2.0 REVIEW OF LITERATURE

The literature pertaining to spinal cord injury and spinal fixation techniques with or without decompression for traumatic posterior paralysis in dogs has been reviewed as follows.

2.1 ANATOMY OF THE THORACOLUMBAR SPINE

The anatomy of the structures associated with the thoracolumbar vertebral column having direct significance to the surgical procedures in this study are described briefly as follows.

2.1.1 Thoracic and lumbar vertebrae

The vertebral column of the dog consists of approximately 50 irregular bones, the vertebrae. The vertebrae are arranged in five groups namely cervical (7), thoracic (13), lumbar (7), sacral (3) and coccygeal (6 to 23, usually 20). All vertebrae except the sacral vertebrae remain separate and articulate with contiguous vertebrae in forming moveable joints. Three sacral vertebrae are fused together to form a single bone, the sacrum. The vertebrae protect the spinal cord and roots of the spinal nerves, aid in the support of the head, and furnish attachments for the muscles governing body movements.

A typical vertebra consists of a body, a vertebral arch, consisting of right and left pedicles and laminae; and various processes for muscular or articular connections, which include transverse, spinous, articular, accessory and mamillary processes.

The body of a typical vertebra is constricted centrally. It has a slightly convex cranial articular surface and a centrally depressed caudal articular surface. The bodies of the thoracic vertebrae are shorter than those of the cervical or lumbar region. In the lumbar region, the vertebral bodies gradually increase in width throughout the series, and in length through the first five or six segments. The body of the seventh vertebra is approximately the same length as the first. The pedicles and laminae are
longer and more massive but, they resemble those of typical vertebrae in the thoracic region. The intervertebral disc is located between adjacent vertebrae. Its center is composed of a gelatinous nucleus pulposus and the outer structure is a fibrocartilaginous ring called annulus fibrosus.

The vertebral arch consists of two pedicles and two laminae. The pedicles of the vertebral arches are short in the thoracic vertebrae. Together with the body, the arch forms a short tube called vertebral foramen. All the vertebral foramina join together to form the spinal canal. On each side the root of the vertebra extends dorsally from the dorsolateral surface of the body, presenting smooth surfaced notches. The cranial vertebral notch is shallow and the caudal vertebral notch is deep. The notches on either side of the adjacent vertebrae, with the intervening fibrocartilage, form the right and left intervertebral foramina. Through these pass the spinal nerves, arteries and veins.

The dorsal part of the vertebral arch is composed of right and left laminae which unite at the mid-dorsal line to form a single spine or spinous process, without leaving any trace of its paired origin. The spinous process is the most conspicuous feature of the first nine thoracic vertebrae. The spine of the first thoracic vertebra is more massive than the others, but is of about the same length. The massiveness gradually decreases with successive vertebrae, but there is little change in the length or direction of the spines until the seventh or the eighth thoracic vertebra is reached. The spines then become progressively shorter and are inclined increasingly caudad through the ninth and tenth segments. The spine of the eleventh thoracic vertebra is nearly perpendicular to the long axis of the bone. This vertebra, the antclinal vertebra, is the transitional segment of the thoracolumbar region. All spines caudal to those of the twelfth and the thirteenth thoracic vertebrae are directed cranially whereas the spines of all vertebrae cranial to the eleventh thoracic are directed caudally. In the lumbar vertebrae, the spinous
processes are highest and most massive in the mid lumbar region. The spines are about half as long and the dorsal borders are approximately twice as wide as those of the vertebrae at the cranial end of the thoracic region.

Most processes arise from the vertebral arch. Each typical vertebra has, in addition to the single, unpaired, dorsally located spinous process, on either side an irregularly shaped **transverse process** which projects laterally from the region where the pedicle joins the vertebral body. The transverse processes of the thoracic vertebrae are short, blunt and irregular. All contain foveae for articulation with the tubercles of the ribs. In lumbar vertebrae, the transverse processes are directed cranially and slightly ventrally. They are longest in the mid lumbar region.

**The mammillary processes** start at the second or the third thoracic vertebra and continue as paired projections through the remaining part of the thoracic and through the lumbar, sacral and coccygeal regions. They are small knob-like eminences which project dorsally from the transverse processes. At the eleventh thoracic vertebra they become associated with the cranial articular processes and continue as laterally compressed tubercles throughout the remaining vertebrae of the thoracic and those of the lumbar region.

**The accessory processes** appear first in the midthoracic region and are located on succeeding segments as far caudally as the fifth or sixth lumbar vertebra. They leave the caudal borders of the pedicles and, when well developed, form a notch lateral to the caudal articular process which receives the cranial articular process of the vertebra behind. In the lumbar region, the accessory processes are well developed on the first three or four vertebrae, and absent on the fifth or sixth. They overlie the caudal vertebral notches and extend caudad lateral to the articular processes of the succeeding vertebrae.
Paired articular processes are present in both the cranial and caudal surface of the vertebrae, at the junction of the pedicles and the laminae. The cranial pairs of facets are widely separated on the first and second thoracic vertebrae, and nearly confluent at the median plane on thoracic vertebrae 3 to 10. On thoracic vertebrae 11, 12 and 13, the right and left facets face each other across the median plane and are located at the base of the mamillary processes. The cranial articular facets, with the exception of those on the last three thoracic vertebrae, face forward and upward. The caudal facets articulate with the cranial ones of the vertebrae behind, are similar in shape, and face downward and backward on thoracic vertebrae 1 to 9. The joints between thoracic vertebrae 10 to 13 are conspicuously modified, since the caudal articular facets are located on the lateral surfaces of dorsocaudally projecting processes. This type of interlocking articulation allows flexion and extension of the caudal thoracic and lumbar region, while limiting sagittal movement. In the lumbar region, the articular processes lie mainly in sagittal planes. The caudal processes lie between the cranial processes of succeeding vertebrae and restrict lateral flexion. All cranial articular processes bear mamillary processes (Evans and Cristensen, 1979). Parts of the lumbar vertebrae are depicted in Fig. 1 and 2.

2.1.2 Joints and ligaments of the thoracic and lumbar vertebral column

2.1.2.1 Synovial joints

The synovial joints appear between the articular processes of contiguous vertebrae and joints between the ribs and vertebrae. In the lumbar region there is essentially a sagittal interlocking of the cranial and caudal articular processes. At the tenth thoracic vertebra the direction of the articular processes change. The caudal articular processes of this segment face laterally and the cranial articular processes face dorsally. The articular processes of all vertebrae cranial to
the tenth thoracic vertebra are in nearly a frontal plane so that the cranial articular processes face dorsally and the caudal articular processes face ventrally (Evans and Cristensen, 1979).

### 2.1.2.2 Long ligaments

The supraspinous ligament extends from the spinous process of the first thoracic vertebra to the third coccygeal vertebra. It is a heavy band especially in the thoracic region, where it attaches to the apices of the spines as it passes from one to another. Bilaterally the dense collagenous lumbodorsal fascia imperceptibly blends with it throughout the thoracic and lumbar regions. The feeble interspinous ligaments send some strands to its ventral surface, but the supraspinous ligaments more than the interspinous ligaments prevent abnormal separation of the spines during flexion of the vertebral column.

The ventral longitudinal ligament lies on the ventral surfaces of the bodies of the vertebrae. It can be traced from the axis to the sacrum, but it is best developed caudal to the middle of the thorax.

The dorsal longitudinal ligament lies on the dorsal surfaces of the bodies of the vertebrae. It therefore forms a part of the floor of the vertebral canal. It is narrowest at the middle of the vertebral bodies and widest over the intervertebral fibrocartilages. The dorsal longitudinal ligament attaches to the rough ridges on the dorsum of the vertebral bodies and to the intervertebral fibrocartilages. It extends from the dens of the axis to the end of the vertebral canal in the coccygeal region. The dorsal longitudinal ligament is heavier than the ventral longitudinal ligament (Evans and Cristensen, 1979). The ligaments of the vertebral column are depicted in Fig. 3 and 4.

### 2.1.2.3 Short ligaments

The intervertebral discs are interposed in every intervertebral space (except C₁ and C₂), uniting the bodies of the adjacent vertebrae.
The thickness of the discs is greatest in the cervical and lumbar regions. Each intervertebral disc consists of an outer laminated fibrous ring called annulus fibrosus and a central, amorphous, gelatinous center called the nucleus pulposus. The fibrous ring consists of bands of parallel fibers which run obliquely from one vertebral body to the next. They provide a means of the transmission of stresses and strains which are required by all lateral and upward movements. These bands of fibers cross each other in a lattice like pattern and are over eight layers thick ventrally. Near the nucleus pulposus the annulus fibrosus loses its distinctive structure and form and becomes more cartilaginous and less fibrous.

The nucleus pulposus is a gelatinous remnant of the notochord. Its position and shape are indicated on each end of the vertebral body as a depressed area surrounded by a line. Since its consistency is semifluid, it bulges when the retaining fibrous ring ruptures or degenerates. Resultant pressure upon the spinal cord may cause pain or paralysis. Parts of the intervertebral disc are depicted in Fig. 5.

**Interspinous ligaments** connect adjacent vertebral spines. They consist of laterally compressed bands of tissue interspersed with the muscle bundles of the interspinalis muscles. The bands run from the bases and borders of adjacent spines and decussate as they insert on the opposed caudal and cranial borders of the adjacent spines near their dorsal ends. The stronger fibers of the interspinous ligaments lie almost vertically. Some of their fibres blend dorsally with the supraspinous ligaments.

**The intertransverse ligaments** consist of bundles of fibers which unite the craniolaterally directed transverse processes of the lumbar vertebrae. They are not distinct in any of the other regions of the spine.

**The yellow ligaments** or the interarcuate ligaments are loose, thin elastic sheets between the arches of the adjacent vertebrae. Laterally
they blend with the articular capsules surrounding the articular processes. Ventral to this ligament is the epidural space, which separates the ligaments and arches of the vertebrae from the dura covering the spinal cord (Evans and Cristensen, 1979).

2.1.3 Epaxial musculature

The dorsal trunk musculature, associated with the vertebral column and the ribs, is divided into three longitudinal muscle masses, each comprising many overlapping fascicles. The muscles act as extensors of the vertebral column and also produce lateral movements of the trunk when acting only on one side. The muscle masses are the iliacostalis muscle system on the lateral aspect, the longissimus muscle system intermediately and the transversospinalis muscle system deep medially. Various fusions of these three primary segmental muscle masses result in patterns which differ according to the species. The transversospinalis consists mainly of the multifidus and the interspinales muscles. In general, the multifidus muscles arise from the mamillary, transverse or the articular processes of the caudally lying vertebrae and attach to the spinous processes of the cranial vertebrae. The interspinales muscles run between contiguous edges of spinous processes and overlap these edges somewhat (Evans and Cristensen, 1979).

Of special significance during the dissection for hemilaminectomy is a thin tendinous attachment that can be seen on the accessory process of the exposed vertebrae. This tendinous attachment has to be cut to expose the neurovascular bundle as it leaves the spinal canal through the intervertebral foramen before hemilaminectomy is started. There is frequently a small branch of the spinal artery that runs dorsal to the accessory process, which may require to be cauterized using bipolar cautery to prevent excessive bleeding during hemilaminectomy (Wheeler
and Sharp, 1994). The deep epaxial muscles of the vertebral column are depicted in Fig. 6.

2.1.4 Nerve supply

Just peripheral to the intervertebral foramen each typical spinal nerve trifurcates into dorsal, ventral and visceral or communicating branches. The dorsal branch extends dorsad and usually subsequently divides into medial and lateral parts. The ventral branch supplies all hypaxial structures, including the limbs. It divides into medial and lateral parts. The communicating branch, also called visceral branch, differs from the dorsal and ventral branches in that it carries only the motor and sensory fibers to and from visceral structures. In general, the epaxial muscles, vertebrae, ligaments and the dura mater may receive their nerve supply by the dorsal branches of the spinal nerves (Evans and Cristensen, 1979). The spinal nerve emerging from the intervertebral foramen is depicted in Fig. 7.

2.1.5 Blood supply

The arterial supply to the vertebral column is segmental, with a spinal branch entering the vertebral canal via the intervertebral foramen, closely associated with the spinal nerve. The origin of the branches varies between the regions of the spine. The venous drainage is via the internal vertebral venous plexus, which comprises of two valveless veins on the floor of the vertebral canal. These are often termed the venous sinuses. The veins converge at midvertebral body (and sometimes join) and diverge over the intervertebral disc. They are thin walled and easily damaged. The venous plexus drains at the intervertebral foraminae via the intervertebral veins into the vertebral veins. The intervertebral veins may be single at each foramen, or may be paired, in which case they surround the spinal nerve. The intervertebral veins are very fragile and can bleed profusely if damaged.
The blood supply to the lumbar spinal cord arises from the spinal arteries. These enter the vertebral canal through the intervertebral foramina and branch into dorsal and ventral radicular arteries which supply an anastomotic network on the surface of the spinal cord deep to the duramater. The venous drainage of the cord also takes place into the internal vertebral venous plexus on the floor of the vertebral canal. The plexus drains at the intervertebral foramina through the intervertebral veins (Wheeler and Sharp, 1994). The blood supply to the lumbar vertebrae and the spinal cord are depicted in Fig. 8 and 9.

2.2 Occurrence of spinal cord injury

Gage (1975) reported that thoracolumbar lesions accounted for 84 to 86 percent of the intervertebral disc problems in dogs.

Feeney and Oliver (1980) noted that most spinal fractures occured at the junction between a moveable segment of the spine and an adjacent stable segment.

Carberry et al. (1989) reported that among 12 dogs having vertebral fractures and luxations, four (33.33%) were mixed breeds, two (16.67%) were Doberman Pinschers and one each (8.33%) were a Collie (8.33%), a Yorkshire Terrier (8.33%), a German Shepherd Dog (8.33%), a Miniature Poodle (8.33%), a German Shorthaired Pointer (8.33%) and an Alaskan Malamute (8.33%). The age of occurrence ranged from four months to nine years (median, two years). The body weights ranged from 4.5 to 35 kg.

McKee (1990) reported that among 41 dogs and 10 cats with traumatic spinal injury, the age of the animals ranged from four weeks to 15 years (mean, 3.3 years). Fifty percent were less than two years old. Seven (17.07%) of the dogs were mongrels and five of the cats were domestic short haired. Four of the 22 (43.14%) males were castrated and 12 of the 29 (56.86%) females were spayed. The author observed that the
The majority of the vertebral fractures were in the lumbar spine and most of the vertebral luxations were seen in the thoracolumbar region. Overall, 39.2 percent of the injuries occurred between T₁₂ and L₂ vertebrae. The author reasoned that spinal fractures and luxations generally occurred at the junction between stable and mobile parts of the spinal column close to the skull, thorax and pelvis. The thoracic vertebrae constituted the most stable section of the spine and hence, the most frequent site of spinal injury was the caudal thoracic area. The interval between injury and presentation of the patient ranged from less than a day to 14 months. However, the dog presented after 14 months had only pain at the site of vertebral luxation and no neurological deficits. Paraplegic animals were presented between less than a day of injury and three weeks of injury.

McKee (1992) reported that among 60 dogs with thoracolumbar disc protrusions, the most commonly affected disc was T₁₂/T₁₃ (33%), with T₁₂/T₁₃ to L₁/L₂ accounting for 75 percent of all protrusions. None of the cases had evidence of multiple disc protrusion.

Ullman and Bourdrieau (1993) reported that among six dogs with L₇ vertebral fracture, two (33.33%) were mixed breeds, two were Golden Retrievers (33.33%) and one each (16.67%) were a Labrador Retriever and a Collie. Four of the dogs were males and two were females. The body weights of the dogs ranged from 19 to 35 kg.

Yovich et al. (1994) reported that 51 percent of 61 dogs with thoracolumbar disc protrusions were Dachshunds, though a total of 17 breeds were represented among the patients. German Shepherds represented only 3.3 percent of the cases. They also found that among the 61 dogs, 32 were males and 29 were females.
Muir et al. (1995) reported that of a total of 98 Dachshunds with intervertebral disc extrusions, 56 percent were males, whereas the remaining 44 percent were females.

Scott (1997) reported that the incidence of thoracolumbar disc disease was highest in the miniature Dachshunds (18) followed by crossbred dogs (3) among a total of 40 dogs. The age of incidence ranged from 2 to 14 years. Twenty-six males and 14 females were affected. The most common site of disc extrusion was T_{12}/T_{13} followed by T_{13}/L_{1} intervertebral discs, together accounting for 65 percent of the cases.

