^6/cu.mm) of the six animals was 7.30 ± 0.73 at 0 min and 7.18± 0.58 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for total leucocyte count (10^3/cu.mm) at 0 minute was 9.53±0.95, and 10.17±0.90 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for haemoglobin concentration (g%) was 14.00±0.58 at 0 min and 14.17 ± 0.59 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for packed cell volume (%) was 39.17 ± 1.58 at 0 min and 40.00 ± 1.32 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for neutrophil count (%) at 0 minute was 67.83±1.79 and 70.66±1.85 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for band cell count (%) at 0 minute was 2.16±0.65, and 1.83±0.83 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for lymphocyte count (%) at 0 min was 26.33±2.17 and 25.16±2.40 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for monocyte count (%) at 0 minute was 2.16±0.48 and 1.80±0.37 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for eosinophil count (%) at 0 minute was 1.50±0.76 and 1.00±0.51 at 24 hours. The variations observed were marginal and within the normal range.

Radiographic studies

Survey radiography

Survey Radiography was conducted in all the six cases in Group-A prior to conducting contrast radiographic procedures. Though all the plain radiographs were of diagnostic quality, identification of the site of lesion were possible in three cases of trauma (A2, A5 and A6) and a single case of cauda equina syndrome (A3). The observations of these cases have been recorded individually.

Animal A2: A circumscribed area of increased soft tissue density was observed at the level of L2-L4 vertebrae which was due to swelling and oedema caused by trauma.

Animal A3: History revealed presence of cauda equina syndrome and plain radiography revealed malarticulation between the spinous processes of L6 and L7 vertebrae. A slight malalignment of the floor between L7 vertebra and sacrum was observed.

Animal A5: The animal had a history of being hit by a motor cycle. Plain radiographs revealed complete ventral compartment transverse fracture of the anterior plate of the L6 vertebral body.

Animal A6: The animal had a history of being hit by a motor vehicle and plain radiographs revealed complete, transverse, overriding fracture of the middle and ventral compartments of the L2 vertebra.

In the remaining cases, though the plain radiographs did not reveal any abnormality suggestive of a lesion, the anatomicalfeatures of the lumbosacral area were well defined and clearly visualized.

Contrast radiographic studies

Quantity of the contrast material injected

In all the six animals of Group-A, Iohexol at a dose regimen of 80 mgI/kg body weight was used for epidurography. An average of 3.81 ± 0.52 ml of 300 mgI/ml contrast solution was used per animal (Table 5).

All the epidurograms obtained were seen with required density of the contrast and excellent opacification of the spinal column in this study.

All the animals were observed for one week post administration of Iohexol and no adverse reactions were observed in any of the cases of Group-A.

Duration of administration

In all the six cases of epidurography, the contrast medium was injected as a slow infusion into the epidural space over a period of 20-30 seconds.

Time sequence

In Group A, it was observed that in 0 and 3rd minute radiographs, opacification of the epidural space was good and were most useful in identifying the lesions. In the 5th minute radiograph, there was blurring of the margins as well as migration of the contrast medium from the vertebral canal. Thus the 5th minute radiograph was not at all significant in terms of diagnostic value.

Radiographic pattern

Epidurography was conducted in one normal dog and in six clinical cases of Group A.

Normal pattern

In the normal animal for epidurography, the spinal column was completely opacified, defining the course of the spinal cord till the migration of the contrast (Fig.1 and 2). The contrast filled the epidural space defining the dorsal and the ventral column of the contrast medium which gradually narrowed from the cranial part of L7 to the caudal part of S1 and the narrowing continued along the level of the coccygeal vertebrae. The spinal column appeared uniformly wavy at the margins owing to the presence of epidural fat and a slight elevation at the ventral margin of the intervertebral space was noticed due to the presence of nerve trunks leaving that area. The radiograph at the fifth minute showed drainage of the contrast medium by the epidural veins (Fig.3).

Case study

The radiographic pattern observed in clinical cases of epidurography were recorded individually:

Animal A1: The epidural opacification was excellent throughout the spinal column in the 0 minute radiograph. Elevation of the ventral floor (about 25%) was evident at the L6-L7 and L3-4 intervertebral level, presumably due to the presence of epidural fat and nerve trunks leaving that region. The 3rd minute radiograph revealed the presence of migration of contrast along the nerve trunks as well as minor elevation of the ventral column observed in the intervertebral spaces at the 0 minute were leveled and the ventral and dorsal margins of the column became more uniform. The 5th minute radiograph showed faint traces of the contrast in the spinal column though some amount of the contrast could be outlined at the thoracic vertebral level (Fig.4 and 5).

Animal A2: The 0 minute radiograph revealed the presence of evenly distributed contrast through out the spinal column from the fifth coccygeal segment to the anterior thoracic vertebral level. The dorsal and ventral margins of the column were uniformly opacified and more revealing than the interior and core of the contrast outlined spinal column. The column was uniformly wavy. At the level of L2-L4 vertebrae, the contrast opacification was poor and the outline of the dorsal margins was absent, even when all the adjacent areas were opacified satisfactorily. The 3rd and 5th minute radiograph showed migration of the contrast into the nerve trunks and reduction in opacification when compared to the 0 minute radiograph. The 3rd minute radiograph taken in the ventrodorsal position did not reveal any additional information (Fig.6).

Animal A3: In the 0 minute lateral radiograph, the opacification of the column was reduced and almost absent at the level of the L5,L6 and L7 vertebral levels even when areas adjacent anteriorly till the thoracic vertebrae had achieved excellent and uniform opacification. Moreover elevation, raised ventral border and narrowing of the column was more prominent than normal at the level of L5 to L7 vertebrae. The 3rd minute radiograph taken in ventrodorsal position though revealed a cylindrical position till the anterior lumbar vertebrae, the posterior region of the column couldnot be clearly visualized (Fig.7).

Animal A4: The typical uniformly wavy pattern of the contrast medium was seen along the spinal column and migration of the contrast was well visualized at the coccygeal vertebral level. Elevation of the ventral margin of the column (less than 25%) was seen at all the intervertebral areas. The ventral and dorsal borders of the column were well opacified. Opacification was less and non-uniform in comparison at the core of the tubular column (Fig.8). The 3rd minute lateral radiograph was the same reproduction as that of the 0 minute radiograph. The 5th minute radiograph taken at ventrodorsal position did not reveal any contrast medium in the vertebral canal.

Animal A5: Complete transverse vertebral body fracture of the L6 vertebra was observed. The contrast medium was visualized in the epidural space till the fractured region of the L6 vertebral body after which there was escape of the contrast medium from the spinal canal into the adjoining areas. Contrast medium could not be visualized in the spinal column anterior to the L6 vertebrae (Fig.9). The 3rd and 5th minute lateral radiographs showed the same picture with the spread of the contrast more diffusing outside the vertebrae.

Animal A6: Complete-overriding fracture of the L2 vertebra was observed. The spinal column was opacified till the level of the middle of the L3 vertebra after which there was abrupt attenuation of the contrast. The fragment of the fractured vertebral body was seen completely obstructing the spinal column in the lateral radiograph (Fig.10). In both the 3rd and 5th minute radiograph, the level of the attenuated contrast remained the same and there was no migration of the contrast into adjoining areas.

Lesions identified

Based on the radiographic pattern of the cases A1-A6 in Group-A, the site and type of lesions identified were described individually (Table 7).

Animal A1: The radiographic pattern revealed a normal epidural filling along the spinal column. The elevation of the contrast column that were observed at the L6-L7 and L3-L4 intervertebral region at the 0 minute radiograph were due to the presence of epidural fat and nerve trunks leaving that region and such changes were not seen in the 3rd minute radiograph (Fig.4 and 5). Hence the epidurograms obtained were normal and the site of lesion that was localized in the neurological examination (L5-S1 cord segments) could not be correlated.

Animal A2: Epidurograms revealed filling defects of the contrast on the dorsal border of the spinal column along the L2 to L4 vertebral bodies, which indicated dorsal compression of the cord in these areas (Fig.6). The diagnosis obtained was in correlation with the thoracolumbar syndrome that was noticed during the neurological examination.

Animal A3: Clear filling defects of the contrast was observed (Fig.7). The narrowing of the column at this region was suggestive of a lesion at the cord segments L5-L7 vertebral region, but the type of lesion could not be identified.

Animal A4: A normal epidurographic pattern was observed (Fig.8). The neurologic examination revealed the presence of cauda equina syndrome, which could not be confirmed.

Animal A5: Radiographs revealed complete ventral compartment body fracture of the anterior plate of the L6 vertebra (Fig.9). The complete extravassation of the contrast media outside the vertebral canal was observed.

Animal A6: Radiographs revealed complete overriding, transverse fracture of the middle and ventral compartments of the L2 vertebra. Overriding segment was found to be completely occluding the spinal column and hence the blockade of the spinal column caudal to it (Fig.10). Epidurograms positively correlated with the results of neurological examination.

Lesions in epidurography were identified as abrupt attenuation of the contrast, elevation of ventral border of the contrast column by more than 50%, extravassation of the contrast into the adjacent tissues, narrowing of the contrast column, and failure of migration of the contrast into the coccygeal epidural space.

Thus epidurography helped in outlining lesions in four out of six cases, which was in positive correlation with the clinical and neurological examination.

Group B

Physiological parameters

The mean values for respiration rate, rectal temperature and pulse rate in animals of Group B are presented in Table 8.

The mean value for the respiration rate (per min) was 25.50±2.53 at the time of clinical examination and 25.83±0.47 at 24 hours after administration of contrast medium. The variations observed were marginal and within the normal range.

The mean value for the rectal temperature (°C) was 38.75±0.34 at the time of clinical examination and 38.76±0.11 at 24 hours after administration of the contrast medium. The variations observed were marginal and within the normal range.

The mean value for pulse rate (per min) was 87.83±3.65 at the time of clinical examination and 85.83±1.53 at 24 hours after administration of contrast medium. The variations observed were marginal and within the normal range.

Neurological examination

Mentation

All the animals presented were alert in mentation.

Gait and Posture

All the animals in this group were non ambulatory and could not stand or bear weight on the hindlimbs.

Postural reactions

The postural reactions for both the forelimbs in all the six animals were normal, whereas abnormalities of varying degrees were observed in hind limbs in all the animals.

Wheel barrowing reaction

A normal response of symmetrical forelimb movement was observed in all the six animals.

Hemistanding/hemiwalking reaction

The hemistanding/hemiwalking reactions were absent in all the six animals.

Hopping reaction

Absence of hopping reactions were observed in the hindlimbs of all the animals due to the inability of the hindlimbs to support body weight.

Extensor postural thrust reaction

Normal extensor postural thrust reaction was not observed in any of the six animals.

Concious proprioceptive reaction

Proprioceptive deficits of varying degrees were observed in both the hind limbs of all the animals.

Placing reaction

Placing reactions were normal in the forelimbs of all the six animals whereas the response was absent or depressed in case of both the hind limbs of all the animals.

Spinal nerve examination

The results of the spinal nerve examination of the six animals of Group-B are presented in Table 10.

Spinal reflexes of the limbs were then studied in all the animals. The forelimb spinal reflexes were normal in all the six animals.

Spinal reflexes of the hind limbs were then examined and have been described individually.

Animal B1: Except for the patellar reflexes, all the other hind limb spinal reflexes were depressed. The neurological signs were typical of lumbosacral syndrome with other observations being flaccid and incontinent bladder, paretic tail, depressed superficial and deep pain perception and severe muscle atrophy of the hind limbs. The lesions were thus localized between L5 and S2 spinal cord segments.

Animal B2: The patellar reflexes were normal but the gastrocnemius, cranial tibial and pedal reflexes were absent and the anal and bulbocavernosus reflexes were depressed. Thus the reflexes showed a lower motor neuron disease with the presence of lumbosacral syndrome. The other observations recorded were incontinent and flaccid bladder, paretic tail and absence of superficial and deep pain perception. The cutaneous trunci reflex however was present through out the dorsal midline. Hyperpathia was observed at the L6-L7 region. The lesion was thus localized between L5 and S2 spinal cord segments.

Animal B3: The patellar reflexes were normal. However the gastrocnemius, cranial tibial and the pedal reflex were absent in both the hind limbs. The anal reflex however remained depressed and the bladder was flaccid and showed incontinence. The superficial and deep pain perception both remained depressed in the hind limbs. The tail was paretic and there was severe muscle atrophy of the hind limbs over the areas of sciatic nerve distribution. Hyperpathia was observed over the lumbosacral region. This neurological examination confirmed the presence of cauda equina lesion with its location between the L5 and S2 spinal cord segments.

Animal B4: The patellar reaction was exaggerated whereas the gastrocnemius, cranial tibial and pedal reflexes were depressed. The flaccidity of the bladder and paretic tail were also suggestive of a lower motor neuron lesion in the lumbosacral spinal cord. The superficial and deep pain perception was absent and the animal exhibited hyperpathia at the L6-L7 vertebral region, which was also suggestive of presence of lesion in the lumbosacral area.

Animal B5: The spinal reflexes of the hindlimbs showed lower motor neuron lesions akin to that of lumbosacral syndrome. The patellar reflexes were normal, but the cranial tibial, gastrocnemius, pedal and anal reflex, superficial and deep pain perception were completely absent indicating the level of lesion between L4-S2 spinal cord segments.

Animal B6: Patellar and gastrocnemius reflexes were normal whereas cranial tibial, pedal and anal reflexes were depressed, the tail remained paretic and there was urinary incontinence. All these are suggestive of affections of the lumbosacral spinal segments. Paresthesia or self mutilation of the tail region, suggestive of cauda equina syndrome was also observed

Haematological examination.

The results of haematological examination are presented in Table 9.

The mean value for total red blood count (10^6/cu.mm) at 0 minute was *6.65±0.61 and 6.55±0.45 at 24 hours. The variations observed were marginal* and within the normal range.

The mean value for total leucocyte count (10^3/cu.mm) at 0minute was 10.13±0.41 and 10.27±0.47 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for haemoglobin concentration (g%) at 0 minute was 14.50±0.58 and 14.50±0.45 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for packed cell volume (%) at 0 min was 38.66±1.52 and 39.16±0.81 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for neutrophil count (%) at 0 minute was 68.00±1.31 and 69.80±1.35 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for band cell count (%) at 0 minute was 1.50±0.22 and 1.66±0.21 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for lymphocyte count (%) at 0 min was 28.50±1.26 and 26.70±0.95 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for monocyte count (%) at 0 minute was 1.50±0.42 and 1.66±0.33 at 24 hours. The variations observed were marginal and within the normal range.

The mean value for eosinophil count (%) at 0 minute was 0.66±0.33 and 0.5±0.34 at 24 hours. The variations observed were marginal and within the normal range.

Radiography

Survey radiography

Lesions could not be identified in any of the six cases of this group in plain radiography. The radiographs appeared normal in all the six cases.

Contrast radiographic procedures

Quantity of the contrast material injected

For venography, Iohexol was used at dose rate of 100 mgI/kg body weight. On an average 6.41 ± 0.97 ml of 300 mgI/ml of contrast medium was used per animal. The quantity of contrast medium used per animal and the individual body weight have been recorded in Table 6.

The standard dose rate of ionic contrast media at 100 mgI/kg body weight was used for venography. The opacification and outlines of the veins in these radiographs were satisfactory for identification of the lesion.

All the animals were observed for one week post administration of Iohexol for any adverse effects and complications viz. CNS irritation, seizures, exacerbation of neurological deficits, and hyperthermia. No neurological, physiological or toxic side effects were observed due to the use of contrast medium in any of the cases in this study.

Duration of administration

The contrast medium in venography was injected as a slow infusion over a period of one minute.

Time sequence

Serial radiographs were taken at 0, 3rd and 5th minute in all animals of this group and it was found that, for cases of venography, the radiographs taken at the 0 minute was most useful. The radiograph was taken as a slow infusion just as the last milliliter of the contrast remained to be injected. In the 3rd and the 5th minute the contrast was not visible, as it had been drained away by the vein.

Radiographic pattern

Normal pattern:

For venography, the radiographic pattern of the vertebral venous sinuses were studied in a normal animal. The opacification of the longitudinal vertebral sinuses coursing along the vertebral floor observed were paired and characterized by their segmentally arranged arcs (Fig.11). The right and left convexities that approached each other in the middle of each vertebral segment was clearly visible in the ventrodorsal view (Fig.12).

Case study:

The pattern observed in six cases of venography are described below:

Animal B1: Longitudinal vertebral venous sinuses were visible till the sacral region after which there was abrupt shunting of the contrast into the vena cava in the lateral radiograph taken at the 0 minute. The wavy pattern of the sinuses (sinuses were depressed at the midvertebral region in conformation with the anatomic contour of vertebral floor and slightly elevated at the intervertebral region in the lateral views) and the drainage of the contrast medium through the intervertebral veins into the vena cava and the paravertebral veins were clearly visible in the 0 minute radiograph. Ventrodorsal views also taken at the 0 minute revealed paired sinus coursing along the coccygea, sacrum and the lumbosacral junction where there was abrupt attenuation and shunting of the contrast into the venacava (Fig.13). The arcade pattern usually seen in ventrodorsal position along the lumbar vertebrae, was not as prominent at the coccygeal and sacral levels where the sinuses were more straighter. The 3rd and 5th minute radiographs showed no traces of the contrast medium and appeared similar to the survey radiographs.

Animal B2: Opacification of the longitudinal vertebral venous sinuses at the lumbar level was absent in the ventrodorsal radiographs taken at the 0 minute and instead faintly opacified veins along the coccygeal level till the lumbosacral junction could be observed. At the coccygeal level, instead of the paired veins only a single faint streak of contrast was visualized indicative of incomplete venous filling (Fig.14). Complete drainage of the contrast and filling of the urinary bladder was observed in the fifth minute radiograph (Fig.15).

Animal B3: Longitudinal vertebral venous sinuses along the coccygeal to the sacral region was clearly opacified after which there was abrupt shunting of the contrast into the venacava via paired intervetebral veins (Fig.16). Vertebral venous sinuses at the lumbar region couldnot be visualized. The arcade pattern of the sinuses at the coccygeal level could be appreciated clearly. The vena cava coursing along the abdomen was also opacified.

Animal B4: The opacification of the venous sinuses along the lumbar vertebrae was observed in the 0 minute lateral radiograph. Considerable elevation of the venous sinus was observed at the lumbosacral intervertebral region and thereafter progressive thinning and attenuation of the sinuses were noticed (Fig.17). The sinuses at the L4 and L5 vertebral level had only half the thickness of that at the L7 vertebral level. The sinus could not be traced anterior to the L4 intervertebral region. Drainage of the contrast into the intervertebral veins and the venacava were also observed.

Animal B5: The longitudinal vertebral venous sinuses were seen opacified, coursing along the coccygeal vertebrae anteriorly to the lumbar vertebrae in the 0 minute lateral radiograph. The paired sinuses were visualized even in the lateral position over the intervertebral spaces. At the level of L6-L7 vertebrae, there was considerable elevation of one of the paired sinus to touch the roof of the spinal column (Fig.18). Venous sinuses, though visible till the L2 vertebral level there was reduced opacification and progressive thinning of the veins anterior to the L6-L7 intervertebral region.

Animal B6: The contrast medium injected from the coccygeal vein straightaway drained in to the caudal vena cava which was opacified along the whole of the radiographic field (Fig.19). Opacification of the longitudinal vertebral sinuses could not be achieved.

Lesions identified

The results are recorded in Table 11.

Animal B1: Abrupt attenuation of the longitudinal vertebral venous sinuses at the lumbosacral region and thereafter abrupt shunting of the contrast into the venacava indicated that the site of lesion was at the lumbosacral region (Fig.13). The neurological examination suggested that the animal was suffering from cauda equina syndrome with compression between the L4-S2 cord segments. But the type of lesion, whether extradural compression or lumbosacral stenosis could not be ascertained.

Animal B2: The site or type of lesion could not be identified as there was failure of filling of the longitudinal venous sinuses (Fig.14 and 15). Failure of filling occurred despite absence of any technical impedance and hence correlation with the results of neurological examination could not be ascertained.

Animal B3: The venous sinuses were opacified till the level of sacrococcygeal junction after which there was abrupt attenuation and shunting of the contrast into the venacava (Fig.16). Though the neurological examination localized the site of lesion at the lumbosacral region, the type of lesion could not be ascertained.

Animal B4: Progressive thinning and attenuation of the contrast medium anterior to the L7 vertebral level was indicative of disc prolapse at this region (Fig.17). This coupled with the breed predispostion and results of the neurological examination, were definitive of intervertebral disc prolapse at the L6-L7 intervertebral region.

Animal B5: Noticeable elevation of the sinuses at the L6-L7 intervertebral level to touch the dorsal roof of the canal indicated that there was extradural compression, most likely intervertebral disc herniation, at this region (Fig.18). This was also positively correlated with the results of the neurological examination.

Animal B6: Due to failure of opacification of the venous sinuses, the site and type of lesion could not be assessed (Fig.19). The neurological examination localized the site of lesion between the L4 and S2 cord segments but it could not be ascertained.

Lesions in venography were identified as abrupt attenuation of the venous sinuses, deviation of the venous sinuses to touch the dorsal roof of the canal and progressive thinning, stenosis of the veins with gradual attenuation of the contrast media.

Thus venograms in three out of six cases were non-diagnostic and hence in these cases the correlation with neurological examination could not be confirmed.

Table 1. History and clinical observations in animals of Group-A and Group-B

(n=12)

Group	Case	Age	Sex	Breed	Type of onset	History and symptoms
A	A1	3yr	F	Doberman Pinscher	Progressive	Difficulty in rising, and running, intermittent in nature seen since two months. Dribbling of urine. At the time of presentation the animal dragged both its hindlimbs during ambulation.
	A2	4m	F	Non-descript	Acute	Dog bite over the lumbar region the day before and unable to walk since then. Swelling at the site of injury.
	A3	6yr	M	Alsatian	Progressive	Intermittent lameness since 4 months. The condition had worsened over the last week and was completely unable to walk. Urination and defecation absent.
	A4	8yr	M	ND	Progressive	Difficulty in running and walking since 2 months, unprovoked yelping while trying to rise, stumbling and falling while running. The condition had worsened since the last five days and the animal was recumbent and could not bear its weight on hindlimbs.
	A5	5yr	F	ND	Acute	Hit by a motor cycle on the same day, unable to walk since then and yelping in pain. Swelling over the midlumbar region and the animal remained in lateral recumbency.
	A6	11yr	M	ND	Acute	Hit by a running vehicle, unable to walk since then. The hindlimbs were in extended position anteriorly as the animal dragged itself with the forelimbs.
B	B1	7m	M	ND	Progressive	Intermittent lameness since one month, dragging and knuckling of the left limb. Condition worsened since last week and is unable to walk.
	B2	5yr	M	ND	Acute	Malicious hurling of stone over the back and the animal was crying in pain and was unable to walk and recumbent, since then.
	B3	6yr	M	ND	Progressive	Difficulty in walking since one month, difficulty in running, the animal walked in slow cautious steps. Condition aggravated since last one week.
	B4	6yr	M	Dachshund	Acute	The animal was playing in the yard when it suddenly started crying in pain and within a few hours it was unable to walk. The animal was presented the next day.
	B5	5yr	M	Dachshund	Acute	Difficulty in walking since one week and recumbent since three days.
	B6	4yr	M	ND	Progressive	Difficulty in walking since 2 months, intermittent in lameness and the condition worsened after running, difficulty in climbing stairs. Condition worsened since last 2 weeks and the animal was paretic.

Table 2. Observations on physiological parameters in animals of Group-A (Mean±S.E) (n=6)

	0 hr	24 hrs
Respiration (/min)	30.33±1.8	30.17±2.1
Temperature (°C)	38.75±0.15	38.88±0.13
Pulse(/min)	80.5±3.15	79.83±5.63

Table 3. Observations on haematological values in animals of Group-A (Mean±S.E) (n=6)

	0 hr	24 hrs
RBC $x10^6$(/cumm)	7.30±0.73	7.18±0.58
WBC x 10^3(/cu.mm)	9.53±0.95	10.17±0.90
Hb (gm %)	14.00±0.58	14.17±0.59
PCV (%)	39.17±1.58	40.00±1.32
Neutrophil (%)	67.83±1.79	70.66±1.85
Band cell (%)	2.16±0.65	1.83±0.83
Lymphocyte(%)	26.33±2.17	25.16±2.40
Monocyte (%)	2.16±0.48	1.80±0.37
Eosinophil (%)	1.50±0.76	1.00±0.51

Table 4. Observations on spinal nerve examination in animals of Group-A (n=6)

Case	Patellar reflex		Gastro-cnemius reflex		Cranial tibial reflex		Pedal reflex		Anal reflex		Panni culus reflex	Superficial pain perception		Deep pain perception		Bladder control	Muscle mass& tone
	L	R	L	R	L	R	L	R	L	R		L	R	L	R		
A1	2	2	1	1	1	1	1	1	2	2	normal	2	2	2	2	Flaccid, incontinence	Atrophy, reduced
A2	3	3	3	3	3	3	2	2	1	1	Till L1	0	0	0	0	Firm, spastic	Normal;
A3	2	2	1	1	1	1	1	1	2	2	Intact	0	0	1	1	Flaccid, incontinence	Atrophy flaccidity
A4	1	1	1	1	0	0	0	0	1	1	Till L4	1	1	0	0	Flaccid, incontinence	Atrophy flaccidity
A5	0	0	0	0	0	0	0	0	0	0	Till T12	0	0	0	0	Flaccid, incontinence	flaccidity
A6	3	3	3	3	3	3	3	3	2	2	Till T12	0	0	0	0	Firm, spastic	spasticity

(0= absent; 1= depressed; 2= normal; 3= exaggerated.)

Table 5. **Quantity of Iohexol (300 mgI/ml) injected for epidurography in animals of Group A (Mean ± SE)**

(n=6)

Case	Body weight (kg)	Quantity of contrast injected (ml)
A1	20	5.3
A2	6	1.6
A3	15	4.0
A4	14	3.7
A5	17	3.5
A6	18	4.8
Average	15.00 ± 2.00	3.81 ± 0.52

Table 6. **Quantity of Iohexol (300 mgI/ml) injected for ascending coccygeal venography in animals of Group B (Mean ± SE)**

(n = 6)

Case	Body weight (kg)	Quantity of contrast injected (ml)
B1	5	1.7
B2	25	8.3
B3	22	7.3
B4	20	6.6
B5	21	7.0
B6	23	7.6
Average	19.33 ± 2.95	6.41 ± 0.97

Table 7. Correlation of radiographic pattern and lesions identified with neurological findings in animals of Group-A studied for epidurography (n= 6)

Case	Radiographic pattern	Lesions identified	Neurological examination and correlation.
A1	Well opacified spinal column. Ventral wavy margins at L6-L7 and L3-L4 inter vertebral regions	Elevations (<25%) judged due to nerve trunks; normal epiduro-graphic pattern obtained and hence presence of a lesion could not be identified.	Localized between L5 and S1 spinal cord segments ; Could not be correlated with epidurography.
A2	Filling defects and poor opacification at the dorsal margin along the L2-L4 level.	Dorsal cord compression due to oedema and haemorrhage at the L2-L4 vertebral level.	Localized between T13 and L3 spinal cord segments; Positively correlated with epidurography.
A3	Narrowing and reduced opacification at the L5-L7 vertebral levels; Column anterior to L5 level well opacified.	Noticeable and abnormal tapering of the column with filling defects indicative that the lesion was along L5-L7 vertebral level but the type of lesion could not be identified.	Localized between L5 and S1 spinal cord segments; Positively correlated with epidurography.
A4	Normal wavy and undulant opacified epidural column along the lumbar and coccygeal level.	No abnormality detected.	Neurological examination revealed lesion at the L4-S2 level but could not be confirmed with epidurography.
A5	Escape of the contrast from the dural column into adjoining areas at the site of vertebral fracture at L6 vertebra.	Acute spinal cord injury, and associated connective tissue damage, loss of spinal integrity at the level of L6	Localized between L4 and S2 spinal cord segments; Positively correlated with epidurography.
A6	Normal opacification of the column till L3 vertebral level. Attenuation of contrast anterior to this level.	Abrupt attenuation and oblique narrowing of the contrast at the level of L3due to the imposing fractured vertebral fragment.	Localized between T13 and L3 spinal cord segments; Positively correlated with epidurography.