Bray and Burbridge (1998) commented that intervertebral disc disease was one of the most common neurological disorders seen in small animal clinical practice.

Necas and Sedlakova (1999) reported the occurrence of thoracolumbar disc disease among various breeds of dogs as 73.2 percent in Dachshunds, 7.22 percent in Pekingese, 7.22 percent in mixed breed dogs, 3.09 percent in American Cocker Spaniels, 2.06 percent in Poodles, 2.06 percent in Basset Hounds, 1.03 percent in Shih Tsus, 1.03 percent in Lhasa Apsos, 1.03 percent in French Bulldogs, 1.03 percent in Cocker Spaniels and 1.03 percent in Miniature Schnauzers in a study conducted among 97 dogs. Forty nine of the affected dogs were males and 48 were females. The age of incidence of the disease ranged from 2 to 11 years with an average of 6.01± 2.1 years.

Lanz et al. (2000) stated that fractures or luxations of the vertebral column usually occurred near the junction of a mobile and an immobile (a kinetic and a static) vertebral segment. In dogs and cats these areas included lumbosacral, thoracolumbar, cervicothoracic, atlanto-axial and atlanto-occipital junctions.
Jensen and Arnbjerg (2001) reported a high incidence rate of intervertebral disc calcification at the age of 6 to 18 months of age among Dachshunds.

Munana et al. (2001) reported intervertebral disc disease in 10 cats. The age of incidence ranged from 4 to 17 years (mean, 9.8 years). The weight ranged from 2.4 to 7.8 kg (mean, 5.37 kg).

Breit (2002) measured the dimensions of the vertebral canals of 122 adult, neurologically normal dogs of various breeds from radiographs of their spine. He found that the mid sagittal diameters of the caudal vertebral foramen limits of T_{10} to T_{12} were significantly lower in Dachshunds relative to other breeds. The author also observed that these diameters were larger in other small breeds like the Maltese and Yorkshire Terrier when compared to those of Dachshunds and large breeds, suggesting that those breeds were at lower risk of developing clinical signs of a compressive disease at that site. In large breeds, minimal values were present at L_{1}/L_{2} and this agreed with the clinical findings of spinal cord compression most commonly observed in this region in non-chondrodystrophic large breeds of dogs. He noted that in Dachshunds and other disproportionate dwarf breeds, clinical signs of spinal cord compression were most commonly related to intervertebral disc disease between T_{11} and T_{13}. This could be attributed to biomechanical indicators, since the trunk at the region around the 10th thoracic vertebra was the most mobile.

Macias et al. (2002) reported that among 99 dogs with thoracolumbar disc disease 69 percent of the affected discs were located between T_{12}/T_{13} and L_{2}/L_{3}.

Laverty et al. (2004) studied the efficacy of intravenous polyethylene glycol on paraplegic dogs aged between two and eight years of age, weighing 40 pounds or less, which had T_{3}-L_{3} myelopathy resulting
from acute intervertebral disc herniation. For inclusion in the study the
dogs had to be paraplegic for 72 hours or less before presentation.

Riaz (2004) observed 46 cases of paraplegia in dogs presented to
Bangalore Veterinary College Hospital during a study period of one year.
German Shepherd Dogs represented 52.17 percent of the cases followed
by non-descript dogs (21.74%), spitz (13.04%), Dachshunds (8.67%) and
Labrador Retrievers (4.38%). The age of the dogs ranged from eight
months to 12 years with an average of six and a half years. Males
represented 60.86% of the cases while 39.14% were females.

Voss and Montavon (2004) reported that the body weight of 22
dogs and 16 cats that sustained spinal injury and were included in their
study ranged from 1.4 to 45 kg with a mean of 13.3 kg. Fractures and
luxations were located between T₁₀ and L₆. In 14 (63.64%) of the 22 dogs
the lesions were between T₁₂ and L₃, whereas in eight of the 16 cats,
lesions were between L₃ and L₆. Fracture types included simple vertebral
body fractures (14), end plate fractures (9), comminuted or compression
vertebral body fractures (5) and fractures of the dorsal lamina (1). Several
animals had fractures of the articular facets, generally in conjunction
with a vertebral body fracture or vertebral luxation. Articular fractures
were sometimes not detected before surgical exploration. Vertebral
subluxation or luxation was the main finding in nine animals.

Tartarelli et al. (2005) reported that among 23 dogs with
thoracolumbar disc extrusions 26 percent were Dachshunds. Eight dogs
weighed more than 20 kg, and 15 weighed less than 20 kg. The mean age
at presentation was 5.9 years (range, 4 to 10 years), and 17 males and
six females were affected.

2.3 Aetiology

Gage (1968) reported tetraplegia in a nine-month-old female
miniature Dachshund due to cervical cord compression as a result of
fractures of the odontoid process and portion of the vertebral body of C₂ vertebra, which were sustained following an automobile accident.

Wright (1980) noted that fractures might involve any part of the vertebra, and the resulting neurological sign would reflect the fracture site and the degree of spinal cord compression. Transverse fractures of the vertebral body generally resulted from direct trauma and usually compressed the cord. They might also be accompanied by a dislocation. Compression fractures of the vertebral bodies resulted from trauma to the head or the rear of the animal’s body and would cause a longitudinal shortening of the vertebral body. These fractures compressed the cord to some degree. In dogs less than one year of age, the most common type of fracture was that of the end plate, which might or might not be accompanied by a dislocation. Dislocations without concurrent fractures could be classified as subluxation with minor displacement or luxations with major displacement. A fractured articular process usually caused some displacement and compression of the cord. Where no fracture occurred, the dislocation resulted from the interruption of ligamentous support.

Morgan et al. (1987) compared the vertebral canal size between chondrodystrophic dogs (50 Dachshunds) and non-chondrodystrophic dogs (50 German Shepherd Dogs). In German Shepherd Dogs the vertebral canal height was greater throughout the length of the vertebral column than that of the Dachshunds. The results of the study indicated that maximal spinal cord and vertebral canal diameters were located further caudally in Dachshunds than the German Shepherd Dogs, and that the maximal spinal cord to vertebral canal ratios were further caudal in the former than the latter. The results of the study also suggested that the spinal cord of German Shepherd Dogs occupied a lesser cross sectional area of the vertebral canal than did the spinal cord
of Dachshunds. Subarachnoid and epidural spaces were less in Dachshunds than German Shepherd Dogs.

Shell et al. (1988) reported paraparesis in a four-month-old Rottweiler pup due to hemivertebrae and stenosis of the spinal canal involving the T9 and T10. Spinal dysrhapsism of thoracic spinal segments 7 to 11 was also seen.

Carberry et al. (1989) reported that among 17 dogs and cats that had vertebral fractures or fracture-luxations, 15 had been hit by automobiles, one had sustained injuries during a dog fight and one had been injured as a result of a fall.

Hazewinkel (1989) discussed in detail the effect of hyperparathyroidism in dogs. He noted that in severe cases, especially in growing animals, the skeleton would weaken to such an extent that it could not withstand the body weight and muscle forces resulting in skeletal deformities, including green stick fractures of long bones, compression fractures of cancellous bones and deformities of pelvis and other flat bones. In acute cases, compression of the spinal cord together with paralysis could take place.

McKee (1990) reported that among 51 animals (41 dogs and 10 cats) with traumatic spinal injuries 30 were hit by cars, six were injured following dog fight, two got injured by tree/weight falling on the spine, two were injured during greyhound racing and one each got injured after jumping from owner’s arms, getting caught under the door, during leash training and getting kicked by a kangaroo. Five animals got injured due to unknown causes. A cat that sustained spinal injury after jumping from the owner’s arms had severe skeletal osteoporosis due to nutritional secondary hyperparathyroidism as it was being fed an all meat diet. They noted that fractures might occur alone or in combination with a luxation as a fracture-luxation. Luxation implied tearing of the annulus fibrosus.
of the intervertebral disc and the associated disruption of the diarthrodial joints and longitudinal ligaments. Trauma might also result in spinal haemorrhage or spinal cord concussion, which was described as a functional or anatomical abnormality of the cord in the absence of bony, ligamentous or disc lesions.

Shores (1992) identified internal and external causes for spinal cord trauma in small animals. Internal trauma was usually related to intervertebral disc extrusion, pathological fractures, or congenital vertebral anomalies or instability. External factors included automobile encounters, projectiles (gunshot injuries), falls from heights, injuries caused by other animals (including humans), and blunt trauma from objects.

Jeffery and Blakemore (1999) also recounted that acute spinal cord injury might result from external trauma such as road traffic accidents or falls, or internal trauma such as that associated with acute intervertebral disc extrusion.

Bagley et al. (2000) stated that spinal trauma was a common cause of spinal cord dysfunction in dogs and cats. When the spine was subjected to exogenous injury, the impact often caused fracture or luxation.

Neel and Dean (2000) reported a case of intradural extramedullary nephroblastoma at the level of L2-L3 in a nine-month-old intact male Leonberger puppy which had progressive hind limb weakness that was first evident at three months of age. They recommended that nephroblastoma, though an uncommon tumour, should be included in the list of differential diagnoses for young large breeds of dogs with an intradural extramedullary tumour located near the thoraco-lumbar junction, and clinical signs compatible with an expansible, compressive spinal lesion.
Davis and Brown (2002) commented that thoracolumbar disc extrusion was the most common cause of pelvic limb paresis in dogs.

Jaderlund et al. (2002) reported paraparesis in a German Shepherd Dog due to T3-T4 disc herniation after it had slipped and fallen while running at high speed on wet surface.

Sanders et al. (2002a) reported an unusual case of spinal cord disease in a dog due to a spinal cord hamartoma, which is a non-neoplastic overgrowth of cells or an improper proportion of cells that are normally seen in the involved tissue. They noted that a variety of disease processes that affect the spinal cord could lead to spinal cord damage due to compression or vascular impairment. Focal intramedullary spinal cord diseases not associated with an obvious extradural disease process in animals resulted most commonly from trauma, haemorrhage, infarction (fibrocartilaginous emboli), myelitis, parasitic migration or tumour. They opined that intramedullary extrusion of intervertebral disc material was a rare complication of intervertebral disc disease and was typically associated with fibrocartilaginous emboli.

Voss and Montavon (2004) reported that among 38 cases of dogs and cats with thoracolumbar spinal injury, 37 had sustained the injury as a result of trauma, including road traffic accidents and falls, while one animal had sustained it following a bite injury.

Webb et al. (2004) noted that acute spinal cord injuries might affect dogs and cats as a result of intervertebral disc disease, congenital vertebral instabilities, penetrating and non-penetrating traumatic injuries, acquired conditions causing stenosis of the vertebral canal, intraspinal synovial and ganglion cysts, arachnoid cysts and neoplasia.

Kinzel et al. (2005) observed that herniation of the intervertebral disc was the most common cause of neurological trauma in the dog.
2.4 Complications associated with paraplegia

Griffiths (1972) observed that the majority of dogs with thoracolumbar disc protrusion showed evidence of a localized myelopathy affecting about two to four cord segments. Post-mortem examination of the spinal cords of eight dogs with ascending syndrome revealed extensive necrosis with ischemic changes in the neurons.

Moore and Withrow (1982) reported that 15 percent of 155 dogs with intervertebral disc herniation had signs of gastrointestinal haemorrhage. Diarrhoea, melena, depression, anorexia and vomition were the most common clinical features in this syndrome. Death might occur without prior signs. They found that approximately two percent of all dogs with intervertebral disc disease would die from gastrointestinal complications. The causes for the gastrointestinal haemorrhage might be due to the synergistic relationship between the severity of the spinal cord injury and the administration of corticosteroids. They noted that in man, acute gastrointestinal haemorrhage was a common complication of severe cervical cord injury. Increased gastric secretion and gastric acid hypersecretion had also been seen in human beings with central nervous system injuries. The mechanism by which haemorrhage occurred was not known. Some believed that injury of the spinal cord resulted in an altered equilibrium between the sympathetic and parasympathetic pathways, resulting in vagotonia (excessive vagal tone). Paralytic vasodilatation followed loss of sympathetic inhibitor effects, which could lead to decreased blood flow through the mucosa, necrosis, ulceration and haemorrhage. A relative increase in parasympathetic stimulation might lead to increased production of gastrin and pepsin. The decreased blood flow and increased acid secretion might cause enormous haemorrhage and necrosis of the mucosa. The authors noted that in man gastrointestinal haemorrhage was associated with cord injury from T_{11-12} to L_{4-5} and at several points in the cervical region. A specific spinal
segment was not associated with a significantly higher prevalence of haemorrhage. They noted that in contrast to man, the sympathetic outflow in the dog aroused diffusely from each of the thoracic and lumbar spinal segments, therefore vagotonia was less likely to occur. They opined that if vagotonia was a factor causing gastrointestinal haemorrhage, it might be related to the severity of the injury to the cord and not the location of the injury. They also noted that there seemed to be a threshold beyond which haemorrhage would occur. This threshold might be reached by an insult to the gastrointestinal mucosa by a factor (either corticosteroid administration, the stress of surgery, or a severe neurological injury), but was more readily reached when a combination of factors occurred simultaneously. It seemed likely that a single agent was not responsible for gastrointestinal haemorrhage.

Carberry et al. (1989) reported injuries like abrasions and lacerations; fractures of ribs, pelvic bones and femurs; sacroiliac and coxofemoral luxations; lung contusions and pneumothorax; and radial paralysis as injuries associated with vertebral trauma in dogs and cats. They observed fractured ribs in two among 12 dogs studied. Both cases had pneumothorax while three other animals had lung contusions.

McKee (1990) reported that among 51 cases of traumatic spinal injury in cats and dogs, 11 cases (21.6%) had additional injuries, of which coxofemoral luxation (three cases) and fractured ribs (two cases) were the most common.

Yovich et al. (1994) reported that three of 61 dogs (5%) with thoracolumbar disc protrusion had severe haemorrhagic diarrhea. Two cases had received high dose (2 to 6 mg/kg) of dexamethasone for three to four days while one had received prednisolone in combination with flunixin meglumin for two days.
Lu et al. (2002) described myelomalacia as haemorrhagic infarction of the spinal cord that could occur as a sequel to acute injury, such as that caused by intervertebral disc extrusion. Clinical signs of myelomalacia might include flaccid paralysis, total arreflexia of the pelvic limbs, tail and anus, loss of deep pain sensation caudal to the site of spinal cord injury, flaccid abdominal musculature, depressed mental state and respiratory difficulty due to intercostal and diaphragmatic paralysis. Although clinical signs of myelomalacia were usually observed within 24 hours of onset of paraplegia, some times they might become evident only in the post-operative period or even days after the onset of paraplegia.

Voss and Montavon (2004) reported that of 38 dogs and cats with thoracolumbar spinal injury, 20 had concomitant injuries. Of these, the most common were fractures and luxations involving sites other than the vertebral column, including the mandible, scapula, shoulder joint, humerus, radius and ulna, sacrum, pelvis and femur.

2.5 Diagnosis

2.5.1 Clinical examination

Gage (1968) reported that the spinal reflexes and muscle tone were near normal in nine-month-old Miniature Dachshund that was tetraplegic following a C₁-C₂ vertebral fracture. A flexion reaction could be elicited by pinching the toe, but was slow. The dog’s temperature was 39°C (102.2°F).

Carberry et al. (1989) evaluated neurological status in dogs and cats with thoracolumbar fractures or fracture/dislocations with respect to the following: 1) ability of the patient to walk, 2) ability to perceive pain caudal to the vertebral lesion, 3) presence of voluntary hind limb movement and 4) presence and quality of flexor and patellar reflexes. Presence of Schiff-Sherrington syndrome was noted. Urinary and fecal
incontinence were evaluated. They defined paralysis as absence of voluntary movement of limbs. They opined that the amount of spinal cord damage following vertebral injuries could be assessed roughly by the degree of motor and sensory dysfunction. They generalized that less severe the neurological sign, better the prognosis. Animals with signs of lower motor neuron dysfunction had a worse prognosis. Presence or absence of peripheral pain perception caudal to the site of spinal lesion also was useful in establishing a more accurate prognosis.

McKee (1990) stressed that an animal with traumatic spinal injury should be assessed on the basis of neurological examination rather than radiographical findings as in some cases there was poor correlation between the degree of displacement of vertebrae observed and the severity of neurological dysfunction recorded.

Wheeler and Sharp (1994) explained in detail how physical, and neurological examination of a patient with spinal cord injury had to be performed to help localize lesions and to help prognostication. They discussed the importance of palpation of the spine to detect abnormalities and for elicitation of signs of pain in the animal. They also explained how detailed neurological examination of a dog with spinal injury had to be conducted with special reference to attitude, posture, gait, locomotor status, conscious proprioception and deep pain sensation. They also explained the evaluation of spinal reflexes like panniculus reflex, patellar reflex, flexor reflex, perineal reflex etc.

Bergman et al. (2000) described Schiff-Sherrington posture as a clinical syndrome seen in severe cases of thoracolumbar spinal cord trauma in dogs. This posture was seen as rigid forelimb extension with paraplegia of the pelvic limbs. It was thought to result from injury to the border cell pathways, which were located on the dorsolateral aspect of the ventral gray column from spinal segments L₁ to L₇. These cells inhibited forelimb extension, and their disruption or injury might cause
the clinical signs associated with the Schiff-Sherrington syndrome. Such clinical signs might last for one or two weeks. While the thoracic limbs had increased tone and were rigid, they retained voluntary motor function and could perform postural reactions normally.

Lanz et al. (2000) suggested that an animal with traumatic injury of the spinal cord be first immobilized and then a neurologic examination be performed to localize the spinal cord segment affected and to determine the severity of the lesion. The spine had to be palpated, the spinal cord reflexes had to be assessed, pain perception had to be evaluated and also the cranial nerve function assessed. They listed the expected neurologic responses in thoracolumbar spinal cord injury as normal responses in the thoracic limbs, upper motor neuron signs in the pelvic limbs or weakness/paralysis of the pelvic limbs, panniculus reflex depressed or absent caudal to the level of the lesion, postural reaction deficits in the pelvic limbs and present or absent Schiff-Sherrington posture. They listed the expected neurological signs in lumbosacral spinal cord segment injury as normal responses in the thoracic limbs, dilated anal sphincter, lower motor neuron sign of the pelvic limbs, urinary and fecal incontinence, flaccid weakness or paralysis of the pelvic limbs and postural reaction deficits in the pelvic limbs.

Sanders et al. (2002a) reported a case of intramedullary spinal cord hamartoma at the level of T6-T7 vertebral area in a nine-year-old female Golden Retriever with a three-year-old history of progressive hind limb lameness. The dog had diffuse atrophy of the hind limb muscles; it was paraparetic and had exaggerated patellar reflexes. Withdrawal reflexes of all four limbs were normal. There was mild bilateral atrophy of the quadriceps, semitendinosus and semimembranosus muscles.

Sanders et al. (2002b) observed in a tetraparetic Doberman Pinscher dog with C4-C5 intervertebral disc extrusion that there was bilateral hyperactive patellar reflexes and no pain on palpation of the
spine. The cranial nerve reflexes and cutaneous truncii reflex were normal. On the basis of these signs they suspected a lesion involving the C₆ to T₂ spinal cord segments.

Riaz (2004) observed that the rectal temperature, heart rate and respiratory rates were not significantly altered in paraplegic dogs either prior to or after initiation of surgical or non-surgical treatment. He observed that four dogs subjected to non-surgical treatment started bladder function by four weeks after initiation of treatment while one dog subjected to surgical treatment started bladder function by two weeks after the surgery.

2.5.1.1 Grading of patients

Griffiths (1982) proposed a simple scheme for grading the severity of spinal cord damage as follows:

Group 1 – paretic
Group 2 – paraplegic, intact bladder control and pain sensation
Group 3 – paraplegic and loss of bladder control, some pain sensation present
Group 4 – paraplegic with loss of bladder control and pain sensation

Levine and Caywood (1984) reported the grading of dogs with spinal cord injury in intervertebral disc disease into four, namely:

I - mild paresis, ataxia and pain
II - severe paresis
III - paralysis, loss of motor function
IV - sensorimotor paralysis, loss of motor and sensory function
Black (1988) graded dogs with intervertebral disc disease into five grades based on clinical signs for assessment of results of decompressive surgery. The grades were:

1. thoracolumbar pain only
2. thoracolumbar pain and mild neurological deficits
3. paresis, unable to walk, but with some hind limb voluntary movements
4. no voluntary hind limb movement
5. paraplegic, without bladder control or deep pedal pain

Wheeler (1988) recommended that dogs with thoracolumbar disc disease be categorized on the basis of severity of the neurological deficit as follows:

- Grade I - hyperaesthesia only
- Grade II - ataxia, proprioceptive loss, paresis
- Grade III - paraplegia
- Grade IV - paraplegia, urinary retention and overflow
- Grade V - paraplegia, urinary retention and overflow and absent deep pain sensation.

McKee (1990) graded dogs and cats with spinal trauma into five grades based on the severity of the neurological dysfunction. The grades were:

- Grade 1 – pain only with no neurological deficits
- Grade 2 – paresis or ataxia
- Grade 3 – paraplegia or quadriplegia
- Grade 4 – paraplegia and quadriplegia with urinary retention and overflow
- Grade 5 – paraplegia or quadriplegia with urinary retention and overflow and absence of conscious pain sensation, *i.e.*, functional transection of the spinal cord.
Among 51 dogs and cats with spinal trauma, five were graded 1 (9.8%), 15 were graded 2 (29.4%), 11 were graded 3 (21.6%), nine were graded 4 (17.6%) and 10 were graded 5 (19.6%). In one case the neurological status was not recorded.

The author graded vertebral displacement in dogs and cats with traumatic spinal injury as mild, moderate and severe based on the percent of narrowing of the spinal canal. The spines were graded as having mild vertebral displacement when there was < 30 percent narrowing of the spinal canal, moderate when having 30 to 60 percent narrowing and severe when > 60 percent narrowing was seen. It was noted that three each of animals without any degree of vertebral displacement had a neurological grade of 4 and 5. Three animals of grade 4 and one of grade 5 had mild vertebral displacement. One animal with moderate displacement had a grade 5 injury, whereas three animals of grade 4 and five of grade 5 had severe vertebral displacement.

McKee (1992) graded dogs with thoracolumbar disc protrusion into three based on the severity of neurological dysfunction as follows:

Grade 1 – non-walking paraparesis or paraplegia
Grade 2 – paraplegia with urinary retention and overflow
Grade 3 – paraplegia with urinary retention and overflow, and absence of conscious pain sensation

Yovich et al. (1994) graded dogs with thoracolumbar disc protrusion into five neurological grades based on clinical findings as follows:

Grade 1 – back pain only
Grade 2 – ambulatory with varying degrees of hind limb paresis/ataxia
Grade 3 – non-ambulatory but voluntary movement, deep pain sensation present
Grade 4 – non-ambulatory, no voluntary movement, deep pain sensation present
Grade 5 – paraplegia, incontinent, no deep pain sensation

Muir et al. (1995) graded Dachshunds with thoracolumbar intervertebral disc extrusions into the following grades based on the results of neurological examination. The grades were:

Grade 0 – normal
Grade 1 – spinal pain
Grade 2 – paresis such that the dog could still walk
Grade 3 – non-walking paresis
Grade 4 – paralysis (absence of voluntary motor function)
Grade 5 – paralysis and absent conscious pain sensation

Dogs that could walk using three legs, but which had severe monoparesis or monoplegia were graded 3. Dogs which could not walk, and which had absence of voluntary motor function in one pelvic limb, with severe monoparesis of the contralateral limb were graded 4. Dogs that had absence of conscious pain sensation in only one pelvic limb were recorded as grade 5.

Scott (1997) graded dogs with thoracolumbar disc disease into five groups based on the severity of neurological dysfunction as follows:

Grade 1 – thoracolumbar pain with no neurological deficits
Grade 2 – ambulatory paraparesis
Grade 3 – non ambulatory paraparesis
Grade 4 – paraplegia with or without bladder control
Grade 5 – paraplegia with loss of both bladder control and deep pain sensation

The author classified the dogs based on the time taken for the onset of clinical signs as follows:

Peracute – onset of signs took less than 1 hour
Acute – onset of signs took between 1 and 24 hours  
Gradual – onset of signs took more than 24 hours

Jeffery et al. (2001) opined that the current methods used to classify functional deficits following spinal cord injury in dogs were very crude consisting of six point scales ranging from normal to paralyzed with no deep pain sensation. They recollected that sophisticated and reproducible behavioral scoring schemes had been devised to quantify restoration of locomotion following spinal cord injury in laboratory animals. Careful analysis of videotaped recordings of locomotion in specific surroundings, including analysis of joint excursions of each limb and the relationship between motion of different limbs during certain patterns of movement have also been used by some. The authors recommended that it would be possible for these methods to be applied to small animal veterinary species like dogs and cats.

Davis and Brown (2002) defined pelvic limb voluntary motor function as the ability to purposefully move either pelvic limb when the animal's weight was supported. They defined presence of sensory function as a repeatable conscious response after a stimulus was applied to the distal pelvic limb (quick head turn and vocalization). Time of ambulation was defined as the number of days until a non-ambulatory dog was able to stand and take a series of steps without assistance.

Ferreira et al. (2002) classified paraplegic dogs into the following categories based on their response to treatment. The classes were: excellent outcome (animals regained the ability to walk without proprioceptive deficits); fair outcome (ongoing paraparesis and/or postsurgical pain); and poor outcome (paraplegia persisted). Cases belonging to the excellent and fair categories were considered successful. Dogs with poor outcome were euthanized.
Macias et al. (2002) graded dogs with thoracolumbar disc disease according to the degree of neurological dysfunction as follows:

- Grade 0 – no neurological dysfunction or pain
- Grade I - spinal pain, no paresis
- Grade II – ambulatory paraparesis
- Grade III – non-ambulatory paraparesis
- Grade IV – paraplegia
- Grade V – paraplegia and urinary incontinence
- Grade VI – paraplegia, urinary incontinence and absent conscious pain perception

Voss and Montavon (2004) graded dogs and cats with spinal injury based on their neurological status as:

- Grade 1 – signs of localized pain only
- Grade 2 – conscious proprioceptive deficit and ambulatory paraparesis
- Grade 3 – non-ambulatory paraparesis
- Grade 4 – paraplegia, bladder dysfunction or both
- Grade 5 – paraplegia with bladder dysfunction and loss of deep pain sensation

Kinzel et al. (2005) classified dogs with spinal injuries as either ambulatory or non-ambulatory with deep pain sensation present (Grade III to IV) or absent (Grade V).

Tartarelli et al. (2005) assigned different grades to dogs with thoracolumbar disc extrusion as follows:

- Grade I – spinal hyperaesthesia only
- Grade II – ambulatory paraparesis
- Grade III – non-ambulatory paraparesis
- Grade IV – paraplegia
Grade V – paraplegia with urinary incontinence
Grade VI – paraplegia, urinary incontinence and absent deep pain sensation

2.5.1.2 Prognosis

Feeney and Oliver (1980) observed in their study on animals with spinal trauma that all animals without pain perception caudal to the spinal lesion had either spinal cord transection or complete malacia at the site.

De Lahunta (1983) opined that although Schiff-Sherrington syndrome was indicative of severe spinal cord injury, it did not imply a hopeless prognosis for return to function. He also noted that the pathways involved with deep pain perception were small diameter fibers that were multisynaptic and bilateral.

McKee (1990) reported that among 17 dogs and cats with traumatic spinal injuries that had to be euthanized due to poor prognosis, eight were grade 5, four were grade 4 and four were grade 3. One animal was not assessed for neurological grade. He opined that animals with grade 1 to 3 injuries generally had a good prognosis with conservative or surgical treatment, but regular neurological examination was essential to detect progressive dysfunction, because such cases were candidates for surgery.

Muir et al. (1995) opined that failure to elicit deep pain sensation in the hind paws during clinical examination of dogs affected with thoracolumbar disc extrusion did not necessarily indicate complete irreversible sensory and motor dysfunction. However, they reported that loss of deep pain sensation at discharge of dogs with intervertebral disc disease after hemilaminectomy or modified dorsal laminectomy was associated with a poorer chance of recovery of function.
Duval et al. (1996) reported that among 46 dogs with loss of deep pain perception following intervertebral disc prolapse, evidence of myelomalacia was found in 20. Of these, two dogs with evidence of focal myelomalacia survived and regained neurological function.

Oliver et al. (1997) noted that smaller diameter nerve fibers were less susceptible to damage caused by compression.

Norman et al. (1998) observed that studies in human patients with spinal cord injuries indicated that most of the recovery of function occurred by one year after injury.

Jeffery and Blakemore (1999) noted that although many animals affected with spinal cord injury recovered satisfactory function, some never regained the ability to walk. They also noted that co-ordinated locomotion could return after an acute experimental injury to the spinal cord, even if only a small proportion (5 to 10%) of the axons in the thoracolumbar spinal cord remained intact, whereas it would not return after the cord had been transected completely. They opined that it would appear that the treatment required to convert a non-ambulatory patient to one with adequate control of limbs might not need to produce extensive connections across the site of the lesion.

Scott and McKee (1999) reported that 62 percent of patients with thoracolumbar disc disease treated with laminectomy recovered neurologic function even after loss of deep pain perception. Of six animals that lacked deep pain perception two weeks after surgery for intervertebral disc herniation, only one regained deep pain perception. They observed evidence of myelomalacia in six among 34 dogs with loss of deep pain perception following disc prolapse.

Bagley (2000) cautioned that if deep pain sensation following spinal trauma was lost for 48 hours or longer prior to therapy, the chance for functional recovery was virtually nil.
Bergman et al. (2000) opined that the retention of deep pain perception was the most important aspect for predicting the prognosis in a veterinary patient with spinal cord injury as a more severe spinal cord lesion was required to disrupt that type of pain perception. Deep pain perception was the last function to be altered with spinal cord injury, indicating that the injury was severe. They also noted that tissues of the spinal cord varied in their susceptibility to injury because they differed in their need for oxygen. Also, thoracic spinal column trauma tended to cause the most severe spinal cord injuries because of the smaller lumen of the spinal canal.

Lanz et al. (2000) recommended that animals with no deep pain perception be given a very guarded prognosis. Exception could be given to animals that had lost deep pain perception secondary to a disc herniation, which might have a 50 percent chance of recovery after surgical intervention.

Jeffery et al. (2001) noted that even animals that had the most severe loss of detectable function – those that had lost deep pain sensation – had a reasonable probability of recovery, at least when the case was intervertebral disc disease. However, animals that had lost deep pain sensation in association with vertebral fractures and luxations were less likely to recover. They suggested that olfactory ensheathing cell transplantation could be tried in those patients. They opined that olfactory ensheathing cell transplantation could also be tried in chronic spinal cord injuries. Hence, those patients that had not recovered following conventional therapy could be treated by this method.

Davis and Brown (2002) noted that it was an established opinion that dogs with absence of deep pain sensation constituted surgical emergencies and that the prognosis for return of pelvic limb function in those dogs was directly related to the timing of decompressive surgery. They reported that among 112 dogs with thoracolumbar disc extrusions,
the mean time to ambulation in dogs with pelvic limb sensation was shorter than the mean time to ambulation in dogs without sensation (12.6 days and 17.3 days respectively), but the relationship was not significant. Cases that had voluntary motor ability post-operatively had a significantly shorter time to ambulation (7.9 days) than dogs without voluntary motor ability (16.4 days). They concluded that the most important prognostic indicator for early return to ambulation was the presence of post-operative voluntary motor function. There was no correlation between the post-operative loss of pain sensation and an increased time to ambulation. They observed that among the 112 dogs treated by decompressive dorsal laminectomy or hemilaminectomy, the overall prognosis for ambulation was good for non-ambulatory dogs with intact pain sensation with 96 percent of the dogs returning to ambulation (mean, 12.9 days).

Ferreira et al. (2002) reported that among 71 paraplegic dogs suffering from thoracolumbar disc disease, treated by hemilaminectomy and fenestration, those animals that had shown clinical signs for more than six days took significantly longer to regain the ability to walk when compared with those which had shown clinical signs for less than two days or more than two but less than six days.

Voss and Montavon (2004) reported that among 38 dogs and cats with thoracolumbar fractures or dislocations, a good to satisfactory outcome was achieved in 30 (79%) patients following spinal fixation by modified spinal stapling and tension band wiring. All 22 patients with pre-operative motor function (neurologic grade 1, 2 or 3) had a complete recovery, but only eight of 12 patients with grade 4 deficits and none of the four patients with grade 5 deficits regained complete or satisfactory neurologic function. These results reflected a generally guarded to fair chance of functional recovery in paraplegic patients with intact pain sensation and a grave prognosis when deep pain sensation was lost.
Kinzel et al. (2005) stated that patients with grade V spinal cord injury had an overall bad prognosis relating to the degree of spinal cord injury, independent of the surgical technique chosen for treatment.