Table 8. Observations on physiological parameters in animals of Group-B (Mean±S.E) (n=6)

	0hr	24hrs
Respiration (/min)	25.50±2.53	25.83±0.47
Temperature(°C)	38.75±0.34	38.76±0.11
Pulse(/min)	87.83±3.65	85.83±1.53

Table 9. Observations on haematological values in animals of Group-B (Mean±S.E) (n=6)

	0 hr	24 hrs
RBC x10^6(/cumm)	6.65±0.61	6.55±0.45
WBC x 10^3(/cu.mm)	10.13±0.41	10.27±0.47
Hb (gm %)	14.50±0.58	14.50±0.45
PCV (%)	38.66±1.52	39.16±0.81
Neutrophil (%)	68.00±1.31	69.80±1.35
Band cell (%)	1.50±0.22	1.66±0.21
Lymphocyte(%)	28.50±1.26	26.70±0.95
Monocyte (%)	1.50±0.42	1.66±0.33
Eosinophil (%)	0.66±0.33	0.50±0.34

Table 10. Observations on spinal nerve examination in animals of Group-B (n=6)

Case	Patellar reflex		Gastro-cnemius reflex		Cranial tibial reflex		Pedal reflex		Anal reflex		Panni culus reflex	Superficial pain perception		Deep pain perception		Bladder control	Muscle mass& tone
	L	R	L	R	L	R	L	R	L	R		L	R	L	R		
B1	2	2	1	1	1	1	1	1	2	2	intact	1	1	2	2	Flaccid, incontinence	Atrophy flaccidity
B2	2	2	0	0	0	0	0	0	1	1	intact	0	0	0	0	Flaccid, incontinence	flaccidity
B3	2	2	0	0	0	0	0	0	1	1	intact	1	1	1	1	Flaccid, incontinence	Atrophy flaccidity
B4	3	3	1	1	1	1	1	1	2	2	till L3	0	0	0	0	Flaccid, incontinence	flaccidity
B5	2	2	0	0	0	0	0	0	0	0	till L1	0	0	0	0	Flaccid, incontinence	Atrophy flaccidity
B6	2	2	2	2	1	1	1	1	1	1	intact	1	1	2	2	Flaccid, incontinence	Atrophy flaccidity

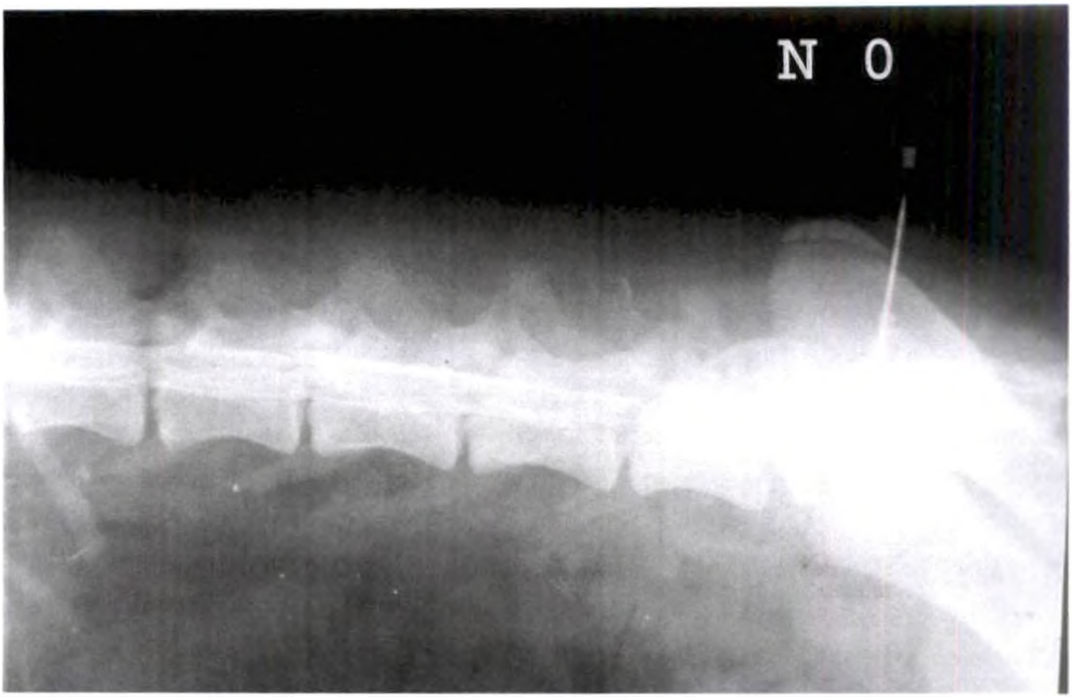
(0= absent; 1= depressed; 2= normal; 3= exaggerated.)

Table 11. Correlation of radiographic pattern and lesions identified with neurological findings in animals of Group-B studied for ascending coccygeal venography. (n= 6)

Case	Radiographic pattern	Lesions identified	Neurological examination and correlation.
B1	Radiographic pattern of the venous sinuses achieved till the lumbosacral region.	Abrupt attenuation of the contrast medium at the lumbosacral junction suggestive of either a compressive mass or stenosis of the vertebral canal at this region.	Lesions were localized between L5 and S2 spinal cord segments on neurological examination and could be confirmed with venography.
B2	Pattern of venous sinuses not achieved. Faint outline of the paravertebral veins observed.	Not identified due to lack of filling of the sinuses.	Lesions were localized between L5 and S2 spinal cord segments on neurological examination but could not be confirmed on venography.
B3	Arcade pattern of the venous sinuses coursing along the vertebrae till the sacrococcygeal junction and there after abrupt shunting into the vena cava observed.	The site and type of lesion couldnot be ascertained.	Lesions were localized between L5 and S2 spinal cord segment on neurological examination, but could not be ascertained on venography.
B4	Arcade pattern of the venous sinuses coursing along the vertebra till the L6 vertebra observed.	Progressive thinning of the veins from the L6 vertebral level and thereafter attenuation of the contrast medium indicative of extradural spinal compression at this level.	Lesions were localized between L4 and S2 spinal cord segment on neurological examination and well confirmed with venography.
B5	Arcade pattern of the venous sinuses coursing along the vertebral floor till the L5 vertebra.	Elevation of the venous sinuses at the L6-L7 intervertebral level to touch the dorsal roof of the canal indicative of extradural spinal compression at this level.	Lesions were localized between L4 and S2 spinal cord segment on neurological examination and well confirmed with venography
B6	Pattern of venous sinuses not achieved.	Not identified due to lack of filling of the sinuses.	Lesions were localized between L4 and S2 spinal cord segment on neurological examination but could not be confirmed with venography.

Fig.1 Skiagram showing opacification of the epidural space denoting the epidurographic pattern in a normal dog at 0 minute

Fig.2 Skiagram of the epidurographic pattern in normal dog at 3rd minute showing the presence of contrast medium throughout the spinal column


N 0

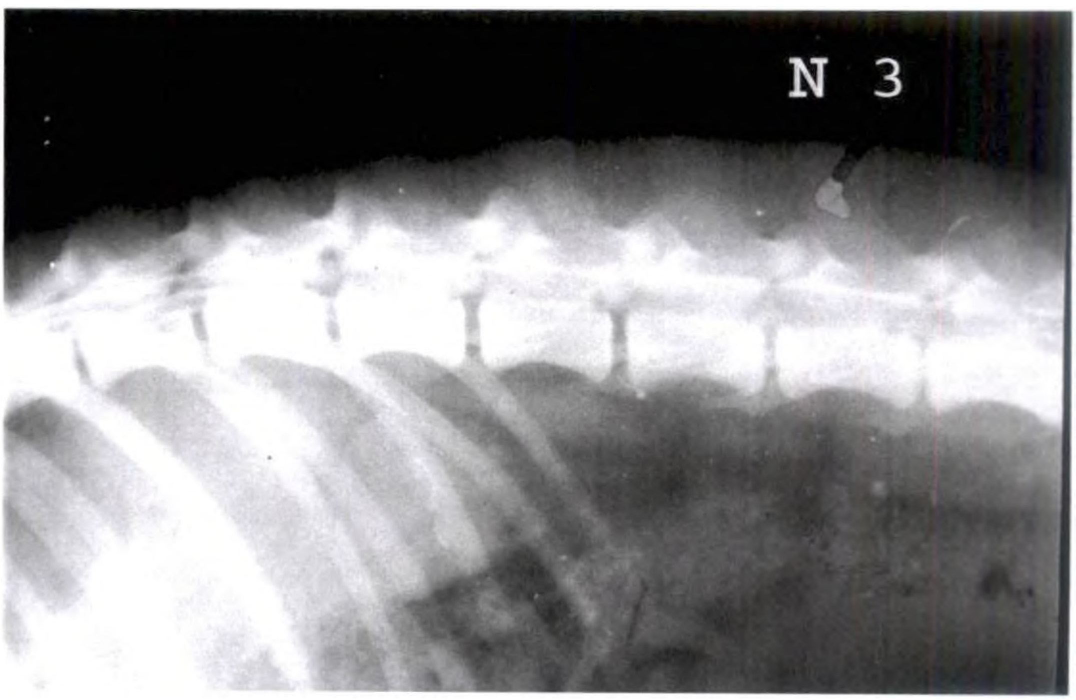
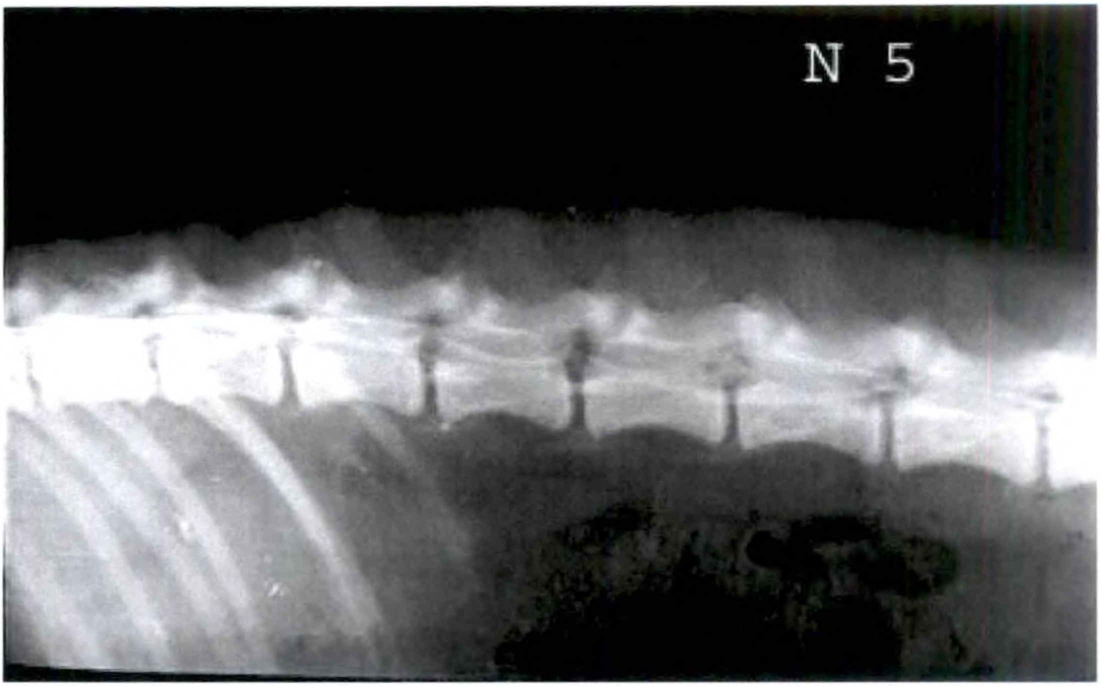

N 3

Fig.3 Skiagram of the epidurographic pattern in normal dog at 5th minute showing reduced contrast density and drainage of the contrast medium into the epidural veins

Fig.4 Skiagram of epidurography (animal A1) at 0 minute showing elevation of the ventral column of the L3-L4 and L5-L6 vertebral interspaces