Tartarelli et al. (2005) reported that out of 23 dogs with intervertebral disc extrusion treated by hemilaminectomy, 21 recovered and regained ambulatory function. Recovery time ranged from one to six days. Twenty dogs regained normal gait. Ataxia persisted only in one case. Two dogs without deep pain perception before surgery did not show any improvement.

2.5.2 Radiography

2.5.2.1 Plain radiography

Carberry et al. (1989) performed radiographic evaluation of patients with thoracolumbar fractures or fracture/dislocations under sedation or general anaesthesia. Radiographical analysis consisted of determination of location of fracture or luxation, approximating reduction in size of the vertebral canal, estimating degree of angulation and estimating amount of vertebral displacement. Compression was expressed as a percentage of normal spinal canal width. Injuries were classified as dorsal compartment injuries, ventral compartment injuries and combined compartment injuries. Follow-up radiographs were obtained from one week to 32 months following injury.

The authors studied the healing of vertebral fractures following non-surgical treatment in cats and dogs radiographically. They observed that in one case with mid body fracture of L5, fractured facets of L5-L6 and 50 percent ventral displacement, periosteal new bone formation was seen 10 days after the initial radiographs. In another case with a chip fracture of the caudal end plate they observed no callus at six months and 32 months. Another case with Salter I fracture and lamina fracture of L1 showed healing of fracture on the radiograph taken at three months.
A case having a compression fracture of L₅ and fractured pedicles showed bony callus ventrally at one month. Another case with Salter II caudal end plate fracture of L₆ and also lamina fracture showed stable bony callus ventrally and laterally at 27 days.

They recounted that in man, fractures of a vertebral body with destruction of the intervertebral disc usually resulted in fusion of the fractured vertebra to the adjacent vertebra. This fusion, independent of ligament healing, would bring about restoration of stability. Among 17 animals with vertebral injuries studied by them, radiographic evidence of vertebral body fusion was seen in one dog. The authors opined that usefulness of radiography in spinal trauma patients was limited. Spinal cord contusion and concussion were not associated with specific abnormalities on plain radiograph. In addition, amount of damage to the spinal cord might differ even in patients with radiographically similar lesions. Constant spinal cord compression was not essential for production of traumatic myelopathy. They also opined that radiographs might be of limited value as prognostic indicators, as they might not show the maximum displacement which occurred at the time of injury. Spontaneous reduction of subluxations, luxations and fractures might occur prior to radiography. They opined that radiographs were more useful for prognosis when severe compression or reduction in canal size was observed. However, in their study, one dog with 40 percent compression improved neurologically, whereas another dog with less than 10 percent compression did not improve and had to be euthanized. They noted that alternative methods to assess spinal canal diameter more accurately were tomography and computerized tomography. They also opined that survey radiographs alone might not delineate which compartments were affected or the full extent of the injury and instability. They contended that radiographic and myelographic surveys were not always reliable. Fractures might occur that were not always evident
radiographically. Moreover, inherent stability of any fracture or luxation was difficult to appreciate radiographically.

McKee (1990) performed radiographic examination of the vertebral column in 51 dogs and cats with spinal trauma, for identifying the type and location of the spinal injury and the degree of vertebral displacement. Stressed views were obtained in some cases by applying traction to the spine, to assess spinal stability. In 50 cases, radiographs revealed evidence of trauma. The most common injuries were fractures of the vertebrae (26 cases, 29 fractures) and vertebral luxations or subluxations (17 cases). A vertebral fracture-luxation was diagnosed in one case and extrusion of the intervertebral disc with narrowing of the disc space in six cases. One dog with intradural haemorrhage had no apparent abnormalities on radiographs. Stressed views demonstrated spinal instability in seven of nine cases. However, it was important to avoid injuring the spinal cord by the manipulations required for these studies. The author emphasized that spinal radiographs demonstrated the position of the vertebrae only at the time of examination. In some cases that showed reasonably good vertebral alignment when radiographed, there would have been severe spinal deformation and cord injury at the time of trauma. This discrepancy might partly account for the poor correlation between the degree of displacement observed and the severity of neurological dysfunction recorded.

McKee (1992) performed lateral radiography of the thoracolumbar and mid-lumbar region of the spine in dogs with thoracolumbar disc protrusion. The radiographs were examined for the evidence of narrowing of the intervertebral disc space and/or extruded disc material in the vertebral canal. Out of 60 dogs, 52 had a narrowed intervertebral disc space or calcified disc material within the vertebral canal. In eight dogs there was no evidence of disc protrusion. In 20 dogs, calcified disc material within the vertebral canal correlated with myelographic evidence
of spinal cord compression. Myelographs also correlated with a narrowing of the intervertebral space in 31 dogs.

Wise (1999) reported that radiographs taken 16 months after vertebral fixation with Steinmann pins and orthopaedic wires showed that all the implants were still in place and the alignment was the same as it was post-surgically.

Bagley et al. (2000) discussed that serial radiographs and cautious palpation of the spine might confirm instability following exogenous trauma. However, instability of the vertebral segment could be difficult to predict from a single radiograph. They recommended the three compartment theory of spinal injury for determining the level of instability at the site of injury. According to this theory the canine and feline vertebrae were divided into three compartments defined by anatomic structures. The dorsal compartment consisted of the articular facets, laminae, pedicles, spinous processes and supporting ligamentous structures. The middle compartment consisted of the dorsal longitudinal ligament, dorsal annulus fibrosus and dorsal vertebral body. The ventral compartment contained the remainder of the vertebral body, lateral and ventral aspects of the annulus fibrosus, nucleus pulposus and ventral longitudinal ligament. Radiographs had to be assessed to determine which compartment or compartments were damaged. Where two or three compartments were fractured or displaced, the fracture was considered unstable. If only one compartment was affected, the fracture was considered stable.

Lanz et al. (2000) recommended that survey spinal radiographs be always obtained in patients with spinal cord injury. Sedation could decrease patient struggling and discomfort and allow one to obtain lateral and horizontal beam (ventro-dorsal projection) radiographs of the suspected area of injury. Radiographs of the entire involved spinal column had to be taken to avoid missing a lesion. It had to be
remembered that radiographs showed the amount of spinal displacement at the time they were taken, and not the amount of displacement that occurred at the time of injury. Thoracic radiographs had to be obtained to rule out pulmonary contusions, diaphragmatic hernia and pneumothorax. Instability of vertebral bodies could be difficult to evaluate based on lateral radiographs. They also recommended that the three compartment theory could be used to radiographically determine whether a spinal fracture or luxation was stable or unstable.

Moore *et al.* (2000) reported the radiographic appearance of osteosarcoma of the L4 and L5 vertebrae of a dog as mottling of the body of L4 and misshapen intervertebral foramen at the L4-L5 junction. Ventral spondylosis at the L1-L2 and L4-L5 were also visible. They could not identify any soft tissue tumour on plain radiography. They opined that conventional radiography was the keystone to diagnosis of bone lesions.

Somerville *et al.* (2001) assessed the accuracy of localization of cervical intervertebral disc extrusion or protrusion in 64 dogs using survey radiographs. In 61 percent of the survey radiographs, evaluators identified sites of disc extrusion or protrusion based on radiographic findings. Of those radiographs where a site was identified, ability to accurately identify the correct site of disc extrusion ranged from 53 percent to 67 percent, with an average of 58 percent. Therefore, the overall accuracy rate for correct identification of the sites of the disc extrusion for all survey radiographs was 35 percent. Twelve cases had more than one site of disc extrusion or protrusion evident myelographically. In cases where multiple sites of extrusion were confirmed myelographically, the ability to localize at least one of the sites on the corresponding survey radiographs ranged from 63 percent to 80 percent, with an average of 70 percent. The major site of disc extrusion or protrusion was incorrectly identified in 16 percent to 31 percent of the survey radiographs, with an average of 26 percent. They concluded that
the use of survey radiographs alone was an inaccurate means for localization of cervical intervertebral disc extrusion or protrusion.

Lamb et al. (2002) assessed the diagnostic accuracy of survey radiography for canine thoracolumbar intervertebral disc protrusion by three independent observers. They found that there were marked differences in observer performance for the diagnosis of intervertebral disc protrusion. The accuracy of the observers for determining sites of intervertebral disc protrusion using survey radiography was in the range of 51 percent to 61 percent. All observers had low accuracy for identification of second sites of intervertebral disc protrusion. They concluded that no observer was accurate enough to justify attempting targeted surgical treatment of intervertebral disc protrusion without myelography.

Riaz (2004) used survey radiographs for identifying spinal lesions associate with posterior paralysis in dogs and to evaluate the stability of implants post-operatively. He was able to identify implant failure in post-operative radiographs in one dog.

2.5.2.2 Myelography

Wright and Jones (1981) reported the performance of myelography in 68 dogs by cisterna magna or lumbar route using metrizamide (160mg I/ml) at the rate of 0.15 to 0.3 ml/kg bodyweight. Failure to obtain good contrast column occurred in 14 dogs, and post-myelographic complications like seizures, convulsion and death were recorded in eight.

Wheeler and Davies (1985) used iohexol for myelography in dogs and cats and compared its efficacy to iopamidol and metrizamide. The drug was injected into the cisterna magna and the concentrations of iodine used were 300 mg of iodine/ml for cats and small dogs, and 350 mg of iodine/ml for medium and large dogs. Iohexol was found to be suitable for dogs and cats for studying spinal lesions. No adverse side
effects were encountered and the radiographic quality was good. The radiographic quality of the drug was found to be superior to that of metrizamide. The authors recommended iohexol as the contrast medium of choice for small animal myelography.

Morgan et al. (1987) observed that the spinal cord - to - vertebral canal ratio in Dachshunds was higher than that of German Shepherd Dogs. So, if a lateral myelographic projection was made in a Dachshund dog with a degree of kyphosis, the spinal cord would get drawn tightly against the floor of the canal and the ventral column would become thin or even fail to contain contrast medium. In contrast, the myelographic pattern in a German Shepherd Dog would be a more nearly straight unbroken column of contrast medium. They stressed that failure to recognize this basic difference might be cause for erroneous myelographic diagnoses in Dachshunds.

Black (1988) performed myelography in 25 dogs with intervertebral disc disease by lumbar puncture using iohexol (180 mg I/ml) or metrizamide.

McKee (1990) reported that among 51 dogs and cats with traumatic spinal injury, myelography was considered helpful in identifying spinal cord compression in five cases in which initial radiographs revealed a slight narrowing of the disc space, in one case with a fractured articular facet and in one case with no abnormality. In each case it demonstrated a space occupying lesion within the vertebral canal. The author stressed that myelography was required either when the radiographs revealed no abnormalities or when the findings failed to correlate with the clinical localization of the cord disease.

McKee (1992) performed myelography in 60 dogs with thoracolumbar disc protrusion by lumbar puncture using iohexol or metrizamide. Lateral views were examined for the evidence of an
extradural mass and/or intradural swelling. The ventro-dorsal view was examined in 41 dogs for evidence of lateralization of protruded disc material. Fifty seven dogs had myelographic evidence of an extradural mass. Of these, 19 were confined to the area dorsal to the disc space. In three cases diffuse intradural swelling was evident. The protruded disc material was predominantly on one side in 15 cases (25%) and located on the right side in eight. In all, 24 cases (40%) had clinical or myelographic lateralization of signs suggestive of a dorsolateral disc protrusion.

Widmer et al. (1992) induced anaesthesia for myelography in dogs with 2.5 percent thiopental sodium intravenously after premedication with atropine sulphate administered subcutaneously. Anaesthesia was maintained with a fluothane - nitrous oxide - oxygen combination. The vaporizer setting was kept at 1.5 percent and the gas flow rates were 1.5 L/min and 1.0 L/min for oxygen and nitrous oxide respectively. They performed myelography in dogs by injecting iopamidol or metrizamide into the cerebellomedullary cistern using a 22 gauge 1.5 inch spinal needle. The concentration of iodine in the preparation of iopamidol was 200 mg I/ml and that of metrizamide was 170 mg I/ml. Either of the agents was used at the rate of 0.45 ml/kg body weight of the animal.

Wheeler and Sharp (1994) stated that the column of contrast agent administered into the cisterna magna would reach the lumbosacral joint within 10 minutes in normal dogs when the cranial end of the spine was kept elevated at an angle of 15 to 20°. They described in detail the procedure for cisterna magna puncture for collection of cerebrospinal fluid and administration contrast agent for myelography.

Yovich et al. (1994) reported the performance of myelography in 56 dogs with thoracolumbar disc protrusion using iohexol administered by cisternal and/or lumbar puncture. When direction of protrusion of the disc material was not evident on ventro-dorsal projections, oblique views were taken.
Muir et al. (1995) performed myelography by lumbar puncture in Dachshund dogs with intervertebral disc extrusions. The myelograms were used to identify extradural mass or intradural spinal cord swelling or both, and for any evidence of lateralization of extruded disc material.

Duval et al. (1996) reported spinal cord swelling as a sign of myelomalacia when myelography was performed.

Scott (1997) performed plain radiography and myelography in dogs with thoracolumbar disc disease under general anaesthesia. For myelography, iohexol (300 mg I/ml) at the rate of 0.3 to 0.5 ml/kg body weight of the animal was injected into the ventral subarachnoid space at the L₅-L₆ junction. The author was able to accurately localize the site of disc involvement in all 40 dogs with thoracolumbar disc disease by myelography. However, lateralization of the lesion was possible only in 18 dogs (45%). Eleven extrusions were lateralized to the left while seven were to the right. When combined with clinical findings and history, lateralization was possible in 28 dogs (70%).

Wise (1999) reported that myelography was avoided in a dog with damage of annulus fibrosus and one articular facet as the vertebral bodies were intact and the lesions were obvious on survey radiographs. He reasoned that the myelogram would have prolonged anesthetic time, which was a concern in the animal as it had pulmonary complications.

Lanz et al. (2000) opined that myelography was not necessary if it was determined that the spinal injury could be treated conservatively or if there was a substantially displaced fracture or luxation as such patients were obvious candidates for surgery. They stressed that myelography should be performed in animals with marked neurological deficits and normal or equivocal radiographs. In such cases, myelography could identify persistent spinal cord compression due to traumatic disc extrusion, which might require surgical decompression.
They noted that myelography had been reported to detect occult spinal lesions in up to 20 percent of animals with spinal trauma. It could also reveal spinal cord transection in animals that were presented with loss of deep pain perception.

Moore et al. (2000) performed myelography by administration of iohexol (300 mg I/ml) at the rate of 0.4 ml/kg body weight at the cisterna magna in a dog with osteosarcoma of L3, L4 and L5. The contrast column terminated within the spinal canal of L4, and the ventral column of the dye appeared to deviate dorsally at termination.

Neel and Dean (2000) reported that survey radiographs were not able to reveal any abnormality in a dog with an intradural extramedullary nephroblastoma at the L2-L3 region. However, a myelogram revealed the lesion.

Penderis (2000) reported the performance of lumbar myelography in a five-year-old Basset Hound with acute paraplegia, loss of voluntary urination and depressed deep pain sensation in the hind limbs. The author identified a focal T13-L1 spinal cord compression with an intradural extramedullary lesion at the site, which was later identified as a Hansen type-1 prolapse during surgery.

Gopal and Jeffery (2001) noted that myelography was far more commonly used to identify spinal cord compression, since the technique was more readily available and often diagnostic. However, swelling occurring secondary to spinal cord trauma presented a problem in myelography, since it was often difficult to fill the subarachnoid space adjacent to the lesion epicenter sufficiently (especially in the absence of live image intensification), preventing identification of any associated extra-parenchymal compression. Myelography was also very limited in its ability to demonstrate lesions within the spinal cord parenchyma, such as congenital or vascular lesions and intramedullary tumours. Moreover,
in cases of traumatic spinal cord injury, myelography was incapable of differentiating differing types of intra-parenchymal pathology that might have an important role in determining prognosis.

Lu et al. (2002) performed myelography in seven dogs with iohexol (300 mg I/ml) at the rate of 0.3 to 0.5 ml/kg body weight. They noted that the myelographic signs in these dogs with myelomalacia included a variable degree of contrast medium infiltration into the spinal cord in six dogs (86%) and/or spinal cord swelling in six dogs (86%). In one dog with focal myelomalacia, the only myelographic sign was spinal cord swelling.

Macias et al. (2002) performed myelography in dogs with thoracolumbar disc disease by injecting iohexol (300 mg I/ml) into the cisterna magna, caudal lumbar spine or both. Lateral and ventro-dorsal projections were obtained in all dogs and oblique views were taken in selected cases. Details recorded were site of spinal cord compression, lateralization of spinal cord compression, myelographic pattern and the presence of contrast agent in the epidural space. Lumbar myelography was preferable to cisternal myelography to determine the location of the lesion in dogs with thoracolumbar nuclear extrusions. However, difficulties in needle placement, mainly due to large size of dogs led to attempts at cisternal injection in many cases.

Rayward (2002) performed myelography in a quadriparetic dog of 17 kg body weight by injection of 4 ml of iohexol (300 mg I/ml) at the cerebellomедullary cistern followed by a lumbar puncture myelogram after injection of 5 ml of iohexol at the L5/L6 junction. An extradural mass (pieces of wood following an oropharyngeal stick injury) causing spinal cord compression was identified from the myelograms.

Tidwell et al. (2002) performed myelography by intrathecal injection of 0.4 ml/kg body weight of iohexol (300 mg I/ml) at the L5/L6
junction for the diagnosis of spinal cord compression due to intervertebral disc herniation in a four-year-old female Rottweiler.

Gnirs et al. (2003) obtained myelograms in 13 dogs with spinal subarachnoid cysts by subarachnoid injection of iohexol (300 mg I/ml) at the rate of 0.3 to 0.4 ml/kg body weight into the cerebellomedullary cistern.

Kumar (2003) did not observe any adverse effect in dogs following myelography using iohexol.

Riaz (2004) used iohexol (Omnipaque®, 300 mg I per ml, Nycomed Ltd., Ireland) at the rate of 80 mg of iodine per kg body weight for myelography in paraplegic dogs by injecting the contrast agent into the cisterna magna. He found that the contrast agent when used in this dose gave adequate contrast for delineating sites of spinal cord compression.

Kinzel et al. (2005) described the performance of myelography in 331 dogs with thoracolumbar disc protrusion by injecting 0.3 ml/kg body weight of iotrolan (300 mg I/ml) into the subarachnoid space at the level of the cisterna magna. After injection, the patients were tilted to 45° with head up. Myelograms were taken until a lesion was shown or the column of contrast agent ceased to show any flow on images taken 10 minutes apart. Lateral and ventro-dorsal views were taken. In case of ambiguous findings, additional oblique views were also acquired. They reported that complications or seizures occurred in 22 out of 331 cases.

Tartarelli et al. (2005) opined that myelography alone could not always distinguish between intramedullary swelling caused by spinal cord edema and wide extradural compression caused by diffused disc material and epidural haemorrhage. Magnetic resonance imaging seemed to be more accurate for delineating the sites of compression.
2.5.3 Advanced diagnostic techniques

Bagley et al. (2000) noted that myelography or advanced diagnostic techniques like computed tomography and magnetic resonance imaging might be needed to establish spinal cord compression or damage.

Lanz et al. (2000) stressed that osseous abnormalities like vertebral fractures were best seen with computed tomography. Computed tomography helped one to determine vertebral fracture instability or stability by identifying which compartments were involved. Three dimensional reconstruction of the vertebral fracture could help the surgeon plan surgery and determine which means of fracture fixation to be used. They opined that magnetic resonance imaging offered superior soft tissue definition compared to computed tomography, which would be helpful when evaluating the spinal cord. Myelography had to be performed only if magnetic resonance imaging was not available.

McKee (2000) opined that electromyography might complement information gained from the neurological examination and radiography by confirming denervation in the muscles innervated by the injured spinal nerve. It was particularly useful for nerves of the cauda equina affected by lumbosacral disc disease. Determination of motor nerve conduction velocity in sciatic and tibial nerve and measurement of evoked spinal cord potentials might also provide indirect evidence of cauda equina dysfunction.

Moore et al. (2000) considered magnetic resonance imaging to be more accurate than computed tomography in defining the extent of medullary tumour and noted that it might detect lesions not revealed by conventional radiography, bone scintigraphy or computed tomography. They used computed tomography to diagnose tumour of L3, L4 and L5 in an eight-year-old dog. Soft tissue mass adjacent to or involving the spinal cord and L4 was also seen. They opined that newer methods of imaging
were far more sensitive in identifying bone destruction in primary and metastatic sites of tumour.

Gopal and Jeffery (2001) reported the use of magnetic resonance imaging in a tetraplegic dog that did not show vertebral abnormalities on plain radiographs of the cervical spine. The technique revealed an absence of extra-parenchymal compression and an area of oedema within the cervical spinal cord, suggesting a favourable prognosis. They commented that magnetic resonance imaging was very useful for the diagnosis of lesions within the spinal cord parenchyma. They recommended magnetic resonance imaging as a technique that could aid in accurate diagnosis and prognostication, thereby avoiding premature euthanasia or inappropriate surgical intervention.

Sanders et al. (2002) performed magnetic resonance imaging of the cervical vertebral column in a tetraparetic miniature Doberman Pinscher. The nucleus pulposus of the C4-C5 intervertebral disc space was hypointense, compared with the adjacent intervertebral disc spaces. A focal area of hyperintense signal was observed within the spinal cord parenchyma over the C4-C5 intervertebral disc space, which extended cranial and caudal to the intervertebral disc space. They also detected enlargement of the spinal cord and a marked hyperintense, vertical, linear signal that crossed the spinal cord parenchyma which continued ventrally into the intervertebral disc space. There was loss of hyperintense signal typically associated with the area of the hydrated nucleus pulposus. Magnetic resonance imaging was useful to determine the extent and character of the intramedullary lesion. However, on a survey radiograph only a narrowing and wedging of the C4-C5 intervertebral disc space could be detected. They contended that one of the most important advantages of magnetic resonance imaging over conventional myelography was the ability to detect the character and extent of intra-parenchymal spinal cord disease.
The authors observed no enhancement of the spinal cord parenchyma after intravenous administration of gadolinium following magnetic resonance imaging in the dog. They noted that gadolinium enhancement of the lesions could not be obtained as the injury resulted from acute nucleus pulposus rupture. The lack of gadolinium enhancement made neoplasia an unlikely aetiology for the dog’s condition.

Sanders et al. (2002b) reported the use of magnetic resonance imaging in a dog with intramedullary spinal cord hamartoma after anaesthetizing it with isoflurane in oxygen and placing it on sternal recumbency in a 1.0 Tesla magnetic resonance scanner. On T2-weighted sagittal images, increased signal intensity involving the spinal cord at the T₆-T₇ vertebral area was evident. The spinal cord was focally enlarged over T₆-T₇ intervertebral space and was hypointense compared with adjacent spinal cord parenchyma. The spinal cord in this region appeared normal on T₁-weighted transverse magnetic resonance images. However, there was homogenous enhancement of the left lateral and ventral region of the spinal cord overlying the T₆-T₇ intervertebral space on T₁ weighted transverse magnetic resonance images after intravenous administration of gadopentetate dimeglumine (0.1 mmol/kg body weight). They opined that magnetic resonance imaging might be helpful in determining the extent of the lesion in dogs with vascular malformation but could not be used to distinguish neoplastic from non-neoplastic formations.

Tidwell et al. (2002) performed magnetic resonance imaging for the diagnosis of spinal cord compression following intervertebral disc herniation in a dog and identified a free disc fragment and extradural haemorrhages. They discussed the magnetic resonance imaging appearance of haemorrhage associated with intervertebral disc herniation.
Axlund and Hudson (2003) performed computed tomography of the normal lumbosacral intervertebral disc in 22 dogs, and measured the normal widths of the intervertebral disc space and the height of the vertebral canal. They noted that a mild bulging of the L7-S1 intervertebral disc could be present without associated neuropathy in medium sized dogs.

Gnirs et al. (2003) used magnetic resonance imaging for the diagnosis of spinal arachnoid cysts in one dog. They also performed computed tomography in five dogs with spinal arachnoid cysts after intrathecal administration of iohexol (240 mg I/ml) at the rate of 0.3 ml/kg body weight.

Ito et al. (2005) studied the prognostic value of magnetic resonance imaging in dogs with paraplegia caused by thoracolumbar intervertebral disc extrusion. They noted that 43 percent of dogs had areas of hypersensitivity of the spinal cord greater than or equal to the length of the L2 vertebral body. All dogs that did not have areas of hypersensitivity had a successful outcome, whereas only 55 percent of the dogs with areas of hypersensitivity did. Only 31 percent of dogs with an area of hypersensitivity that had also lost deep pain perception had a successful outcome. The odds ratio for an unsuccessful outcome for a dog with an area of hypersensitivity was higher than the odds ratio for a dog that had lost deep pain perception. Duration and rate of onset of clinical signs were not associated with clinical outcome. Their findings suggested that the results of magnetic resonance imaging could be used to predict clinical outcome in dogs with paraplegia caused by intervertebral disc extrusion.

Ness (2005) noted that till recently myelography was considered the gold standard for the diagnosis of canine disc disease. But, the use of advanced imaging techniques like computed tomography or magnetic resonance imaging was gaining popularity.
Platt et al. (2006) reported the use of magnetic resonance imaging for the diagnosis of intervertebral disc extrusion in a four-year-old dog. They also observed parenchymal hypersensitivity on T2-weighted images and similarly located diffuse hypointensity on gradient echo images cranial and caudal to the compressive extradural lesion. Haemorrhagic myelomalacia was suspected, which was confirmed surgically and histopathologically.

2.5.4 Cerebrospinal fluid analysis

Indrieri et al. (1980) evaluated the creatinine phosphokinase activity in the cerebrospinal fluid of dogs with different neurological disorders. Serum and spinal fluid creatinine phosphokinase concentration were determined by a quantitative, ultraviolet spectrophotometric technique based on the hexokinase/glucose-6-phosphate dehydrogenase enzyme coupled system. Concentration of creatinine phosphokinase in cerebrospinal fluid and serum were diagnostically non-specific. Although a diagnostic advantage was not found in measurement of creatinine phosphokinase concentration in cerebrospinal fluid and serum, it appeared that increased creatinine phosphokinase concentration in cerebrospinal fluid was associated more frequently with a guarded-to-poor prognosis. The concentration of creatinine phosphokinase in cerebrospinal fluid was statistically independent of creatinine phosphokinase concentration in serum. Cerebrospinal fluid concentration was significantly correlated to the number of red blood cells in the cerebrospinal fluid. However, cerebrospinal fluid concentration of creatinine phosphokinase was not significantly correlated to serum, blood or cerebrospinal fluid variables evaluated. They reported the creatinine phosphokinase concentration in a cisternal cerebrospinal fluid sample from a dog with T₃ astrocytoma to be 1.0 IU/L (normal values; 0 to 10 IU/L). The creatinine phosphokinase concentration in a lumbar cerebrospinal fluid sample from the same dog
was 200 IU/L. They recommended that therefore, it was essential that a lumbar cerebrospinal fluid sample be obtained in any dog with a suspected lesion caudal to the cisterna magna. They opined that this would hold true, not only when the concentration of creatinine phosphokinase were to be determined, but any time a lesion was suspected to be caudal to the foramen magnum.

Griffiths (1982) stated that for traumatic injuries of the spinal cord like fracture/dislocation, traumatic disc, cord concussion and vertebral collapse, cerebrospinal fluid analysis was not usually performed for diagnostic purposes. However, useful information for the diagnosis of inflammatory diseases could be obtained. Although a multitude of tests were possible, total and differential cell counts and estimation of total protein levels and a Pandy test were the most useful examinations.

Bailey and Higgins (1985) analyzed lumbar and cisternal cerebrospinal fluid from 31 healthy dogs. They found that the mean total protein of the lumbar cerebrospinal fluid samples was 28.68 mg/dl and that in the cisternal cerebrospinal fluid was 13.97 mg/dl. The mean total white blood cell count of lumbar cerebrospinal fluid was 0.55 cells/µl and that of cisternal cerebrospinal fluid was 1.44 cells/µl. Statistical analysis indicated that the protein and white blood cell count differences between cerebrospinal from the two sites were significant.

Thomson et al. (1989) studied 118 cerebrospinal fluid samples from dogs with intervertebral disc disease. The fluid was removed from the cerebellomedullary cistern, lumbar cistern or both. The samples were analyzed within 30 minutes of collection, as cells in the fluid degenerated rapidly. The total white blood cell count was determined using a haemocytometer. Calculation of the differential white blood cell count was done on a cytocentrifuge after addition of a drop of 27 percent bovine albumin to 100µl of cerebrospinal fluid. This mixture was then centrifuged at 750 revolutions per minute for five minutes. The sediment
was examined on a glass slide after staining with Leukostat (Fisher Scientific, USA). The protein level was determined by Bio-Rad Protein Assay (Bio-Rad Chemical Division, USA) using a dye binding technique with Coomassie Brilliant Blue stain. The upper values for cerebrospinal fluid were considered as less than 250 mg/l protein and less than five white blood cells/µl for the cerebellomedullary cistern samples and less than 450 mg/l protein and less than eight white blood cells/µl for lumbar cistern samples. Of the cerebellomedullary cistern samples 36 of 97 (37.1%) were abnormal, with respect to protein, total white blood cell count or both, compared to 18 of 21 (85.7%) of lumbar cistern aspirates.

Changes in the cerebellomedullary cistern samples occurred more frequently with cervical lesions than those affecting the thoracolumbar area. Compared with the cerebellomedullary cistern cerebrospinal fluid, the spinal fluid from the lumbar cistern was more frequently altered by lesions anywhere along the neuraxis. With respect to protein concentration, three of three (100%) lumbar samples were abnormal in dogs with cervical disease while 15 of 18 (83.3%) were abnormal in case of thoracolumbar lesions. The degree of lumbar cerebrospinal fluid protein elevation appeared to be proportional to the severity and acuteness of neurological signs. That is, dogs with acute paraplegia had more dramatic elevation in protein than those that were less severely, or more chronically affected. Protein elevation correlated better than total white blood cell count with the severity of clinical involvement. However, pleocytosis was present in six of 25 (24%) and nine of 72 (12.5%) cerebellomedullary cistern samples from dogs with cervical and thoracolumbar lesions, respectively. Thoracolumbar disease caused a pleocytosis in seven of 18 (39%) lumbar cistern samples. Pleocytosis was mostly due to mononuclear cells in majority of cases. However, the median value for neutrophils tended to exceed one third of the total white blood cell count in clinically severe disease.
In general, the cerebrospinal fluid changes were most pronounced in samples taken near or caudal to the lesion. Proximity of the cerebrospinal fluid aspiration site to the lesion was apparently partly responsible for this. However, while both the cervical and thoracolumbar junction lesions were within seven vertebrae of the cerebellomedullary and the lumbar cistern sites, a much greater percentage of lumbar samples were abnormal compared with cerebellomedullary cistern samples. This suggested that the predominant caudal flow of cerebrospinal fluid from the brain to the terminal spinal cord was the most important factor causing the preponderance of lumbar cistern abnormalities.

McKee (1990) reported that in one case of traumatic spinal injury with no radiographic abnormality, the cerebrospinal fluid contained numerous erythrocytes, consistent with intradural haemorrhage and haematoma formation. However, they did not mention the site from which they had collected the cerebrospinal fluid.

Thomson et al. (1990) opined that the cerebrospinal fluid collected caudal to a spinal lesion was consistently abnormal than that obtained cranial to it because of the predominant caudal flow of the fluid.

Widmer et al. (1992) evaluated cerebrospinal fluid of normal dogs after iopamidol and metrizamide myelography. Each sample was evaluated for physical properties, including colour, turbidity and specific gravity (using refractometer). Protein determination (Coomassie Brilliant Blue method), Pandy test and total red blood cell and white blood cell counts were also done. A sedimentation technique and Wright-Giemsa stain were used to prepare each sample for cytological analysis. In both groups, post-myelographic cerebrospinal fluid changes included high specific gravity, Pandy score, protein concentration and white blood cell count. The high specific gravity and Pandy score were false-positive effects attributed to non-ionic contrast media. The differences between
the groups were not statistically significant. The differential white blood cell counts were consistent with mild, acute leptomeningitis. They opined that iopamidol and metrizamide should be considered low-grade leptomeningeal irritants in dogs.