N 5

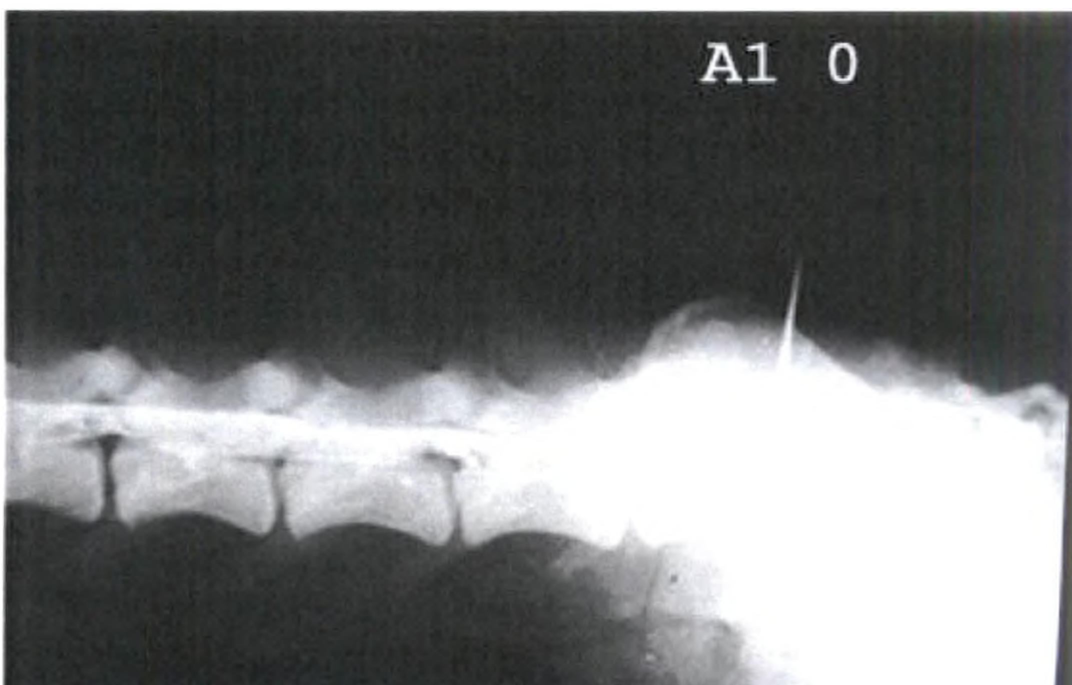
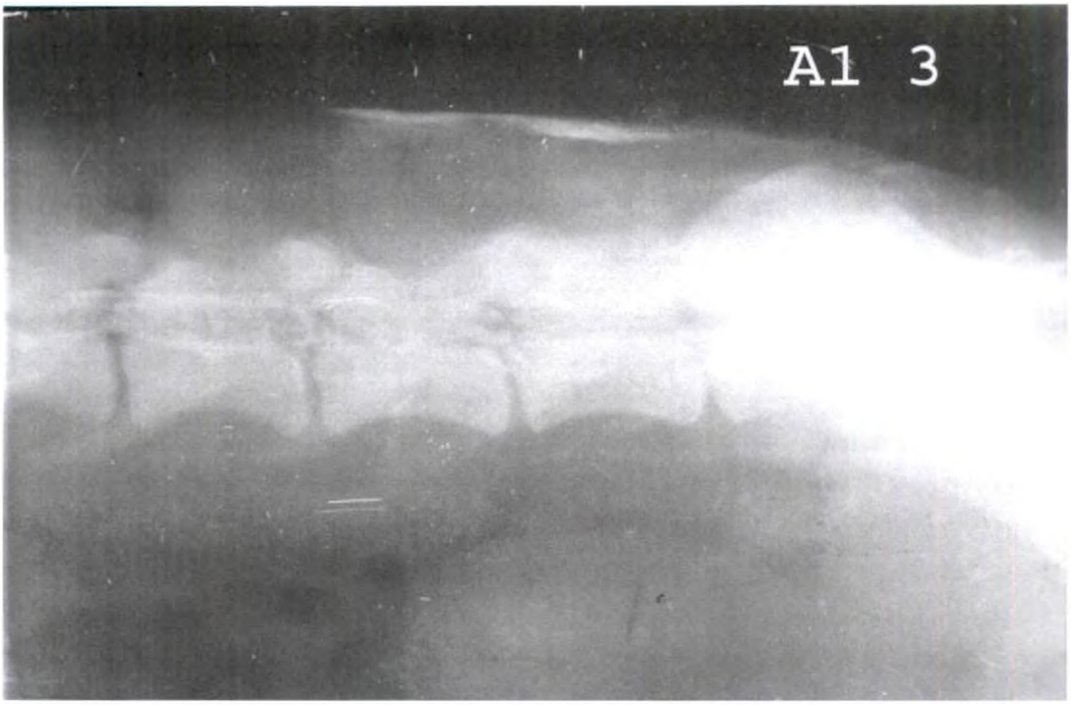

A1 0

Fig.5 Skiagram of epidurography (animal A1) at 3rd minute showing leveling of the ventral column, thus depicting a normal pattern

Fig.6 Skiagram of epidurography (animal A2) at 0 minute showing filling defects at the dorsal border of the column along the L2-L4 vertebrae


A1 3

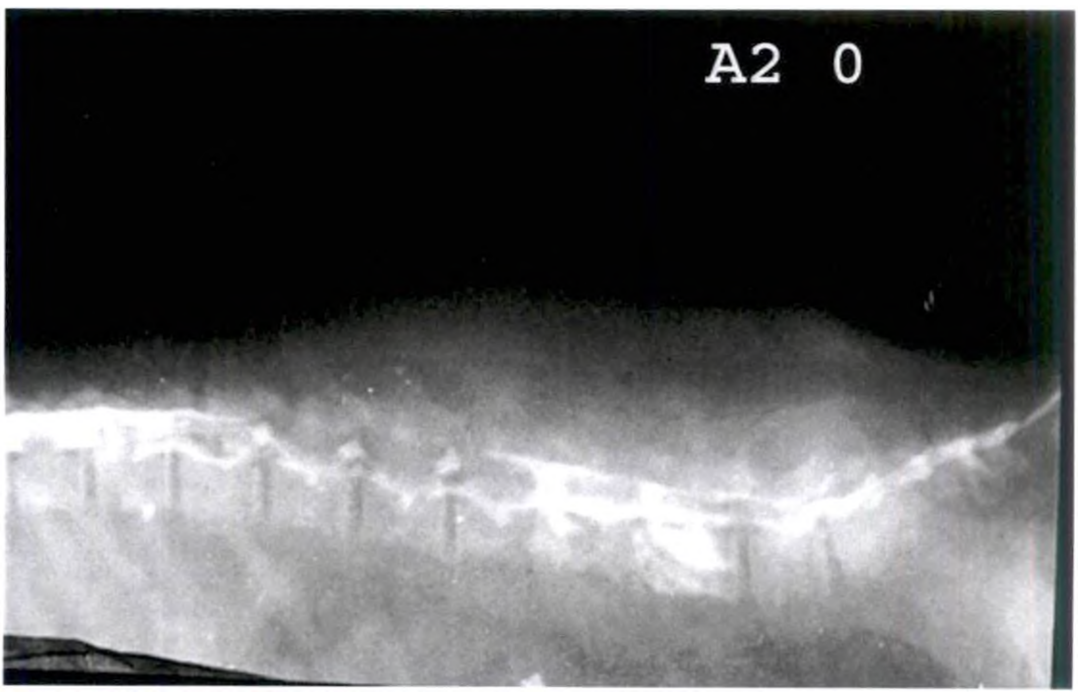
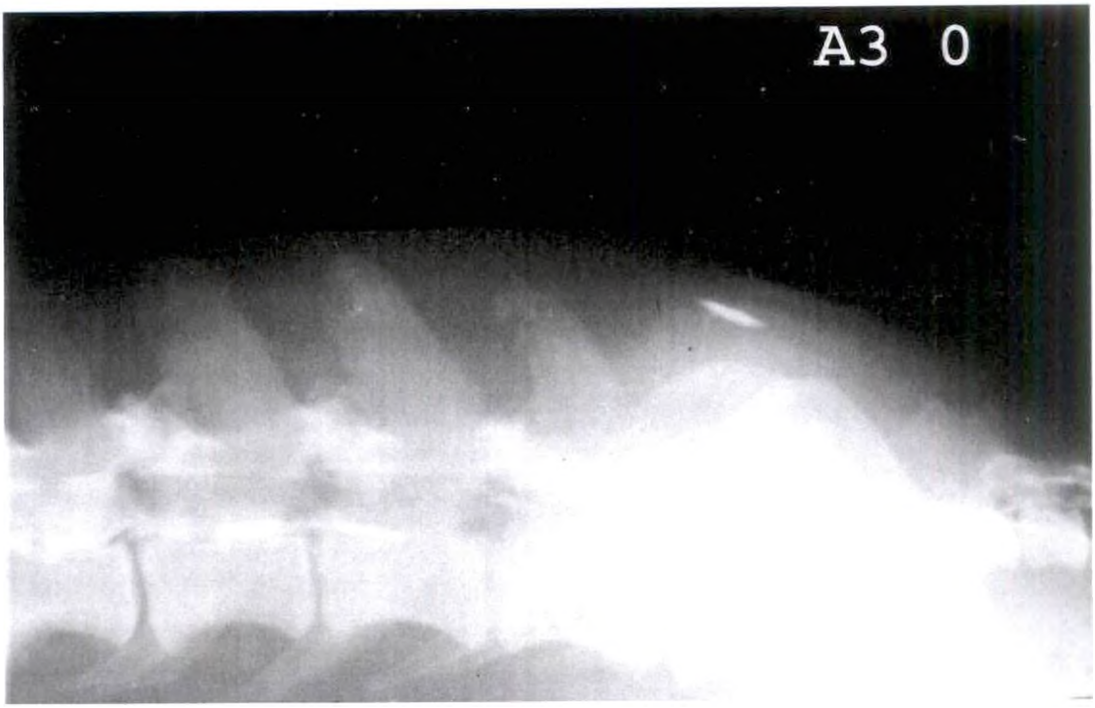

A2 0

Fig.7 Skiagram of epidurography (animal A3) at 0 minute showing elevation and narrowing as well as filling defects of the column at the L5-L7 vertebral level

Fig.8 Skiagram of epidurography (animal A4) at 0 minute showing the normal wavy undulant pattern of the opacification of the epidural space


A3 0

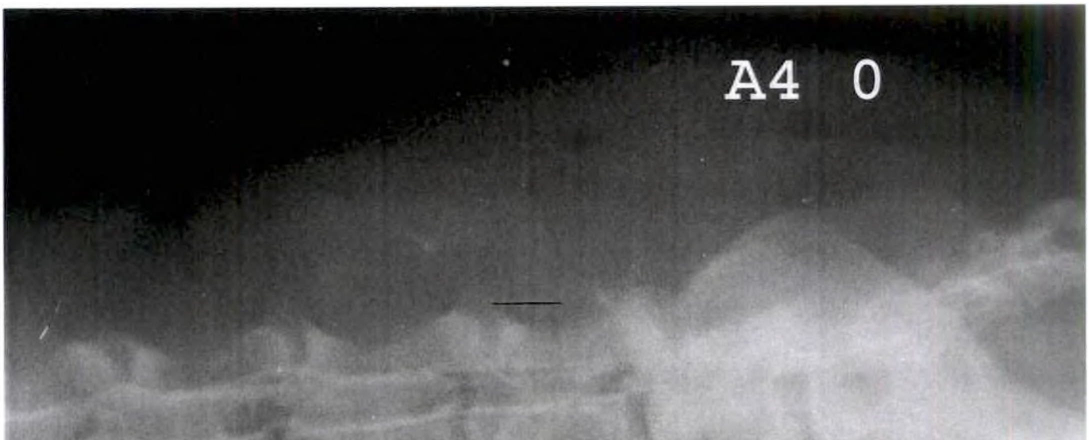
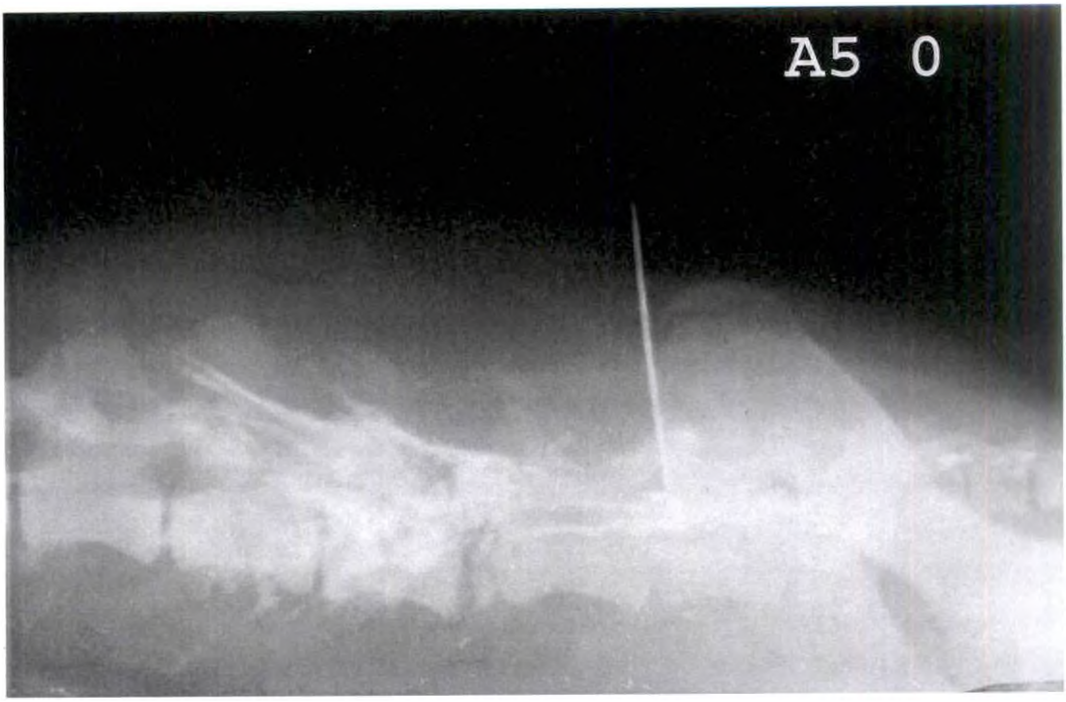

A4 0

Fig.9 Skiagram of epidurography (animal A5) at 0 minute showing fractured L6 vertebra and escape of the contrast medium into the surrounding tissues

Fig.10 Skiagram of epidurography (animal A6) at 0 minute showing fracture of the L2 vertebrae and abrupt attenuation of the contrast medium


A5 0

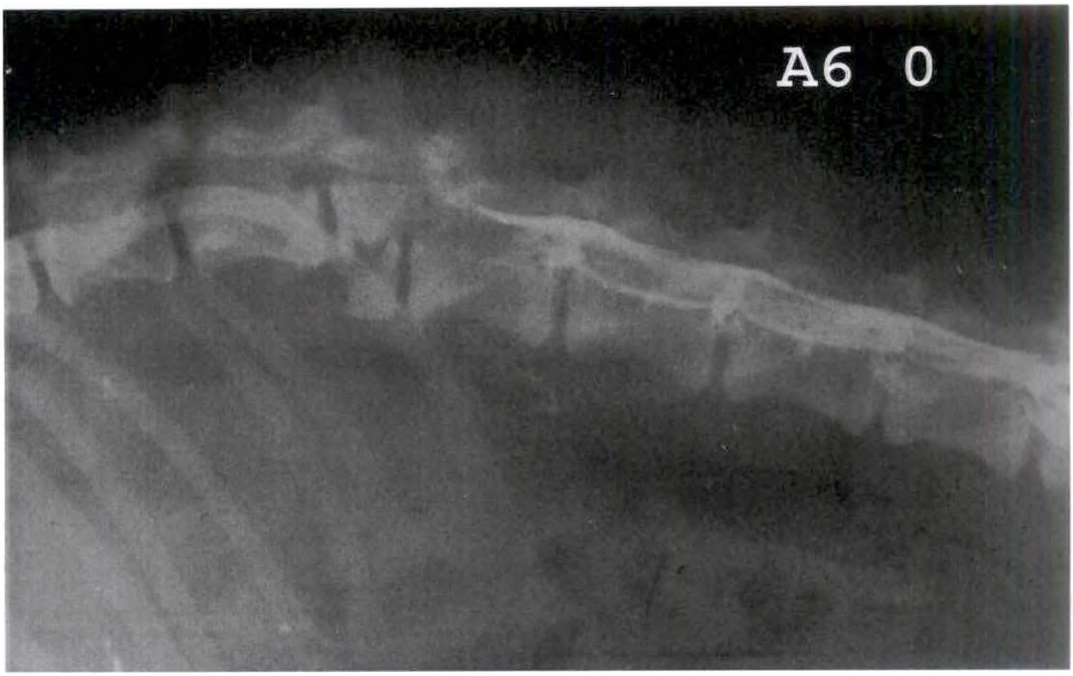

A6 0

Fig.11 Skiagram of venography (normal animal) in ventro-dorsal position at 0 minute showing the arcade pattern of the venous sinuses coursing along the floor of the spinal column

Fig.12 Skiagram of venography (normal animal) in lateral position at 0 minute showing the normal arcade, segmental pattern of the longitudinal vertebral venous sinuses


N O

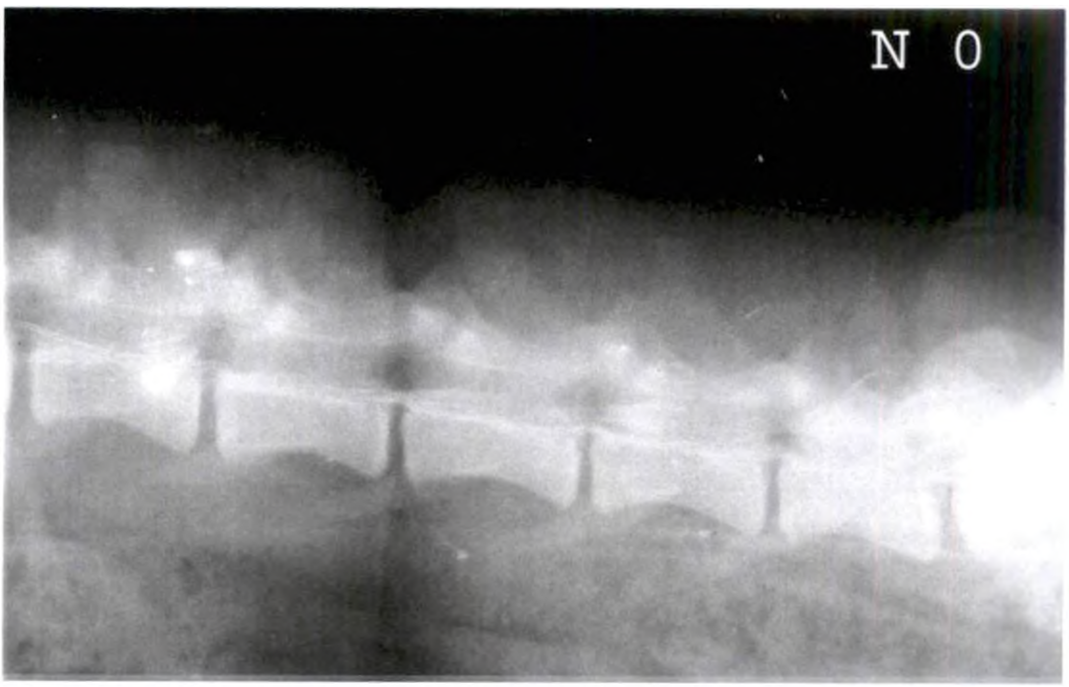
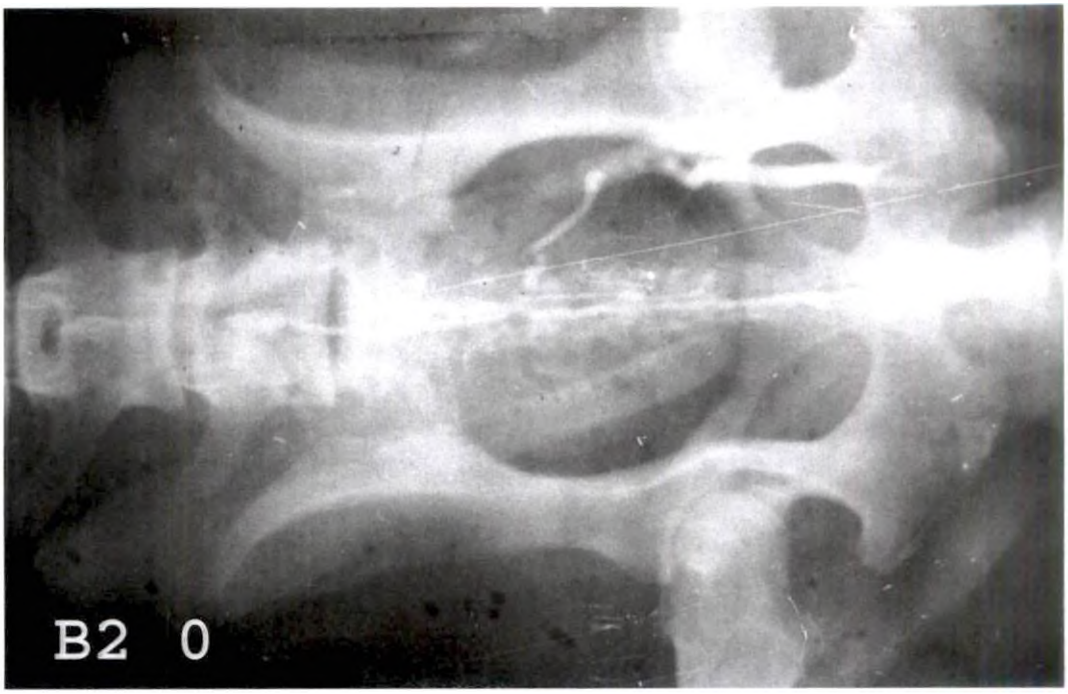

N O

Fig.13 Skiagram of venography (animal B1) in ventro-dorsal position at 0 min showing opacification of the venous sinuses till the lumbosacral region and thereafter abrupt drainage into the venacava


B1
0

Fig.14 Skiagram of venography (animal B2) in ventro-dorsal position at 0 min showing the faintly opacified paravertebral veins

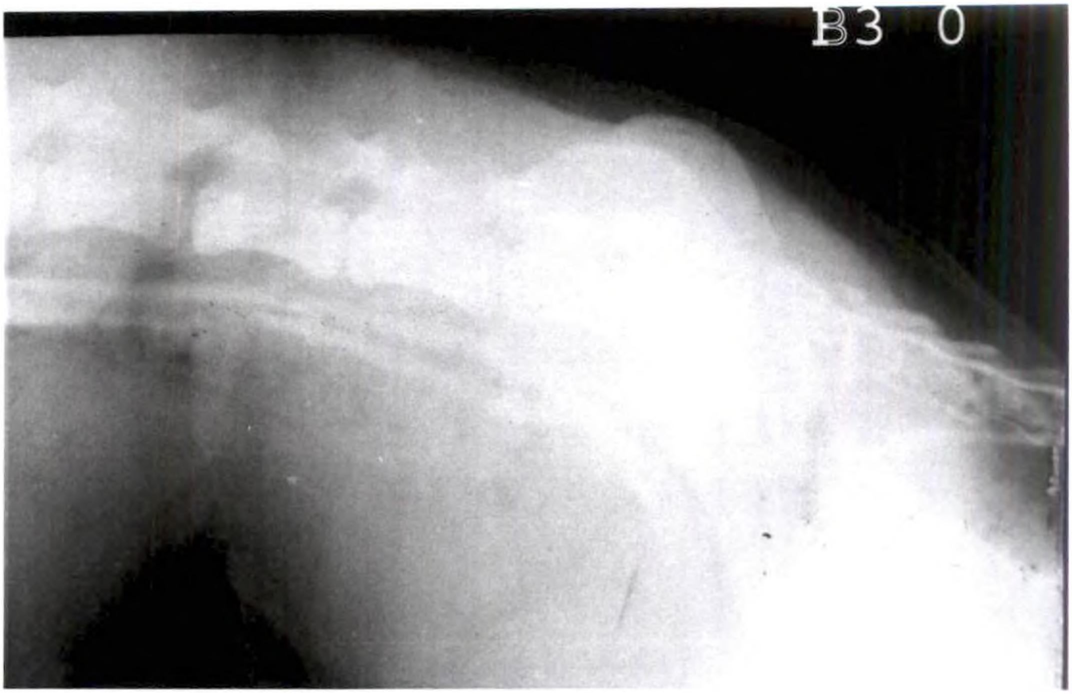
Fig.15. Skiagram of venography (animal B2) in 5[th] minute showing the completely opacified urinary bladder denoting its compete drainage by 5[th] minute


B2 0


B2 5

Fig.16. Skiagram of venography (animal B3) at 0 minute showing opacification of the venous sinuses till the sacrococcygeal junction and thereafter abrupt drainage of the contrast medium into the venacava

Fig.17 Skiagram of venography (animal B4) at 0 minute showing progressive thinning of the sinuses anterior to the level of L6-L7 inter vertebral level