Necas and Sedlakova (1999) reported the collection of cerebrospinal fluid from the cisterna magna and the lumbar subarachnoid space in 97 dogs with thoracolumbar disc disease using a 22 gauge spinal needle. They were able to collect successfully the required amount of cerebrospinal fluid in all 97 patients by cisterna magna puncture, whereas only 45 samples could be obtained by lumbar puncture. They could not obtain the required amount of cerebrospinal fluid in the remaining animals by lumbar puncture or those samples were grossly contaminated by blood. They found statistically significant difference in the creatinine kinase and lactate dehydrogenase concentration between the cerebrospinal fluid from the cisterna magna and the lumbar subarachnoid space. The levels of the enzymes were higher in the cerebrospinal fluid from the lumbar cistern compared to that from the cisterna magna. Significant difference between the activities of the two enzymes in the cerebrospinal fluid of healthy dogs and those with thoracolumbar disc extrusion was also seen.

Olby et al. (1999) conducted lumbar cerebrospinal fluid analysis in dogs with acute intervertebral disc herniation and found that the level of glutamate had increased. The level of glutamate correlated with the severity of clinical signs.

Lemarie et al. (2000) reported that the results of cerebrospinal fluid examination were normal in four dogs with cervical intervertebral disc prolapse.

McKee (2000) stressed that cerebrospinal fluid analysis was essential in cases of intervertebral disc disease in which non-contrast
vertebral radiographs did not fully define the location, nature and extent of spinal cord disorder. In suspected cases, he recommended that it should be performed prior to myelography to rule out inflammatory diseases of the cord and meninges. Normal cerebrospinal fluid was clear and colourless. Subarachnoid haemorrhage secondary to intervertebral disc extrusion might result in pink discolouration, or xanthochromia if more than 48 hours had elapsed following haemorrhage. Cerebrospinal fluid analysis should include a quantitative estimation of protein content. Cytological studies should be completed within 30 minutes of fluid collection since the cells degenerate rapidly. A total white blood cell count should be performed on non-concentrated fluid and cell morphology and a differential cell count performed in a concentrated sample. Degenerative disc disease might cause a mild elevation of cerebrospinal fluid protein.

Moore et al. (2000) reported that the cerebrospinal fluid collected from the cisterna magna in a male dog with osteosarcoma of L3, L4 and L5 vertebrae and spinal compression at L4 having progressive paraparesis of two to three weeks duration, did not reveal abnormalities in protein concentration or cytologic findings.

Neel and Dean (2000) analyzed the cerebrospinal fluid obtained from cisternal and lumbar punctures in a dog with intradural extramedullary nephroblastoma at the L2–L3 region. The cisternal sample had three red blood cells/µl, three nucleated cells/µl and a protein content of 33.1 mg/dl. Cytologic examination of a 100µl centrifuged preparation revealed 13 large mononuclear cells (87%) and two small mononuclear cells (13%). The lumbar sample had a protein content of 160.2 mg/dl, zero nucleated cells/µl and 527 red blood cells/µl. Cytologic examination of a 100µl centrifuged preparation showed 11 large mononuclear cells (55%), four non-degenerate neutrophils (20%), four small mononuclear cells (20%) and one eosinophil (5%).
Benjamin (2001) described the method for differential count of cells of the cerebrospinal fluid as follows. If the total cell count was under 500/µl the sample had to be centrifuged. Then the supernatant had to be poured off, a drop or two of serum added and a smear had to be made. Then, the smear had to be air-dried and stained with methylene blue, Wright’s stain or Giemsa stain as for blood smear. The cells had to be counted and tabulated in 100 cells, if present.

Munana et al. (2001) evaluated the cerebrospinal fluid collected from the cerebellomedullary cistern in seven cats with intervertebral disc disease. White blood cell count and protein concentration were within reference ranges in six of these samples. The remaining sample had elevation in both white blood cell number and protein determination. However, the sample had substantial blood contamination (red blood cell count, 11,000/µl) such that the significance of the elevation was unclear.

Jaderlund et al. (2002) reported that routine cisternal cerebrospinal fluid analysis indicated an elevation of protein level (0.8 g/l, reference value < 0.25g/l) as the only abnormality in a German Shepherd Dog that was paraparetic due to T3-T4 disc herniation.

Macias et al. (2002) observed xanthochromic cerebrospinal fluid in eight out of 99 dogs with thoracolumbar disc disease. Six of these dogs had an extradural myelographic filling defect over two or more vertebrae. No other abnormalities were reported. However, they did not mention the site from which the cerebrospinal fluid was collected.

Sanders et al. (2002b) reported that the cerebrospinal fluid from the lumbar cistern contained a high protein concentration (121.9 mg/dl; reference range, <35mg/dl) without evidence of pleocytosis (albuminocytologic dissociation) in a dog with paraparesis due to intramedullary spinal cord hamartoma.
Gnirs et al. (2003) reported an increased level of protein without pleocytosis in the cerebrospinal fluid collected from the cisterna magna in two out of seven dogs with spinal subarachnoid cysts. The fluid was normal in five dogs. No pathogenic organisms were identified.

2.5.5 Haematology

Griffiths (1982) did not list any possibility of blood abnormality in fractures and subluxations of the vertebral column.

Moore and Withrow (1982) noted that loss of blood into the gastrointestinal tract could probably cause anemia in spinal patients.

Wheeler and Sharp (1994) noted that the haemogram was unremarkable in majority of animals with spinal disease, although a stress leukogram was a common finding. The indicators of stress leukogram were lymphopenia, eosinopenia and leukocytosis.

Neel and Dean (2000) reported that the results of a complete blood count and urinalysis in a nine-month-old dog with intradural extramedullary nephroblastoma in the L2-L3 region were within the normal reference ranges.

Benjamin (2001) described in detail the procedures for the estimation of haemoglobin concentration in blood using Sahli’s haemoglobinometer and packed cell volume by microhaematocrit method. The author also described the methods for estimation of total erythrocyte count, total leukocyte count and differential leukocyte count in blood samples.

Sanders et al. (2002b) reported that the results of a complete blood count were within reference ranges in a tetraparetic three-year-old female miniature Doberman Pinscher with C4-C5 intervertebral disc herniation. However, it had a high activity of alanine aminotransferase (123 U/L, reference range 10 to 100 U/L) and mild hyperglycaemia (152 mg/dL, reference range, 77 to 125 mg/dL). Urine contained blood protein and
numerous white blood cells. They also reported that the results of a complete blood count, serum biochemical profile and urinalysis were normal in a nine-year-old dog with paraparesis due to intramedullary spinal cord hamartoma.

Riaz (2004) did not observe any statistically significant variation in the haemoglobin count, packed cell volume, total erythrocyte count, total leukocyte count or differential leukocyte count in paraplegic dogs treated by surgical or non-surgical means. All values were observed in the normal physiological range.

Rebar et al. (2005) listed the pattern of stress leukograms as increase in white blood cells and neutrophils, decrease in lymphocytes, increase or no change in monocytes, decrease or no change in eosinophils and no change in band cells.

2.5.6 Serum biochemistry

Singh et al. (1976) reported non-significant variation in the serum calcium and phosphorus levels during the healing of ulnar fractures in dogs. They observed a significant increase in the serum concentration of alkaline phosphatase during the healing of these fractures.

Simesen (1980) did not associate paraplegia in animals with changes in serum calcium or phosphorus.

Chaudhary (1997) observed non-significant variation in the serum calcium and phosphorus values in dogs during the healing of fractures. The author also found that the serum alkaline phosphatase values increased significantly till the 30th to 45th day during the healing of tibial fractures.

Lemarie et al. (2000) reported that a complete blood count, serum biochemistry profile and coagulation profile were within normal reference ranges in an eight-year-old male Lhasa Apso that had subluxations of
the cervical vertebrae following ventral slot decompression for intervertebral disc prolapse.

Moore et al. (2000) reported that the results of complete blood count, serum biochemistry profile and urine analysis were within reference ranges in a paraparetic dog with osteosarcoma of the lumbar vertebrae (L₃, L₄, L₅). The dog was suffering from progressive paraparesis of two to three weeks duration.

Benjamin (2001) did not mention that changes in serum alanine aminotransferase or aspartate aminotransferase were to be expected in association with paraplegia in animals. Serum calcium, phosphorus and potassium levels were also not expected to change in animals with paraplegia.

Tidwell et al. (2002) reported that complete blood count and serum chemistry profile were normal in a four-year-old neutered female Rottweiler with intervertebral disc disease having bilateral pelvic limb paresis with only minimal voluntary motor function and severe postural reaction deficits.

Riaz (2004) did not observe any statistically significant variation in the serum alanine amino transferase and aspartate amino transferase levels in dogs having posterior paralysis. He also did not notice any change in the values of these enzymes in association with surgical or non-surgical treatment of the condition. However, he observed that the serum alkaline phosphatase levels increased significantly till the end of the study period (six weeks) in dogs with vertebral fractures treated by surgical stabilization of the vertebral column.

2.6 Non-surgical treatment

Moore and Withrow (1982) noted that there was highest prevalence of gastrointestinal haemorrhage in dogs that underwent spinal surgery, received dexamethasone and had a severe neurological status.
Levine and Caywood (1984) reported a recurrence rate of 40 percent in dogs with intervertebral disc disease treated by medical therapy alone. Medical management consisted of a combination of cage rest, physiotherapy, corticosteroids and bladder evacuation. A recurrence rate of 26.5 percent was reported when such dogs were treated by decompressive procedures like dorsal laminectomy or hemilaminectomy. When the decompressive procedure was combined with fenestration, the recurrence rate was 16.6 percent. They reported that when fenestration alone was done only 14.8 percent of the cases recurred.

Black (1988) reported the medical treatment of 39 dogs with intervertebral disc disease on which lateral spinal decompression was performed. Nineteen dogs were administered prednisolone, dexamethasone or phenyl butazone prior to referral for surgery. Four dogs received dexamethasone (2 mg/ kg body weight intravenously twice a day) for two days before referral. Thirty dogs received one dose of dexamethasone (2 mg/kg intravenously) immediately before surgery. Seventeen dogs received low doses of prednisolone orally for two to nine days post-operatively.

Trotter et al. (1988) reported that the systemic administration of a potent glucocorticoid (dexamethasone) in the dosage commonly used in neurosurgical cases for its protective effects in spinal cord trauma resulted in delay rather than in beneficial limitation of laminectomy membrane formation. They noted that in other investigations, local administration of repositol form glucocorticoids in the laminectomy site had resulted in no limitation of scar tissue in some and in abscess formation, and increased scar tissue invasion of the vertebral canal in others. They also reported that the use of dexamethasone intra- and post-operatively in dogs in which modified dorsal laminectomy was done caused a decrease in the proliferation of granulation tissue and new bone.
Carberry et al. (1989) treated vertebral fractures and luxations in 12 dogs and 5 cats using corticosteroids with or without external support. When dexamethasone therapy was initiated, treatment was administered for three days (0.55 mg/kg body weight subcutaneously divided thrice a day for one day). Strict cage rest was implemented for a minimum of one week in all cases, and exercise restriction was advised for a minimum of four weeks. External support in the form of body splint was applied in seven animals. Fourteen animals regained the ability to walk, one was euthanized four weeks after injury and two remained paralyzed up to three years following surgery.

Brown and Hall (1992) recommended the use of methylprednisolone in the following manner for the treatment of central nervous system injury in dogs and cats. The drug had to be used at the rate of 30 mg/kg body weight intravenously followed by 15 mg/kg body weight two and six hours later and then at the rate of 2.5 mg/kg body weight/hour for 48 hours. They noted that the drug had to be used early i.e. less than eight hours after injury. The mechanisms by which methylprednisolone produced the neuroprotective mechanism were inhibition of lipid peroxidation, inhibition of lipid hydrolysis (e.g. arachidonic acid release) and eicosanoid formation, maintenance of tissue blood flow, maintenance of aerobic energy metabolism, reversal of intracellular Ca\(^{2+}\) accumulation, reduction of neurofilament degradation and enhanced neuronal excitability and synaptic transmission.

Coughlan (1993) emphasized the importance of early treatment of a patient with spinal cord injury with methylprednisolone sodium succinate to help improve neuronal outcome. The author noted that there was evidence that indicated that corticosteroids inhibited early adaptive and regenerative responses of the central nervous system following injury. He suggested the following protocol for the administration of methylprednisolone sodium succinate for spinal injury
patients. First, the drug had to be given at a dose rate of 30 mg/kg body weight intravenously, given over several minutes. This had to be followed by a further dose of 15 mg/kg body weight every four to six hours. The drug had to be administered within eight hours of trauma and the treatment should not exceed 24 hours. There was poor neurological recovery when the protocol was begun after eight hours or if continued for longer than 24 hours.

Yovich et al. (1994) reported that all out of 61 dogs with thoracolumbar disc protrusion treated by lateral spinal decompression received either 2 mg/kg of dexamethasone or 10 mg/kg prednisolone sodium succinate intravenously immediately pre-operatively, except in three dogs that had haemorrhagic diarrhea.

Muir et al. (1995) used peri-operative corticosteroids in 46 of 47 Dachshunds in which hemilaminectomies and 49 of 51 Dachshunds in which dorsal laminectomies were performed for the treatment of intervertebral disc extrusion.

Scott (1997) reported that corticosteroids were not used in 40 dogs in which hemilaminectomy was performed for thoracolumbar disc disease peri- or post-operatively.

Lanz et al. (2000) recommended that conservative management of spinal trauma consisted of strict cage rest for a minimum of four to six weeks. They suggested that corticosteroids be discontinued after the initial neurotrauma protocol and to continue gastrointestinal protective agents for a minimum of seven days. Analgesics also had to be provided. Neurological examination had to be performed twice a day for the first few days. Deterioration in neurological status warranted re-evaluation (radiographs, computed tomography, magnetic resonance imaging or myelography) and possible surgical intervention.
Gopal and Jeffery (2001) reported the recovery in ability to walk in a tetraplegic nine-year-old female crossbred dog, which had sustained cervical spinal cord injury following a fall, with routine nursing care to prevent complications of recumbency, manual expression of bladder, manual removal of faeces from the rectum and physiotherapy. They decided against surgical treatment as there was no extra-parenchymal compression of the cervical spinal cord on magnetic resonance imaging.

Davis and Brown (2002) reported that among 112 dogs with thoracolumbar disc extrusion 42 dogs (39%) were not administered corticosteroids. Eight dogs (7%) were administered dexamethasone intramuscularly (0.4 to 2 mg/kg body weight). Fifty one dogs (48%) were administered methylprednisolone sodium succinate intravenously (15 to 30 mg/kg body weight) that was repeated at 15 mg/kg body weight intravenously every six hours for 24 to 48 hours. They found that among these dogs there was no difference in the time taken to ambulation between dogs that were treated with any glucocorticoid protocol and dogs not treated with glucocorticoids prior to decompressive surgery. No steroid protocol was found to have benefits.

Macias et al. (2002) reported that nearly half of the dogs with thoracolumbar disc disease that were treated non-surgically deteriorated within a year and had to be euthanized.

Sanders et al. (2002b) reported that a tetraparetic three-year-old Doberman Pinscher was treated medically by intravenous administration of dexamethasone sodium phosphate (4 mg), subcutaneous administration of famotidine (4 mg), and subcutaneous administration of metoclopramide (2 mg) on the day of presentation. From next day onwards it was administered prednisolone orally (5 mg every 12 hours) and conservative management by cage rest was undertaken. However, the animal did not respond to conservative management as it had spinal cord damage due to intramedullary disc material.
Riaz (2004) subjected paraplegic dogs whose owners did not agree for surgical treatment due to financial or emotional reasons to non-surgical treatment which involved ultrasound therapy of the back of 15 minutes duration on alternate days, and methyl prednisolone acetate at the rate of 1 mg per kg body weight IM and B complex injection IM at weekly intervals. The dogs were also administered B complex vitamin tablets orally daily for a period of six weeks. The author found that this method of treatment was better than surgical stabilization of the vertebrae in paraplegic dogs.

Steiss (2004) detailed the use of therapeutic ultrasound for the rehabilitation of dogs with neurological injuries. The thermal effect of the therapy was the major indication for its use. The ultrasound waves could increase the tissue temperatures upto three to five centimeters deep. The author recommended that the intensity of the ultrasound waves required to elevate tissue temperatures to the range of 40 to 45°C vary from 1.0 to 2.0 watts per cm² with continuous wave mode for five to ten minutes.

Kinzel et al. (2005) opined that medical treatment was indicated for animals with intervertebral disc disease experiencing back pain or mild paresis or chronic loss of pelvic limb deep pain, as well as whose owners decline surgical treatment.

Ness (2005) opined that controversies abounded in the treatment of canine disc disease. He observed that it was surprising that high dose dexamethasone therapy continued to be used in spite of the fact that such treatment was found to cause gastrointestinal bleeding in as many as 15 percent of the patients and mortality rates of upto two percent.

2.7 Surgical treatment

Gage (1968) reported the treatment of fracture of the odontoid process and the cranial vertebral body of axis in a miniature Dachshund using a heavy, malleable wire (20 or 22 gauge orthopaedic) by tying the
dorsal arch of the atlas to the dorsal spine of the axis. The spinal cord was decompressed by hemilaminectomy.

Swaim (1971) reported the immobilization of unstable spinal column by applying small bone plates to the dorsolateral aspect of the vertebral bodies. The primary indications for spinal immobilization using bone plates on the vertebral bodies in dogs were spinal luxations or subluxations. The technique was also applicable in cases of dislocation or fractures where the vertebral body was intact, and in cases of transverse fracture of the vertebral body if a large part of the body was left intact (e.g. epiphyseal separation). The technique was found to be physiologically and mechanically sound as a means of spinal immobilization in spinal fractures and luxations. Hemilaminectomy was also found to be compatible with this technique.

Brasmer and Lumb (1972) reported the replacement of second lumbar vertebrae in 12 normal dogs with polyvinylidene prostheses. They reported that the prosthesis and modified plating technique provided a secure and stable substitute for the second lumbar vertebra. The prosthetic materials did not cause local tissue reaction over the 400 days of observation.

Gage and Hall (1972) reported the application of an Auburn plate on each side of the dorsal spines of C5, C6 and C7 vertebrae for stabilization of subluxations of C6-C7 intervertebral disc space in a nine-year-old Doberman Pinscher. The plate was fixed to the dorsal spinal processes using bolts through holes drilled through them.

Yturraspe and Lumb (1972) reported the use of dorsal plastic spinal plates for the fixation of canine vertebral column.

Dueland et al. (1973) reported the treatment of C3-C4 luxation in a 16-month-old Old English Sheepdog by dorsal fusion of the vertebrae using autogenous thoracic spinous process bone graft fixed using 20
gauge orthopaedic wire threaded through the caudal and cranial facets of C₃ and C₄ respectively. A dorsal laminectomy involving the caudal half of C₃ and cranial half of C₄ was done using surgical air drill equipment. Absorbable gelatin foam was placed over the decompression site to reduce laminectomy membrane formation. The musculature and the skin were closed routinely.

Flo and Brinker (1975) explained that the principle of fenestration was to create a window in the annulus allowing removal of any remaining nucleus pulposus after intervertebral disc prolapse from the disc. Fenestration without decompression could be used for mildly affected cases.

Swaim (1975a) described the technique of dorsal spinal stapling for the treatment of thoracolumbar vertebral instability in small animals.

Swaim (1975b) evaluated four surgical techniques for immobilization of unstable cervical vertebrae in dogs. The techniques were, placing screws bilaterally through the articular processes, placing wires bilaterally through the articular processes, placing a bone screw through vertebral bodies and placing a bone plate on the ventral surface of the adjacent vertebral bodies. Each technique was found to have certain advantages and disadvantages.

Braund et al. (1976) reported the technique of minihemilaminectomy for decompressive surgery of the spinal cord that preserved the articular processes and hence resulted in less instability.

Some authors have recommended fenestration rather than decompressive surgery for dogs with acute, severe neurological signs (paresis or paralysis) due to intervertebral disc disease (Denny, 1978; Butterworth and Denny, 1991; Coates, 2000).
Shores (1985) noted that dorsal laminectomy allowed access to both sides of the vertebral canal but provided no additional advantages and required more extensive muscle dissection.

McAnulty et al. (1986) reported the use of modified segmental spinal fixation for spinal fractures and dislocations in dogs.

Black (1988) reported lateral spinal decompression in 34 dogs with intervertebral disc disease. Haemostatic sponge or fat was not placed over the spinal cord at the completion of surgery.

Blass et al. (1988) reported the use of Steinmann pins driven into the vertebral bodies and polymethylmethacrylate for the stabilization of two cervical vertebral fractures and one cervical luxation in three dogs. They noted that the procedure was technically simple, but required good knowledge of anatomy and careful pin placement. The technique combined with external support using a neck brace provided adequate stability for bone and soft tissue healing. Complications due to improper pin placement were not seen. One case of pin migration responded to pin removal without any untoward effect. They concluded that Steinmann pins and methylmethacrylate would be very useful for the treatment of cervical vertebral fractures and dislocations.

Trotter et al. (1988) discussed that absorbable gelatin sponge had been claimed to prevent laminectomy membrane formation, but later the same had been condemned.

Wheeler (1988) stressed that the method of treatment for thoracolumbar disc disease had considerable influence on the prognosis of an individual case. Generally, the recovery rates of dogs in grades I to IV were similar if conservative treatment or fenestration was employed. Decompression carried a significant benefit for dogs in grade III and IV as the time taken to recover would be shorter. In grade V, only two to five percent of dogs treated by conservative means or by fenestration would
recover the ability to walk. However, if decompression was carried out within 48 hours, approximately 50 percent of them would walk again. Thus, the major potential benefits of decompressive surgery were higher recovery rate in paraplegic dogs and a more rapid return to function, because of the removal of large amounts of disc material from the spinal canal.

Carberry et al. (1989) stressed that the method of treatment of vertebral injuries in cats and dogs had to be determined on the basis of complete neurological examination, radiographic assessment, timing of injury and presence of other injuries. Type of vertebral fracture or luxation and degree of instability were criteria used to determine not only the need for internal spinal stabilization, but also the type of stabilization that would be most effective. An important factor was the stability of the vertebral fractures or luxations. They opined that the criteria for determining stability or instability of spinal injuries in animals often were based on evaluation of the biomechanics of fractures and luxations in humans and might not be applicable to veterinary patients. They also opined that stabilization provided by rib cage and hypaxial and epaxial musculature, although complicated and difficult to evaluate, should not be underestimated.

Kupper et al. (1989) described for the first time the minimally invasive technique of partial discectomy by percutaneous approach in dogs.

Shores et al. (1989) reported the use of combined Kirschner-Ehmer device and dorsal spinal plate fixation for caudal lumbar vertebral fractures in dogs.

Janssens (1991) noted that progression of nerve tissue damage subsided completely within 24 hours following spinal trauma. They
opined that treatment should focus on this period and that therapies initiated after that could only centre on regeneration.

Cook (1992) recommended hemilaminectomy for decompressing the spinal cord before applying fixation devices for fractures/luxations. This was because the technique provided access for visual inspection of the spinal cord while preserving the dorsal spinal processes for the application of fixation devices such as K-wire staples, Auburn spinal plates or Lubra plates. The author did not recommend dorsal laminectomy for spinal decompression before stabilization of fractures or luxations.

Harari and Marks (1992) noted that foraminotomy was indicated in cases with lateral intervertebral disc extrusions. They recommended that surgical intervention should be considered in cases of gradually progressive, acutely severe or recurrent symptoms.

McKee (1992) reported the surgical treatment of intervertebral disc protrusion in 30 dogs by hemilaminectomy and in another 30 dogs by dorsal laminectomy. Hemilaminectomy significantly improved the ability to retrieve protruded disc material compared to dorsal laminectomy, and the removal of protruded disc material significantly improved the degree of recovery. Hemilaminectomy was performed by a dorsolateral or a lateral approach. In both approaches the area of pedicle and laminar bone removed was the same. The facet joints were not preserved. Surgery was routinely performed on the left side unless there was clinical or myelographic lateralization of signs on the right. Cool saline solution was used to lavage the spinal cord throughout the procedure and a free fat graft was placed over the spinal cord at the completion of surgery. Wound closure included apposition of the lumbodorsal fascia.
Touliatos *et al.* (1992) listed faster recovery, lower infection rates and less perineural fibrosis as advantages of the use of minimally invasive methods of spinal surgery.

Coughlan (1993) recommended that in view of the risks of iatrogenic cord damage during surgical procedures entering the spinal canal, a 30 mg/kg dose of methylprednisolone sodium succinate be given at the induction of general anaesthesia in those cases not already on the normal protocol of the drug or where it was not appropriate, like an exploratory dorsal laminectomy in cases of suspected neoplasia.

Rosin *et al.* (1993) listed extensive neurosurgical procedures as ones that warranted antimicrobial prophylaxis. They stressed that antibiotics should be present in the tissue at the surgical site during the time of bacterial contamination.

Wheeler and Sharp (1994) recommended that the dog be controlled on sternal recumbency for dorsal approach of the spinal column. They recommended that the thoracolumbar fascia on either side of the tips of the dorsal spines and muscles on the articular processes be incised using No. 11 Bard Parker blade. They suggested that the muscles on either side of the dorsal spinous process, laminae and over the articular processes be bluntly elevated using periosteal elevators. They also recommended the use of Gelpi retractors to retract the dissected muscles from the vertebrae. Hemilaminectomy could be performed using rongeurs or electrical or pneumatic drills and bleeding from the cancellous bone at the site of hemilaminectomy could be controlled using bone wax.

Yovich *et al.* (1994) performed a modified lateral spinal decompression technique in 61 dogs with thoracolumbar disc protrusion. They positioned the animal in ventral recumbency and the surgery was performed through a dorsal midline incision. They used gelfoam if sinus bleeding was a complication. Fat grafts were not placed over the defects.
Muir et al. (1995) noted that removal of disc material from the spinal canal was the most important objective during decompressive surgery, and poorer results after surgery had to be expected if disc material remained in the spinal canal, as residual spinal cord compression was likely.

Scott (1997) performed a standard dorsolateral hemilaminectomy for thoracolumbar disc disease in dogs. The articular facets were first removed with bone cutters and then a pair of rongeurs. In large breeds, an air driven burr was used to remove sufficient bone to permit removal of extruded disc material and to decompress the spinal cord in cases where there was myelographic evidence of intramedullary swelling. Haemostasis was achieved using bipolar diathermy. Extruded disc material was carefully removed from the vertebral canal with a combination of fine instruments and gentle suction. The cord was gently lavaged with warm saline solution throughout the procedure and gentle flushing with saline was used to dislodge any small particles of disc material remaining in the vertebral canal. A free autogenous free fat graft was placed over the exposed spinal cord before closure. The author performed unilateral hemilaminectomy when the lesions could be clearly lateralized on the myelogram or when the myelogram did not provide conclusive evidence of lateralization, based on history and results of neurological examination. In those cases, where there were no lateralizing signs, surgery was arbitrarily performed on the left side. The author noted that it was generally accepted that decompressive surgery for thoracolumbar disc disease was superior to either conservative management or fenestration, especially for those dogs that were non-ambulatory.

Necas and Sedlakova (1999) premedicated dogs with thoracolumbar intervertebral disc disease for surgery, if they had risk for anaesthesia, with 30 to 50 µg/kg of medetomidine intramuscularly.
General anesthesia was induced with propofol at the rate of 2 to 4 mg/kg intravenously to effect. Endotracheal intubation was performed and a surgical plane of anaesthesia was maintained by administration of a mixture of oxygen and halothane (1 to 2.5%). Patients with potential risk were premedicated with a combination of 0.5 to 0.8 mg/kg of droperidol and 10 to 16 µg/kg of fentanyl intravenously. General anesthesia was induced with 2 to 4 mg/kg of propofol given intravenously to effect. Isoflurane (1 to 2.5%) was used instead of halothane for the maintenance of inhalation anaesthesia. They administered cefazolin at the rate of 22 mg/kg intravenously, methylprednisolone sodium succinate at the rate of 30 mg/kg by slow intravenous infusion and ranitidine at the rate of 1 to 2 mg/kg peri-operatively.

Bagley (2000) noted that indications for surgical treatment of spinal trauma were numerous and often inconsistent among clinicians. It was recounted that some authors had suggested that similar results were obtained with both surgical and non-surgical treatments of spinal fracture, irrespective of severity of clinical signs. However, improvements in diagnosis and surgical techniques might affect these outcomes. A variety of surgical techniques had been reported by many authors. However, each technique had its advantages and disadvantages, with the success of each depending on the surgeon’s experience with that particular technique.

Bagley et al. (2000) described the procedure for achieving a satisfactory spinal stabilization. The skin over the affected area had to be incised and the paraspinal muscles had to be removed from the affected vertebrae. However, care had to be taken when removing muscles because the animal’s normal anatomy might have been disrupted by the trauma and the removal of supporting muscles, tendons and ligaments during surgery could aggravate existing vertebral instability. The vertebral segments had to be aligned either before or after placement of
screws or pins. More anatomic alignment could decrease compression of associated duramater and nerve roots.

Excessive spinal manipulation had to be avoided to minimize additional cord damage. Manual reduction of vertebral fractures could be difficult. Surgical tools could provide counterbalancing forces or torque to aid in realignment. Because most vertebral fractures were associated with collapsed vertebral segments, lamina spreaders were useful. By slowly increasing the distraction of the vertebral segments, the surgeon could avoid some of the paraspinal muscle spasms and contracture that would result in vertebral segment collapse. Manipulation might also be aided by neuromuscular blockage during anaesthesia. If achieving a solid purchase point at the vertebrae on either side of the fracture became difficult, the lamina spreader could be positioned on previously placed screws or pins. The jaws of the lamina spreader had to be positioned as close to the screw-bone interface as possible to minimize the potential of screws becoming loose when distraction force was applied. When the vertebral segments were distracted, they were easier to realign manually or using surgical instruments.

They stressed that because each spinal injury was unique, treatment guidelines needed to be individualized. The indications for surgical treatment of spinal trauma were numerous, but controversial. But, they opined that surgical treatment should be considered for animals with spinal instability and/or cord compression related to exogenous injury. They commented that additional bone removed from the damaged spine in luxations and fractures during laminectomy might increase the degree of instability and make internal fixation more difficult.

The authors recommended that of the decompressive procedures, hemilaminectomy was preferable as it caused the least amount of instability. However, they recommended realigning the vertebrae and not performing a hemilaminectomy in order to preserve as much of bone integrity as possible. They also noted that durotomy and myelotomy
might also be indicated in severely affected animals to afford further decompression and to assess the severity of the spinal cord damage. Myelomalacia could be accurately assessed only after durotomy.

Lanz et al. (2000) stated that the indications for surgical treatment of spinal injuries included substantial neurologic deficits and evidence of spinal cord compression based on radiographs, myelography or computed tomography imaging. Other indications included a stable fracture that was responding poorly to conservative therapy, a deteriorating neurologic status after conservative management, or vertebral instability (2 or 3 affected compartments) demonstrated on radiographs or computed tomography scans.

Moore et al. (2000) performed hemilaminectomy to retrieve spinal cord compression due to an osteosarcoma in a dog.

Munana et al. (2001) reported the treatment of seven cats with intervertebral disc disease by hemilaminectomy. Two cats were treated by conservative means. Four of the cats that underwent surgery had an excellent recovery. One had a fair recovery but another was not available for follow-up. Of the two cats that were treated conservatively, one had a poor outcome but the other made a good recovery.

Davis and Brown (2002) opined that dogs with inability to ambulate after spinal cord injury following thoracolumbar disc extrusions were best treated by decompressive surgery. They reported a mean duration of anaesthesia of 3.7 hours (range, 1.7 to 7.1 hours) and a mean duration of surgery (dorsal laminectomy or hemilaminectomy) of 1.4 hours (range, 0.5 to 3.3 hours) when myelography was immediately followed by decompressive surgery in these dogs.

Ferreira et al. (2002) reported that the success rate after hemilaminectomy and fenestration in paraplegic animals in a study in 71 dogs with thoracolumbar disc disease was 86 percent with a recurrence
rate of 14.8 percent and a mean recovery time (time to regain the ability to walk) of 10.8 days.

Jaderlund et al. (2002) reported dorsal laminectomy for the decompression of the spinal cord due to T3-T4 disc herniation in a dog. They recommended that since the spinal cord was a highly vulnerable tissue, care had to be taken not to displace it during dorsal laminectomy.

Lu et al. (2002) identified liquefactive necrosis of the spinal cord in a dog with myelomalacia during decompressive surgery.

Macias et al. (2002) treated 72 dogs with thoracolumbar disc disease by hemilaminectomy. Two of these dogs had vertebral body plating as well. They opined that the role of surgical stabilization of the affected vertebrae in dogs with thoracolumbar disc disease remained unclear, though it had been earlier suggested that it might be useful to prevent further protrusions of the annular material. They postulated that vertebral stabilization was more likely to be useful in larger, younger dogs with a single affected disc.

Rayward (2002) performed a right-sided dorsolateral hemilaminectomy to remove two pieces of wood from the right hand side of the vertebral canal immediately adjacent to the spinal cord in a quadriparetic dog that had sustained an oropharyngeal stick injury.