B3 0

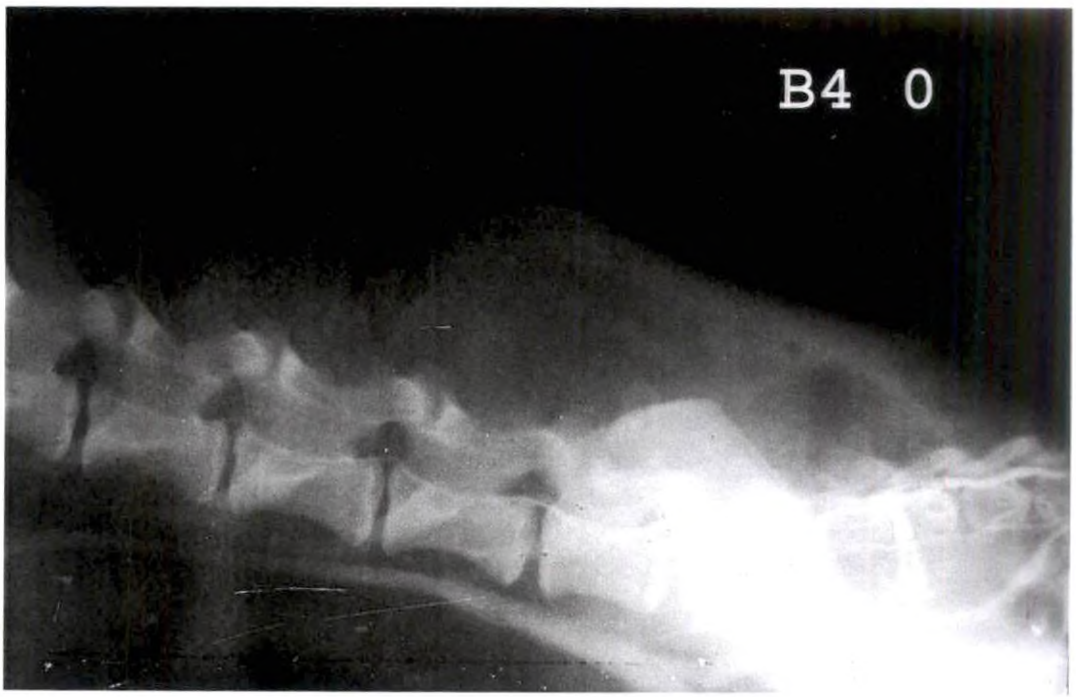
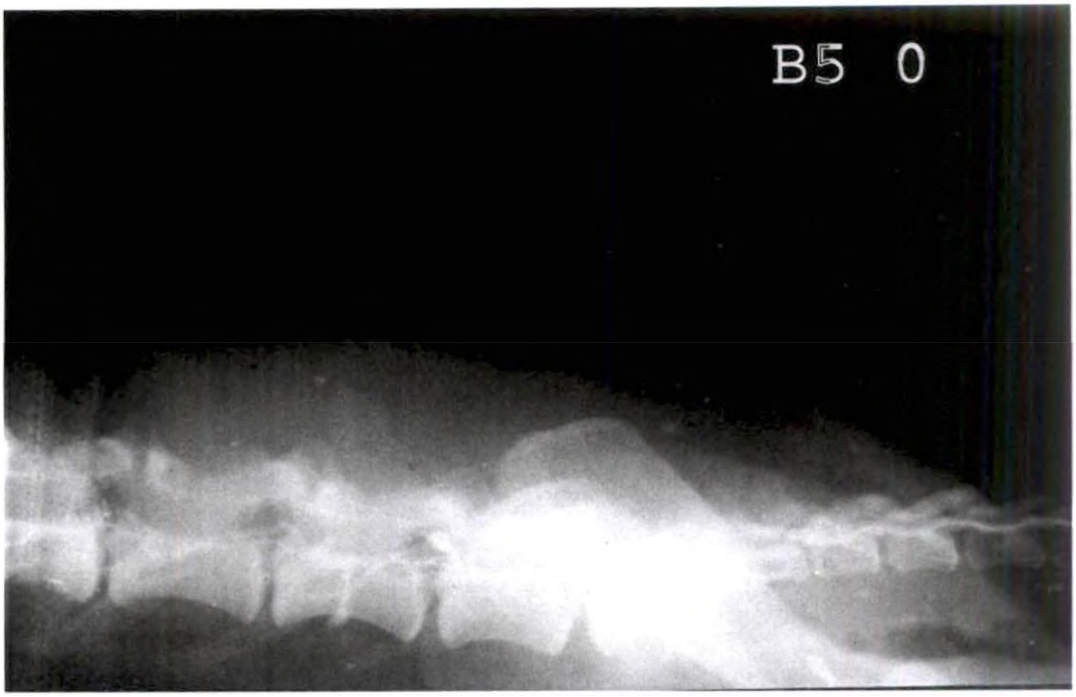
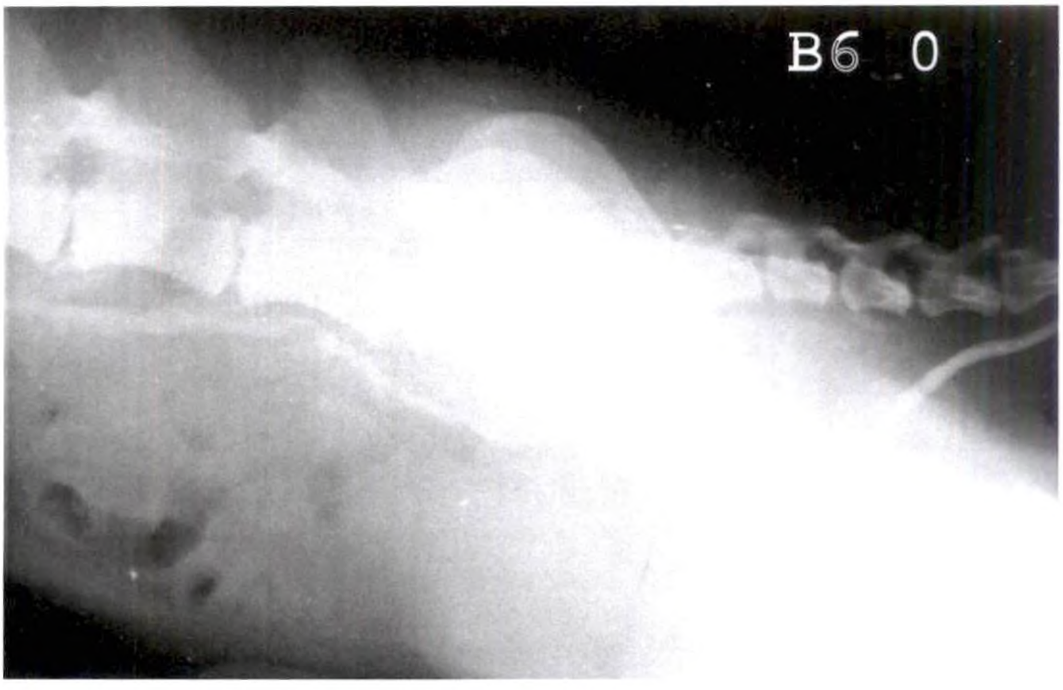

B4 0

Fig.18 Skiagram of venography (animal B5) at 0 minute showing elevation of the venous sinuses at the level of L6-L7 inter vertebral region to touch the roof of the canal and thereafter progressive attenuation of the contrast medium

Fig.19 Skiagram of venography (animal B6) showing absence of failure of opacification of the venous sinuses


B5 0


B6 0

Discussion

DISCUSSION

Radiographic evaluation

Even though various diagnostic procedures are now available, radiography still remains foremost in identifying lesions of the vertebral column, especially those involving the bone. But the soft tissue damage or insult cannot be assessed fully by survey radiography. Contrast radiography remains a valuable procedure for diagnosing lesions of the vertebral column and associated structures. Hence the present study has been undertaken to evaluate the contrast radiographic techniques namely epidurography and ascending coccygeal venography along with physical and neurological examination in diagnosing spinal lesions leading to paraplegia in dogs.

Survey radiography

Survey radiographs taken in all the animals of Group-A showed clear visualization of the lumbosacral area. Abnormalities of bone such as fracture of the vertebrae could be visualized in two cases, A5 and A6. Animal A2 showed soft tissue swelling over the level of L2-L4 vertebrae without any bony changes whereas in animal, A3 a slight malalignment of the floor between L7 vertebrae and sacrum was observed. These changes were indicative of presence of a lesion.

In Group B, abnormalities were not detected in any of the six cases. However the radiographic visualization of the spine including that of the vertebrae, intervertebral spaces at the last lumbar, sacral and coccygeal level were satisfactory.

Observation of both the groups were suggestive that plain radiography was more accurate in diagnosing lesions such as fracture and luxation of vertebrae, however subtle changes due to the soft tissue involvement within the canal were difficult to identify, This is in agreement with the findings of Griffiths (1982), Hathcock *et al.* (1988), Brawner Jr. *et al.* (1990) and Fenner (2000).

It could also be inferred from the plain radiographs of both the groups that, with proper radiographic technique and parameters, the lumbosacral region was well visualized like any other region and the superimposed pelvic structures did not at all pose a problem in studying the lumbosacral area, though observations contrary to this were reported earlier by Hathcock *et al.* (1988) and Lang (1988).

Cases of trauma, fracture and subluxation of vertebrae can be well established and diagnosed in plain radiography as found in this study and thus plain radiography remained a basic procedure before going for any special contrast procedures.

Brawner Jr. *et al.* (1990) had studied in detail the importance of plain radiography in spinal trauma and opined that information from the radiograph should be used in conjunction with information obtained from the neurological examination and other clinical tests to assess the condition of the spinal cord and develop a diagnosis and treatment plan.

Contrast radiography

Contrast medium and dosage

For animals of Group-A, where epidurography was conducted, Iohexol at a dose regimen of 80 mgI/kg body weight was used. Thus an average of 3.81 ± 0.52 ml of 300 mgI/ml contrast solution was used per animal. All the epidurograms obtained were seen with required density of the contrast media and excellent opacification of the spinal column in this study and hence the dose rate of 80 mgI/kg body weight Iohexol was sufficient for epidurography.

Allan and Wood (1988) has given the dose of Iohexol for myelography as 0.25 ml/kg of a 180 mgI/ml solution, i.e., 45 mgI/kg body weight. However Thilagar *et al.* (1994) opined that myelograms with Iohexol at 45 mgI/kg body weight were not of any diagnostic value, where as excellent density and morphology with Iohexol at a dose rate of 75 mgI/kg body weight was recorded for all regions of the spinal column in general, which is in agreement with the present study.

For conducting venography in animals of Group-B, Iohexol was used at dose rate of 100 mgI/kg body weight. On an average 6.41 ± 0.97 ml of contrast medium was used per animal. The opacification and outlines of the veins of these radiographs were satisfactory for identification of the lesion.

All the animals of both the Groups were observed for one week post administration of Iohexol for any adverse effects and complications viz. CNS irritation, seizures, exacerbation of neurological deficits and hyperthermia. Neurological, physiological or toxic side effects were not observed in any of the cases in this study, which were in agreements with the findings of Lewis (1991) and Olby *et al.* (1994). Funquist (1962a&b) described blood pressure changes, hyperreflexia, aggravation of the existing neurological deficits and death as the possible complications from the use of ionic contrast medium. But such complications were not observed with Iohexol in any of the 12 cases. This was in agreement with the reports of Herrtage and Dennis (1987), Allan and Wood (1988) and Widmer (1992).

Duration of administration

In all the six cases of epidurography, the contrast medium was injected as a slow infusion into the epidural space over a period of 20-30 seconds. The epidural space being not so uniform and being filled with fat, as reported by Ramirez and Thrall (1998), the flow of a viscous solution especially Iohexol, required gradual pressure of the contrast medium into the space to avoid pooling and achieve complete filling of the epidural space. The radiographs so obtained, in terms of the contrast medium flow along the column, were complete and satisfactory in all respects. The whole lumbar vertebral canal was opacified sufficiently in all the six cases. Thus the injection provided as a slow infusion resulted in complete perfusion of the epidural space. These observations were in par with that made by Feeny and Wise (1981) and Hathcock *et al.* (1988) who reported good quality epidurograms by the use of slow injection for introducing the contrast medium and exposure taken as the last millilitre of contrast medium remained to be given.

In animals of Group-B for venography, the contrast medium was injected as slow infusion.

For venography, tight abdominal compression was brought about in all the animals prior to injecting the contrast medium. If the caudal venacava was occluded or compressed, blood would shunt into the vertebral venous sinuses and azygos vein. Injecting contrast medium into a peripheral vein or into a vertebral body when the caudal venacava is compressed, would therefore result in opacification of the venous sinuses (Lang, 1988; Ramirez and Thrall, 1998).

Time sequence

Series of radiographs were taken at 0, 3rd and 5th minute in all the animals for both the procedures. In Group A, it was observed that 0 and 3rd minute radiographs were most useful in identifying the lesions. In the 5th minute radiograph, there was blurring of the margins as well as migration of the contrast medium. The 5th minute radiograph had poor contrast and was not satisfactory for diagnosing the lesion. Radiographs taken at the 3rd minute contained the same information as that of the 0 minute, but it aided the 0 minute radiograph in diagnosing the lesions. In cases where complete perfusion of the contrast medium were not achieved in the 0 minute radiograph, either due to the presence of epidural fat or pooling, the 3rd minute radiograph aided in identifying whether the defect was due to a lesion or was a normal one due to incomplete perfusion.

For the six cases of venography in Group-B, the radiographs taken at the 0 minute was most useful. The radiograph was taken during the slow infusion, as the last milliliter of the contrast medium remained to be injected (Blevins, 1980; Ramirez and Thrall, 1998). In the 3rd and the 5th minute the contrast medium was not visible, as it had been drained away by the vein either through the venacava or the azygos vein into the heart. (Worthman, 1956). Hence in venography the 3rd and 5th minute radiographs were not of diagnostic value.

All the radiographs for both the procedures were taken either as ventrodorsal or right lateral position. It was observed that the right lateral was easy to perform at 0 minute in that it did not interfere with the conduct of the procedure and was easy to interpret. The symmetry of a ventrodorsal radiograph also affected the interpretation and also more opacification was needed to differentiate the column from the bony background. Feeny and Wise (1981) observed similar findings and reported that the sequence of a recumbent right lateral radiograph followed by a ventrodorsal radiographic projection as most useful in epidurography. Similar results were also reported by Hathcock *et al.* (1988).

Radiographic pattern

The contrast radiographic procedures - epidurography and venography were conducted in one normal dog and in six clinical cases of posterior paralysis each and the contrast radiographic pattern of the vertebral column has been assessed in detail.

In the normal animal for epidurography, the spinal column was completely opacified, defining the course of the spinal cord upto the limit of migration of the contrast medium. The contrast medium filled the epidural space defining the dorsal and the ventral column of the column of the vertebral canal which gradually narrowed from the cranial part of L7 to the caudal part of S1 and the narrowing continued along the level of the coccygeal vertebrae. The spinal column appeared uniformly wavy at the margins owing to the presence of epidural fat and a slight elevation at the ventral margin of the intervertebral space was noticed due to the presence of nerve trunks leaving that area.

Similar reports for normal epidurograms were described by Hathcock *et al.* (1988) who further stated that the longitudinal outline of the epidural column on a lateral radiograph was more revealing than the ventrodorsal radiograph where the bony structures appeared to camouflage the contrast outline. Feeny and Wise, (1981) and Ramirez and Thrall, (1998) opined that in ventrodorsal radiographs, the contrast medium column had a tubular shape, but less caudal tapering was seen than on the lateral radiograph. The columns of both radiographic projection had linear filling defects representing lumbar and sacral nerve roots as well as there was tendency of migration of the contrast medium to follow the nerve roots through the intervertebral foramen. The authors further stated that irrespective of position in the radiographic sequence, no definitive change in the size or shape or any other additional information could be obtained.