Sanders et al. (2002a) performed spinal cord exploration in a tetraparetic miniature Doberman Pinscher by performing hemilaminectomy over C3-C6 intervertebral disc spaces after approaching the sites by means of a dorsal approach to the C2 to C7 vertebral bodies. There was no evidence of extradurally extruded disc material or haemorrhage within the spinal canal. However, they found a focal area of discoloured spinal cord over C4-C5 intervertebral disc space. After durotomy a grey-yellow liquefied region of soft to liquefied spinal cord was found. They removed a piece of extruded disc material from the
affected part of the spinal cord after performing a lateral linear myelotomy.

Walker et al. (2002) reported that external skeletal fixation of the canine spine had several advantages over internal fixation like minimal dissection for pin placement, the ability to span affected vertebrae with placement of implants distant from the site of injury, post-operative adjustability and complete removal of implants after healing. They inferred that external skeletal spinal fixation constructs had biochemical properties comparable with polymethymethacrylate/pin internal fixation techniques.

Gnirs et al. (2003) performed dorsolateral hemilaminectomy in the thoracolumbar and cervical areas as ventrally as possible (close to the vertebral canal floor) for spinal sub arachnoid cysts in 12 dogs.

Voss and Montavon (2004) reported the use of tension band stabilization of fractures and luxations of the thoracolumbar vertebrae in dogs and cats. The surgical approach consisted of a dorsal midline incision extending from three vertebrae cranial to three vertebrae caudal to the lesion. The dorsal fascia was incised bilaterally on each side of the four spinous processes centered over the lesion, leaving the supraspinous and interspinous ligaments intact. The epaxial musculature was then elevated from the dorsal lamina with a periosteal elevator. Muscular attachments on the mammillary and accessory processes were left intact in patients that did not require decompressive procedures. The musculature was retracted bilaterally with two self retaining Gelpi retractors.

A Kirschner wire (K-wire) was then passed through the skin and epaxial muscles and through the base of the largest spinous process cranial or caudal to the involved spinal segment. To avoid inadvertent damage to the vertebral canal, the K-wire was inserted dorsal to an imaginary curved line between two adjacent articular processes. The K-
wire was 15 cm long and 1 to 1.25 mm in diameter in cats and small dogs, and 28 cm long and 1.6 to 2mm in diameter in large dogs. The entire K-wire was passed through to the opposite side of the vertebra above the epaxial musculature, and the insertion side of the vertebra was cleared of skin and musculature so that the wire could be freely reinserted to its midpoint. The K-wire was then bent into a “U” shape with bending pliers and positioned bilaterally along the dorsal lamina in the groove between the spinous and articular processes of four vertebrae.

The fracture or luxation was reduced with the assistance of Kocher forceps placed on the spinous processes adjacent to the lesion, and the free ends of the K-wire were then secured with a hemicerclage wire through the spinous process of the first of the four vertebrae. Holes were drilled through the bases of the spinous processes ventral to the K-wire on each side of the lesion. An orthopaedic wire (0.6 to 0.8 mm in diameter in cats and 0.8 to 1.2 mm in diameter in dogs) was passed through the holes and placed over the “U” shaped K-wire and beneath the supraspinous and interspinous ligaments in a figure of “8” fashion. The wire was tightened bilaterally under usual control to ensure correct positioning of the articular facets. If the K-wire was correctly positioned, the fracture was reduced as the figure “8” wire was tightened. If considered necessary by the attending surgeon, additional hemicerclage wires were placed around the ribs or transverse processes to increase implant stability and avert implant avulsion. This was generally performed in large, immature dogs with relatively soft bone and in dogs with unstable fractures of the vertebral body.

In patients with clinically important spinal cord compression, a hemilaminectomy or pediculectomy was performed with rongeurs, and bone fragments and herniated disc material were removed following exploration of the foramen and the floor of the vertebral canal. Finally, the surgical site was thoroughly lavaged, and the dorsal fascia was closed with interrupted cruciate sutures. The overlying subcutaneous
layer was adapted with three point interrupted sutures to minimize seroma formation, and skin was closed with simple interrupted sutures.

The technique was tried in 38 cases and the results suggested that the tension band technique might be appropriate for stabilization of fractures and luxations of the thoracolumbar vertebrae in cats and small and medium sized dogs (< 20 kg body weight). In larger dogs, fixation strength might be insufficient to stabilize certain fracture types and ancillary external or internal fixation methods might be needed.

Webb et al. (2004) opined that treatments for spinal cord injury which might be considered ineffective in people might be useful in animals. This was because the criteria used to assess the behavioural outcome of clinical trials in people might be more stringent than those required for adequate function in dogs and cats.

Kinzel et al. (2005) studied 331 dogs in which partial percutaneous discectomy was done to treat thoracolumbar disc protrusion. Partial percutaneous discectomy involved minor trauma and least pain, and produced results comparable with open fenestration. It could be done in addition to open surgical decompression technique or prophylactically. They opined that regardless of treatment modality, exact localization of the lesion using myelography, computed tomography or magnetic resonance imaging was mandatory. Surgical management of thoracolumbar disc disease included therapeutic procedures for spinal cord decompression and intervertebral disc fenestration. Decompression was indicated when extrusion of disc material into the spinal canal resulted in ataxia, paresis or paralysis. Dorsal laminectomy and hemilaminectomy were most commonly used for intervertebral disc disease. Hemilaminectomy provided good decompression and easy access to the bottom of the vertebral canal for the removal of disc material. They opined that results for surgical treatment of intervertebral disc disease depended on early intervention and atraumatic surgical technique.
Ness (2005) opined that even though intervertebral disc disease had long been recognized as a cause of pain, disability and even death in dogs, controversies existed about the decision to manage the condition conservatively or surgically, the choice of the surgical technique, the use of high dose dexamethasone, the importance of secondary cord injury and the prognostic relevance of loss of deep pain sensation.

Tartarelli et al. (2005) performed hemilaminectomy in 23 dogs with intervertebral disc extrusion and 21 dogs (91%) recovered and regained ambulatory function.

### 2.7.1 Post-operative care

Bardet et al. (1983) reported the use of a combination of cephalexin and gentamicin for the treatment of osteomyelitis in small animals.

Blass et al. (1988) used cephadrine and dexamethasone intravenously immediately after induction of anaesthesia for spinal surgery in dogs. Post-operatively, cephadrine was administered three times a day orally for three to five days in two dogs after surgical stabilization of the cervical vertebrae. A third animal in which cervical stabilization was performed surgically was administered cefazolin and dexamethasone intravenously immediately after induction of anaesthesia. Cephadrine was administered orally thrice a day post-operatively. Post-operative dexamethasone was not used when blood was present in the stools.

McKee (1990) reported that the post-operative care of cats and dogs with spinal injuries generally consisted of the administration of broad spectrum antibiotics until the voluntary control of urination returned, and the administration of corticosteroids. The bladder was manually expressed or catheterized when necessary. All animals were nursed with care; some were kept strictly at rest in cages, and some
received regular physiotherapy in a whirlpool bath. The choice of these depended on the stability of the animal’s spine.

Bagley et al. (2000) recommended that special care had to be taken to prevent complications following spinal trauma or surgery. The patient had to be turned every one to four hours to prevent decubital ulcers from developing on bony prominences (e.g. hip and shoulders). Extra padding of bedding material and waterbeds would help prevent development of bedsores. Frequent turning would also prevent atelectasis which could lead to pneumonia. Ideally these patients had to remain in a sternal or sternal oblique position to allow chest expansion. Absorbent water proof pads had to be used to soak up urine and prevent urine and fecal saturation of the bedding material. Frequent bathing might be required to protect patients from urine scald. They recommended that physical therapy be undertaken for post-surgical spinal patients. Massage could effectively prevent limb oedema and muscle atrophy and improve general circulation to the limbs. Passive range of motion exercises like extending and flexing of each joint in the thoracic and pelvic limbs could also thwart joint stiffness, oedema and muscle atrophy. It could be helpful to mimic an exaggerated walking motion by moving the limbs in a circular fashion. These exercises had to be done daily for 10 to 20 minutes. If the patient was incontinent, urine had to be manually expressed by pressing via the abdominal wall or using a sterile catheter. Indwelling catheters were not recommended as they predisposed to cystitis.

The authors recommended that opiate analgesics be administered as spinal injury and surgery were associated with considerable post-operative pain. Fentanyl patches could be used to manage pain for up to 72 hours. Because 12 to 24 hours might be required to reach adequate blood levels of fentanyl, initial pain management could be supplemented with injectable agents (e.g. morphine at the rate of 0.3 mg/kg intramuscularly every four hours for at least the first 12 hours). The
fentanyl patches had to be applied on the dorsal neck or rump area away from the surgical site after shaving a three square inch area.

Rayward (2002) used cephalexin orally at the rate on 250 mg every 12 hours for 14 days, oral enrofloxacin at the rate of 100 mg every 24 hours for 14 days and oral carprofen at the rate of 30 mg every 24 hours for five days for a 17 kg dog in which hemilaminectomy of C₅-C₆ vertebra was performed. Morphine was administered periodically by intramuscular injection over the first four post-operative days.

Kinzel et al. (2005) reported that after partial percutaneous discectomy, dogs received 0.5 mg/kg prednisolone orally once a day for five days. None of the dogs received analgesics. In case of urinary dysfunction urinalysis was carried out and antibiotics were administered according to antibiogram. The bladder was emptied three times daily manually or a urinary catheter placed. Paraplegic dogs were repositioned every two to four hours. Physiotherapy was started 24 hours after surgery. None of the patients received any antibiotic prophylactically as risk of infection was minimum with the procedure.

2.7.2 Post-operative complications

Swaim (1971) discussed the disadvantages of applying plates on the dorsal spinous processes for spinal stabilization. The author noted that when screws had been used to secure the plates to the dorsal processes, the results had been poor. The use of nuts and bolts provided much better fixation. However, in overactive, large, or immature dogs with soft bone structure, excessive stress might be placed on the dorsal spines, resulting in either the bolts tearing through the spines or fracture of the spines. When either occurred, the spine would no longer be stable and the spinal could be subjected to additional trauma. To help prevent fracture of the dorsal processes, the application of body cast following spinal plating had been advocated. The use of vinylidene plates affixed to
the dorsal processes by bolts through the interspaces between the processes had also been reported to alleviate the problem of dorsal spinous fracture. It was evident that the dorsal spinous processes of the vertebrae were neither mechanically nor physiologically suited for spinal immobilization by means of plates. Individual dorsal spinous processes were not composed of sufficient osseous tissue to supply anchorage for fixation devices. If this deficiency was overcome by using many spinous processes to supply enough substantial tissue for spinal fixation with plates, the result was a non-physiological spinal fixation as if many vertebrae had been fused into one unit.

The author also reported neurological complications in a dog in which screws were placed through lumbar intervertebral disc space when plates were applied to the vertebrae. It caused kyphosis of the spine, ataxia in the hind quarters, priapism and poor proprioception for few days after surgery. After 60 days, the dog could walk normally but still had kyphosis of the spine and periodic priapism. Examination of the plated vertebrae at necropsy revealed osseous proliferation at the intervertebral spaces in which screws had been placed and some osseous proliferation over the bone plate.

Moore and Withrow (1982) observed no death related to gastrointestinal complications in spinal patients that did not receive dexamethasone. They suggested that the use of dexamethasone increased the prevalence of gastrointestinal haemorrhage and pancreatitis. Complications could be kept to a minimum by administering a corticosteroid for as short a period as possible. Intestinal protectants in conjunction with antacids or H2 antagonists (cimetidine) also might help to reduce the prevalence of gastrointestinal haemorrhage.

Bartels et al. (1983) noted that scoliosis and lateral abdominal wall weakness were the possible complications following fenestration by the dorsolateral muscle separation technique.
Trotter et al. (1988) noted that in dogs, severe post-operative spinal cord compression (constrictive fibrosis), caused by laminectomy membrane formation remained the major factor limiting the exposure and decompression achieved by laminectomy in the thoracolumbar region. They studied the healing of laminectomy defects in dogs following modified dorsal laminectomy and observed that during the early period (1 week) there was rapid proliferation of anastomosing spicules of woven bone at the cut surface of the bony pedicle. By two weeks the woven bone that proliferated to varying extent from the cut surfaces of the laminar pedicles had begun to be remodelled to laminar bone. At four weeks there was further maturation of the scar tissue. Most woven bone had been remodelled, but the rate of bone growth into the defect appeared to decrease. At eight weeks there was further maturation of the scar tissue and in some of the dogs the appearance of cartilage within the fibrous tissue near the intervertebral spaces preceded endochondral bone formation. At 16 weeks, there was further maturation of the scar tissue, and bony proliferation was variable from virtually none in the dogs in which only a durotomy was done to nearly complete bridging of the defect in the dog in which absorbable gelatin sponge was implanted.

McKee (1990) reported that plating of the thoracolumbar vertebral bodies was employed most commonly among 51 cases of traumatic spinal injury in cats and dogs, and was associated with few complications. In one dog a broken screw required replacement three weeks after surgery. In another dog a dorsal laminectomy resulted in spinal instability and progressive neurological dysfunction. Owing to the integrity of the articular facets, radiography under traction had failed to demonstrate any evidence of instability. Subsequently, the vertebral bodies were plated. The author reported that out of 16 dogs and cats with traumatic spinal injuries that were treated by surgical methods three dogs with grade 3 injuries, three with grade 2, one with grade 1
and one with grade 4 recovered completely, while two with grade 5 were euthanized as there was no sign of improvement. Residual paresis and ataxia was observed in two animals of grade 2, and one with grade 4 injury. The other animals were not available for follow-up.

McKee (1992) noted that a significant problem with an extensive dorsal laminectomy technique which improved the access for removal of disc material was the development of a constrictive laminectomy membrane. The laminectomy membrane was a dense fibrous tissue that replaced the bone removed by the laminectomy and bound the duramater to the overlying muscles. It might itself compress the spinal cord when laminar bone was removed to a level below that of the spinal cord. Autogenous fat grafts had been advocated for the prevention of this invasion of the vertebral canal.

Yovich et al. (1994) reported that one dog out of 61 dogs with thoracolumbar disc protrusion treated by modified lateral spinal decompression exhibited permanent scoliosis post-operatively. They opined that the dog probably suffered trauma to the lateral and medial branches of the thoracic and lumbar vertebral spinal nerves. One dog with grade 3 injury deteriorated to grade 5 post-operatively and was euthanized.

Muir et al. (1995) reported laminectomy membrane formation associated with the use of haemostatic sponge (Gelfoam®, Upjohn) in one dog out of 98 Dachshunds in which laminectomy was performed for intervertebral disc extrusion. They did not encounter complications associated with the formation of laminectomy membrane in those animals in which free fat graft was used in the laminectomy site. They reported neurological deterioration after surgery in eight percent of dogs after hemilaminectomy and in 21 percent of dogs in which dorsal laminectomy was performed.
Lemarie et al. (2000) reported cervical vertebral subluxations following ventral slot decompression for intervertebral disc disease in nine dogs. Seven of these dogs were subsequently treated by distraction of the vertebrae and stabilization using pins and polymethylmethacrylate.

Voss and Montavon (2004) reported that complications associated with tension band fixation of the vertebral column were seen in six (16%) out of 22 dogs. In one small dog a hemicerclage wire entered the spinal canal. Another dog had signs of sacral area pain caused by a K-wire that was too long. Complications attributable to fixation or implant failure were identified in four dogs. All four dogs were large, weighing between 16 and 35 kg. Fixation or implant failure occurred during the first postoperative week in all four and was accompanied by worsening of neurological status or physical condition, or lack of expected recovery. In one dog the figure “8” wire avulsed from the bone because the dog was young and the bone was soft. In another, there was a collapse of $L_1$ and subluxations of $L_1$ and $L_2$. The implants became loose with subluxation of $T_{12}$-$T_{13}$ in one dog. In the fourth dog the figure “8” wire broke because the implant size was too small (0.8 mm for 35 kg dog) and the K-wire became dislocated. In 20 animals, follow-up radiographs were obtained between three weeks and eight months after surgery. Five had substantial callus formation and ventral body bridging, and two dogs with vertebral body fractures had partial collapse of the vertebral body. These radiographic changes did not seem to interfere much with clinical recovery.

Tartarelli et al. (2005) reported that none of the 23 dogs with intervertebral disc extrusion in which extensive hemilaminectomy was performed had any secondary post-surgical complications like subluxations or chronic back pain, even in those in which a large number of spinal segments were involved.