In the individual case study of animals of Group A, epidural opacification was achieved in all the six cases. Except for animals with vertebral fractures viz. A5 and A6 where the contrast medium was attenuated at the site of the lesion, epidurograms in all other cases had a uniformly undulating, wavy, tubular pattern with caudal tapering from the L7 vertebrae posteriorly. Feeny and Wise (1981) reported that the wavy pattern was presumably due to the slight elevation of the column (less than 25% of the canal diameter) at the intervertebral region, where the nerve trunks came out of the vertebral column.

Another feature of the radiographic pattern observed in all the six cases in Group-A was that there were differences in the density of the contrast medium within the density of upper and lower margins of the column and the core, in lateral radiographs. This could be due to the presence of epidural fat and hence filling defects and non-uniform perfusion of the contrast occurred in the epidural space. Similar findings were also reported by Feeny and Wise (1981).

In two cases viz., A1 and A4, the epidurograms revealed a completely normal radiographic pattern where as deviation from the normal pattern was observed in A2, A3, A5 and A6. The deviations observed from normal pattern were failure of opacification of the dorsal margins of the column along the L2-L4 vertebral levels as in animal A2, failure of opacification and considerable narrowing and elevation of the column at L5-L7 levels in animal A3, and attenuation of the contrast at the site of fracture in animals, A5 and A6.

Hathcock *et al.* (1988), Barthez *et al.* (1994) and Ramirez and Thrall (1998) reported that such changes from normal pattern were significant for detection of presence of a lesion

For venography, the radiographic pattern of the vertebral venous sinuses were studied in a normal animal. The opacification of the longitudinal vertebral sinuses coursing along the vertebral floor observed were paired and characterized by their segmentally arranged arcs, the right and left convexities that approached each other in the middle of each vertebral segment.

Similar findings were reported by Worthman, (1956 a&b) and Parker, (1974) who further reported that the curvature of these arcades was greatest in the lumbar and sacral regions and least arched in the coccygeal and anterior half of the thoracic region. At the level of the fifth lumbar segment, a marked reduction in the caliber of the sinuses was noticed, which was progressive from one segment to the next. At the level of sixth coccygeal segments, they were reduced to two fine threads like after which they could no longer be traced.

In individual case study in Group B, opacification of the longitudinal vertebral venous sinuses could be achieved only in three cases viz., B1, B4 and B5. The venous sinuses were seen in paired wavy pattern coursing along the floor of the spinal column till the site of lesion, after which there was abrupt or progressive attenuation of the contrast medium. The expected radiographic pattern could not be obtained in the remaining three cases, viz. B2, B3 and B6. Inconsistency of filling of the venous sinuses and abrupt shunting of the contrast into the venacava were the main drawbacks seen in these cases. Opacification of the paravertebral veins, complete escape of the contrast medium into the venacava and very faint and vague opacification of the sinuses were the other distinct pattern that outlined the inconsistency of this technique.

Based on the study of the radiographic pattern, radiographs of case B2, B3 and B6 were termed as nondiagnostic.

In the cases B1, B4 and B5, where opacification of the veins were achieved, the deviations from the normal pattern were observed in the form of abrupt attenuation of the veins and shunting into the vena cava, progressive thinning and attenuation of the contrast and elevation of the venous sinuses to touch the roof of the canal and there after attenuation of the contrast respectively. Blevins (1980), Lang (1988), Hathcock *et al.* (1988) and Ramirez and Thrall

(1998) observed that such deviations from the normal pattern were significant for presence of lesions.

Hathcock *et al.* (1988) reported that in good quality radiographs, the contrast medium filled the caudal lumbar and sacral venous sinuses whereas in poor quality radiographs there was faint or no visualization of the venous sinuses in this region.

Clinical evaluation

History

Of the twelve cases of posterior paralysis studied, the age groups ranged from four months to 11 years with the maximum number of cases in the 4-6 years range.

Though various authors have studied different causes of paraplegia, there was no disparity regarding the age range of occurrence, as seen with this study.

Thilagar (1993) in a study on disc protrusion in dogs stated that the maximum number of affected animals were in the 4-7 years range. Yovich *et al.* (1994) in study on thoracolumbar disc protrusion in dogs found that the age of occurrence ranged from 1-11 years with the maximum in the 5-7 year range. Shell (1996c) opined that Type II disc protrusions tend to occur in middle aged to older large breeds of non-chondrodystrophoid breeds. Ramirez and Thrall (1998) stated that cauda equina syndrome has been reported to occur between the ages of 3-9 years. McKee (2000) stated that disc disease was uncommon in dogs under two years of age.

Of the twelve cases suffering from paraplegia, eight animals were non-descript, two were Dachshund, one German Shepherd and Doberman Pinscher each. Literature revealed that breed disposition to posterior paralysis varied according to the cause. Hoerlein (1978b), Yovich *et al.* (1994) and Shell (1996b) in studies on type-I disc protrusion stated that Dachshund and other members of the chondrodystrophoid breeds were more prone to acute Type-I intervertebral disc herniation. Tarvin and Prata (1980) and Ramirez and Thrall (1998) stated that paraplegia due to cauda equina syndrome were more common in larger nonchondrodystrophoid breeds of dogs. Shell (1996c) stated that Type-II intervertebral disc herniations occurred in middle aged to older, large breed nonchondrodystrophoid breeds, whereas McKee (2000) was of the opinion that any breed could be affected with degenerative disc disease.

The samples of this study being fewer, and the representation of non-descript animals being more (8/12), it could be inferred that non-descript breeds are also equally prone and affected with posterior paralysis.

Of the 12 cases, nine animals were males and three were females. Similar findings were recorded by Ramiraz and Thrall (1998).

Six animals showed an acute onset of paralysis while the remaining six showed progressive onset of paralysis. In the animals with progressive onset, the owners could not recall any specific incident or time from which the animal showed paralysis. Of the six animals with acute onset, four animals had a history of traumatic injury on the lumbar region.

The general history obtained from all the cases of progressive case of paralysis were in-coordination and difficulty in walking over long periods of time, reluctance to rise or jump in the initial stages, intermittent nature of ataxia in some cases, and knuckling and dragging of the hind limbs.

These observations were similar to the findings of Tarvin and Prata (1980), Denny *et al.* (1982) and Shell (1996c).

Acute onset of paraplegia has been observed in Type I intervertebral disc prolapse commonly in chondrodystrophoid breeds (Hoerlein, 1978b) and cases of traumatic injury, which included vertebral fractures, hit by motor vehicles and heavy falling objects, gunshot injuries, kicking and bite wounds which caused rapid deformation of the cord. The vascular damage and severity of traumatic injury was found to be directly proportional to the speed and degree of deformation as well as the duration (Braund *et al.* 1990; and (Shell, 1996b)

General clinical examination

All the animals presented were alert and reacted normally to visual, auditory and the tactile stimuli.

Four animals had a history of traumatic injury on the back. The onset of paralysis was immediate in these cases. Clinical signs of four cases of trauma was manifested as immediate onset of paralysis, swelling and oedema at site of trauma, pain on palpation, tense abdomen, absent micturition and defecation.

From the observations on these cases, it could be inferred that trauma often initiated acute onset of paraplegia. Shell (1996a) stated that trauma to the spinal cord occurred most frequently when dogs were hit by motorized vehicles, heavy falling objects, gunshot injuries, kicking and bite wounds, vertebral fractures or luxations/subluxations or traumatic disc extrusions which caused rapid deformation of the cord and vascular damage.

The reason for acute onset of paraplegia during trauma has been described by Braund *et al.* (1990). They reported that trauma to the spinal cord caused direct morphological distortion of the neuronal tissue resulting in ischaemia, cord inflammation and biomechanical and metabolic abnormalities, thus causing acute onset of paralysis

Six animals showed signs similar to that of cauda equina syndrome. Lameness, impairment of bladder function, reluctance to rise, unwillingness to jump or climb stairs, faecal incontinence, unilateral or bilateral paralysis were the main clinical signs observed. And they were in agreement to the findings of Ramirez and Thrall (1998). The paresis was intermittent and exacerbated after exercise or running. Licking and mutilation of tail was evident in one case. Tail paresis and severe muscular dystrophy was observed in all the cases. All the animals evinced pain on palpation of the lumbosacral area. In all the cases, exercise and running aggravated the condition.

The remaining two animals showed an acute onset of paralysis without any remarkable cause or incident and were suspected for extradural spinal compression due to intervertebral disc prolapse. Clinical signs were manifested as non-ambulatory paraplegia, flaccidity of the hindlimbs, pain on manipulation of the lumbar region, urinary incontinence and limp tail. Keeping in view that both the animals were Dachshund, and with the history of acute onset along with clinical signs of lower motor neuron signs exhibited, Type-I intervertebral disc herniation was suspected (Hoerlein,1978b; Griffiths,1982; Shell,1996b).

Physiological parameters

In animals of both groups the values of respiration, temperature and pulse taken just before radiography were within the normal limits and the same parameters recorded after 24 hours did not show any statistically significant difference.

This indicated that the administration of Iohexol in both the epidurography and venography did not create any undue effect on the physiological parameters.

Neurological examination

All the animals in both the groups presented were alert in mentation.

Animals in both the groups were non ambulatory and could not stand or bear weight on hindlimbs. None of the six animals of either Group A or B revealed any cranial nerve deficits or brain reactions and had normal postural reactions for both the forelimbs.

Based on the above observations, lesions in brain were ruled out in both the groups and the site of lesion was localized below the level of the foramen magnum. Shell (1996a) stated that in the absence of any general syndromes of brain due to cranial lesion viz. pontomedullary syndrome, cerebellar syndrome, vestibular syndrome, midbrain syndrome, hypothalamic syndrome and cerebral syndrome, the lesions could be ruled out from the brain.

The spinal reflexes for both the forelimbs in all the animals of both the groups were normal and there was full weight bearing as well as normal voluntary activity. This as well as presence of normal wheel barrowing reactions ruled out lesion upto the brachial plexus in the cervicothoracic spinal cord. The lesions were thus localized in all the animals posterior to the brachial plexus i.e. posterior to the T3 spinal segments. This was in agreement with the reports of Braund *et al.* (1990), Braund (1995) and Shell (1996a).

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Before analyzing the individual spinal reflexes for locating the lesions, the reflexes were classified into Upper motor neuron (UMN) or Lower motor neuron (LMN) type.

In Group A, two animals viz. A2 and A6 showed a UMN disease while the remaining animals of this group showed a LMN type of spinal lesion. In Group B, all the six animals showed signs of LMN disease.

The UMN signs were elicited as exaggerated spinal reflexes and increased muscle tone of the limbs with paresis/paralysis. The LMN signs were elicited as decreased or absent spinal reflexes with paraplegia. (Braund *et. al.*, 1990). The basic features governing the UMN and LMN were described by Oliver Jr. (1978), Griffiths (1982) and Shores and Braund (1993), who stated that the upper motor neurons and their axons have an inhibitory influence on the lower motor neurons that maintain normal muscle tone and spinal reflexes. Hence when the upper motor neurons or their axons were injured, the spinal reflexes were not controlled, and became exaggerated and hyperreflexic.

Based on the type of lesion (UMN/LMN), the symptoms were broadly classified into two categories i.e. Thoracolumbar and Lumbosacral syndrome. Thoracolumbar syndrome was exhibited as UMN lesion of the hindlimbs with normal forelimb functions and it denoted an injury between the T3 and L3 spinal cord segments. Lumbosacral syndrome was seen as LMN lesions of the hindlimbs with normal forelimb functions and it indicated an injury between the

L4 and S2 cord segments. The localization of the lesions so made were in agreement with the reports of Braund *et al.*, (1990), Braund (1995) and Shell, (1996a).

Thus in Group A, lesions were localised between L4 and S2 cord segments in four animals and between T3 and L3 cord segments in two animals. In Group B as per the spinal reflexes, all the animals showed lumbosacral syndrome and lesions were localized between L4 and S2 cord segments.

Haematological parameters

Blood samples were taken just before and 24 hours after the radiographic technique to evaluate whether administration of Iohexol elicited any haematological changes in canines.

In animals of Group A and B, the mean values of total erythrocyte count, total leucocyte count, haemoglobin concentration, packed cell volume and differential leucocyte count of the blood samples taken just before and 24 hours after the radiographic technique were with in the normal range. Fenner (2000) stated that in majority of patients with nervous system diseases, there were minimal hematological changes except for certain conditions like encephalitis and systemic diseases that secondarily affect the nervous system. Shell (1996d) undertook complete blood count, serum chemistry and urinalysis in six cases of paraparesis and found them within the normal range.

In the present study, the initial hematological values in animals suffering from paraplegia were within the normal limits and the values obtained at 24 hours after administration of Iohexol showed marginal increase of total leucocytes as well as neutrophils in differential leukocyte count. The changes were not significant. Hence Iohexol did not appear to make any hematological or systemic reactions with the dose rate adopted in the present study.

Diagnostic relevance

All the epidurograms obtained in Group A were good quality ones, of which epidurograms of four cases were diagnostic.

The animal A5 showed complete middle and ventral compartment transverse fracture of the anterior plate of the L6 vertebral body. Luxation of the L5 vertebral body along with complete tearing of the annulus of the intervetebral disc was also suspected (Brawner Jr. *et al.*, 1990). On epidurography there was complete attenuation of the contrast media at the fracture site and total escape of the contrast medium outside the vertebra into the perivertebral areas. Subsequent third and fifth minute radiograph showed further migration of the contrast, thus indicating complete obstruction of the spinal column and acute spinal cord compression and paraplegia. Loss of spinal integrity including rupture and tearing of the dorsal longitudinal ligament and associated intervertebral ligaments and also possible trauma to the cord was implicated as evidenced by the extravassation of the contrast medium due to exposing of the dural space (Brawner Jr. *et al.*, 1990).

In case A6 with a history of high velocity trauma, plain radiograph revealed complete, transverse, overriding fracture of the middle and ventral compartments of L2 vertebra. The neurological changes were well correlated with the lesion observed during plain radiography. Epidurography was conducted in lateral position; complete oblique and abrupt attenuation of the contrast at the L3 vertebral level and the attenuation was observed slightly caudal to the fracture site, which was indicative of cord oedema and hemorrhage at the site of lesion. (Braund *et al.*, 1990). There was no progress of the contrast anteriorly even in the 3rd and the 5th minute radiograph.

In the 3rd case of trauma, A2, with a history of dog bite over the lumbar region, plain radiography could not reveal any fracture or affection to the bone other than increased soft tissue density swelling over the mid-lumbar region and adjoining regions. The neurological changes observed were that of upper motor neuron signs and the epidurography revealed filling defects of the contrast on the dorsal border of the spinal column along the L1, L2, L3 vertebral bodies. The ventral region of the spinal column of these segments as well as other adjoining regions of the spinal column were well opacified and this indicated slight compression of the dorsal column at the site of lesion which could be due to oedema or hemorrhage within the dural space as a result of trauma. Brawner Jr. *et al.* (1990) stated that an attenuation of the contrast medium over the dorsal border without a vertebral fracture in a case of trauma indicated neural compression due to hemorrhage or oedema.

In animal A3, the clinical and neurological examination suggested the presence of cauda equina syndrome, and epidurography revealed noticeable and prominent elevation and narrowing of the spinal column along the L6, L7 and lumbosacral spinal column. A clear filling defect was observed in these areas, however the filling was complete both anterior to the lumbosacral vertebral level as well as posteriorly, along the sacrum and coccygeal vertebrae. The elevation and narrowing of the contrast medium at the L6-L7 region with clear filling defects might be due to the presence of narrowing and stenosis of lumbosacral canal, most probably due to the narrowing and hypertrophy of the associated ligaments within the canal or due to the presence of a mass lesion. Similar conclusions were drawn by Tarvin and Prata, (1980), Hathcock *et al.* (1988) and Ramirez and Thrall (1988).

The changes that denoted the presence of a lesion in epidurography included signs of narrowing, elevation, deviation or obstruction of the epidural contrast medium (Barthez *et al.*, 1994). Elevation of the ventral column and narrowing of the canal by more than 50% was consistent with significant neural compression (Ramirez and Thrall, 1988).

Two cases, A1 and A4 with signs of the cauda equina syndrome, revealed normal epidurograms. From this it can be deduced that epidurograms may produce false negative results and that this procedure was unable to detect subtle changes and defects and compressive changes associated with the compression of cauda equina syndrome at the lumbosacral region. The changes accompanying such lesions were often difficult to identify from the irregular filling of the contrast due to the presence of epidural fat and nerve trunks.

In this study, of the four out of six cases of epidurography, the site and type of lesions could be identified and correlated with the neurological and clinical signs and history. This is also indicative that epidurography is not an ultimate procedure in detecting spinal lesions and may be supported by symptoms, neurological examination and other diagnostic aids.

From the results obtained from this study, it might be concluded that epidurography was a easier technique, less stressful to the patient and had the greater probability to detect an abnormality, but was not always easy to interpret and hence could not be advocated as a sole diagnostic procedure.

Of the six cases studied for venography, diagnostic quality radiographs were obtained in three cases (B1, B4 and B5). Two of these cases (B4 and B5), were diagnostic of extradural compression suspected of disc prolapse. The neurological examination localized the sites in both the cases in between L4-S2 cord segments. Position and appearance of the vertebral venous sinuses were then used to assess the presence of space occupying lesions in the vertebral canal as reported by Hathcock *et al.*(1988).

Lesions were identified as progressive thinning of the veins and gradual attenuation of the contrast media anterior to the L7 vertebral level in B4 and deviation of the venous sinus at the L6- L7 interspace to touch the dorsal roof of the canal in case B5. The gradual attenuation in case B4 could be accredited to cord oedema at the L6-L7 intervertebral region.

Hathcock *et al.* (1988) stated that because of the close association between the venous sinus and the dorsal surface of each vertebral body, compressive lesions of the spinal cord or vertebral canal are highly likely to cause compression of the vertebral sinus. Blevins (1980) stated that if a herniated intervertebral disc was present, a vertebral sinus filling was absent in the area of spinal cord compression. The venous sinuses are extremely thin walled and collapsed and therefore a mass lesion or stenosis of the spinal cord with or with out vertebra sub-luxation would cause an obstruction to contrast medium flow in the sinuses, narrowing of the sinuses or deviation of the sinuses. Lang, (1988) has described three types of venous changes for identifying lesions in venography viz. stenosis of blood vessels, dorsal dislocation of venous sinuses and total obstruction of the contrast medium flow.

In animal B1, with cauda equina syndrome, the venous sinuses along the sacrum and lumbosacral space were clearly visible, after which there was abrupt shunting of the contrast medium into the vena cava. This was diagnostic for the presence of a lesion at the lumbosacral junction, most likely a compressive lesion or stenosis of the lumbosacral vertebral canal. Ramirez and Thrall (1998) has stated that abrupt ending of contrast medium at the lumbosacral junction suggests the presence of a lesion.

There was a positive correlation of all these cases with the neurological examination, even though no abnormality was detected with survey radiography.

In the remaining three cases of venography, only the extravertebral veins could be opacified. Faint outline of the longitudinal venous sinuses could be seen coursing from the coccygea to the sacrum and then draining into the vena cava. All the three venograms obtained on ventrodorsal projection were of poor quality and nondiagnostic. The outlines of veins remained faint and vague in one case. The typical arcade pattern of the venous sinuses was absent and instead there was opacification of the paravertebral veins.

The inconsistency of venography in outlining the vertebral venous system and hence producing poor diagnostic radiographs may be due to lack of filling of vertebral sinuses from midsacrum cranially in the absence of technical difficulties. Further progress of the contrast medium from the lumbosacral junction and abrupt shunting of the contrast into the vena cava was another commonly encountered difficulty even when no technical errors were observed (Fig.19). This inconsistent filling could be attributed to the following reasons (a) inaccurate placement of the needle, (b) inadequate abdominal compression and (c) the possibility of anatomic or physiological variation among normal dogs (Hathcock *et al.*, 1988).

Shunting of the contrast at the lumbosacral region with out any apparent reason was observed in two cases. Similar findings were also observed by Feeny and Wise (1981) and Blevins (1980) who reported that this could be due to either by a defective technique or presence of any lesion diverting the flow of contrast. Hence it was difficult to distinguish between a technically unsuccessful procedure and an adequate procedure demonstrating a lesion.

Venography as per this study had only 50% sensitivity as venograms in three out of six cases were non diagnostic. Though successful venograms could be obtained in three cases and in which lesions were diagnosed, further studies are still required to establish this procedure as a routine diagnostic aid.

Summary

SUMMARY

The study was conducted in twelve clinical cases of posterior paralysis in dogs, presented at Veterinary College Hospital, Mannuthy to evaluate the comparative efficacy of Epidurography and Ascending Coccygeal Venography in diagnosing and localizing spinal lesions.

The animals were divided into two groups of six animals each, Group A and B. Epidurography was conducted in Group A and Ascending Coccygeal Venography was conducted in Group B.

All the animals were subjected to thorough clinical and neurological examination prior to radiography. Survey radiographs were taken in all the animals prior to the contrast radiographic procedure.

Physiological and haematological parameters were evaluated just before and 24 hours after radiographic procedure and the animals were observed for one week for the occurrence of side effects or complications, if any.

Iohexol (300 mgI/ml) was used as the contrast medium at a dose rate of 80 mgI/kg body weight for epidurography and 100 mgI/kg body weight for venography.

In Group A, epidurography was conducted by introducing the contrast medium through the lumbosacral junction into the epidural space. The contrast medium was given as slow infusion and the zero minute radiograph was taken,

as the last milliliter of the contrast remained to be injected. Subsequent radiographs were taken at the 3rd and the 5th minute.

In Group B, venography was conducted by introducing the contrast medium intravenously as slow infusion into the superficial lateral coccygeal vein of any one side near the base of the tail, after sufficient abdominal compression. Lateral and/or ventrodorsal radiographs were taken, as the last milliliter of the contrast remained to be injected. Subsequent radiographs were taken at the 3rd and the 5th minute.

It was observed that the administration of the contrast did not cause any significant alteration of the physiological or haematological parameters. Side effects or complications were not observed from the use of Iohexol.

The plain radiographs could detect abnormalities in four cases in Group A. In Group B, no abnormalities were detected in any of the six cases. It was seen that plain radiographs were more useful to detect abnormalities involving the bone.

Epidurography produced consistently good radiographs and was technically simple and easier to perform. Though abnormalities were detected in all the six cases on neurological examination, only four cases could be confirmed with epidurography. The technical difficulty involved was interpretation. The subtle changes involving the column were difficult to differentiate from the poor filling and elevation of the contrast due to presence of nerve trunks and epidural fat.

The changes that were diagnostic of lesions in epidurography was attenuation of the contrast column, considerable narrowing and elevation of the column, and failure of the opacification of a specific region of the column.

Venography did not produce consistent opacification of the venous sinuses in all the animals. Venous sinuses were opacified in only three out of six cases and the lesions in these cases were diagnosed and correlated with neurological examinations. In the remaining three cases, the venous sinuses were not opacified and hence definitive diagnosis could not be made.

The changes identifiable with a lesion in venography were abrupt attenuation of the venous sinuses, considerable elevation of the venous sinuses and progressive narrowing and attenuation of the veins.

Failure of opacification of the sinuses, abrupt shunting of the sinuses into the venacava at the sacrococcygeal junction and failure of further progress of the contrast into the lumbar venous sinuses and opacification of paravertebral veins were the drawbacks observed and hence it was difficult to identify whether the non filling was due to the presence of a lesion. Hence the chances of false negative interpretation was greater.

Though epidurography possessed a distinct advantage over ascending coccygeal venography in consistency and technical and diagnostic feasibility, it should be used as an adjunct with other diagnostic procedures. Venography showed only 50 per cent efficacy and hence further studies are required to establish it as a routine diagnostic technique

The following conclusions were drawn from this study:

1. Survey radiography was not sufficient for localizing the lesions within the vertebral canal.

2. Iohexol was found to be a safe contrast medium for both epidurography and ascending coccygeal venography.

3. Epidurography produced consistently good radiographs in all the six cases and was technically simple and easier to perform and showed considerable accuracy in diagnosing spinal lesions at the lumbar and sacral vertebral levels.

4. Ascending coccygeal venography could not produce diagnostic radiographs in all the cases due to inconsistency in opacification of the venous sinuses and abrupt shunting and drainage of contrast into the venacava.

5. Though epidurography was found to be advantageous over venography, further studies in the technical aspects for both procedures are required before recommending them as routine diagnostic aids.

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ASCENDING COCCYGEAL VENOGRAPHY IN EVALUATION OF PARAPLEGIA IN DOGS

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ABSTRACT OF A THESIS

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ABSTRACT

The study was undertaken with an objective of evaluating the comparative efficacy of ascending coccygeal venography and epidurography in locating the site and type of lesion in dogs suffering from paraplegia.

The study was conducted in 12 clinical cases presented at the Surgery unit of Veterinary College Hospital, Mannuthy and were designated into two groups (Group A and B) of 6 animals each.

Survey radiographs were taken in all the animals prior to the contrast radiographic procedures.

Iohexol (300 mgI/ml) was used as the contrast medium at a dose rate of 80 mgI/kg body weight for epidurography and 100 mgI/kg body weight for ascending coccygeal venography.

In Group A, epidurography was conducted by introducing the contrast medium through the lumbosacral junction into the epidural space. The contrast medium was given as slow infusion and the zero minute radiograph was taken, as the last milliliter of the contrast medium remained to be injected. Subsequent radiographs were taken at the 3rd and the 5th minute.

In Group B, ascending coccygeal venography was conducted by introducing the contrast medium intravenously as slow infusion into the superficial lateral coccygeal vein of any one side near the base of the tail, after

sufficient abdominal compression. Lateral/ventrodorsal radiographs were taken, as the last milliliter of the contrast remained to be injected. Subsequent radiographs were taken at the 3rd and the 5th minute.

All the animals were subjected to a thorough clinical and neurological examination prior to radiography. Physiological and haematological parameters were evaluated just before and 24 hours after radiography. All the animals were observed for one week for the presence of any side effects/complications.

The physiological and haematological parameters were within the normal range in all the animals both before and 24 hours after radiography. Iohexol was found safe for neuroradiological studies as none of the animals exhibited any side effects/complications during the period of observation for one week.

In Group A, epidurography produced good quality radiographs and was consistent in all the six cases. Abnormalities/lesions could be located in four cases. The remaining two cases showed normal epidurographic pattern and could not be correlated with the neurological examination.

In Group B, successful venograms were obtained in three cases in which lesions were located and correlated with the neurological examination. In the remaining three cases, the venous sinuses could not be opacified and hence failed in identification of lesion.

The changes identifiable as lesions in Group A were attenuation of the contrast column, considerable narrowing and elevation of the column, and failure of the opacification of a specific region of the column.

The changes identifiable with a lesion in venography were abrupt attenuation of the venous sinuses, considerable elevation of the venous sinuses and progressive thinning and attenuation of the veins.

Thus epidurography showed consistency in all the six cases and diagnosis could be made in four out of six cases whereas diagnostic venograms were obtained only in three out of six cases. Thus ascending coccygeal venography was found inconsistent and required further studies before recommending this as a routine practice.

Though epidurography possessed a distinct advantage over ascending coccygeal venography in consistency and technical and diagnostic feasibility, epidurography couldnot be advocated as a sole diagnostic procedure and should be used as an adjunct with other diagnostic aids after proper clinical and neurological examination.