**2.0 REVIEW OF LITERATURE**

The available literature related to the studies on spinal plating with or without laminectomy for traumatic posterior paralysis in dogs is reviewed under the following headings.

2.1 Etiology and occurrence of traumatic paraplegia

2.2 Complications of posterior paralysis

2.3 Clinical examination and grading of patients

2.4 Diagnostic imaging

2.5 Laboratory examination

2.6 Non surgical treatment

2.7 Surgical treatment

2.8 Post-operative care

2.9 Post-operative complications

2.10 Surgical anatomy of thoracic and lumbar region

**2.1 Etiology and occurrence of traumatic paraplegia**

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

Brown *et al.* (1977) reported 10.2% of recurrences in thoracolumbar disc disease in a retrospective study of dogs due to laminectomy membrane formation.

Feeney and Oliver (1980) observed the occurrence of most spinal fractures at the junction between a moveable segment of the spine and an adjacent stable segment.
Wright (1980) stated 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 causes compression of the cord. A dislocation might also accompany them. Compression fractures of the vertebral bodies resulted from trauma to the head or the rear of the animal's body would cause a longitudinal shortening of the vertebral body. 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 causes some displacement and compression of the cord. Where no fracture occurred, the dislocation resulted from the interruption of ligamentous support.

Ball et al. (1982) reported that among breeds of dogs, the Dachshund is the most frequently affected by intervertebral disc disease, with 19% to 24% of Dachshunds expected to develop clinical signs of thoracolumbar intervertebral disc disease during their life times.

Decamp and Braden (1985) reported that 93% of dogs with unilateral sacroiliac luxation had associated pelvic fractures.

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) observed paraparesis in a four-month-old Rottweiler pup due to hemivertebrae and stenosis of the spinal canal involving the T9 and T10. Spinal dysraphism of thoracic spinal segments 7 to 11 was also seen.

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

Hazewinkel (1989) described the effect of hyperparathyroidism in dogs. In severe cases, of 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) noted 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 shorthaired. Four of the 22 (43.14%) males were castrated and 12 of the 29 (56.86%) females were spayed. Thirty 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. The author noted that fractures might occur alone or in combination with a luxation as a fracture-luxation.
McKee (1992) found 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.

Shores (1992) enlisted the 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.

Ullman and Bourdrieau (1993) found 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%) was 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) found that 51 percent of 61 dogs with thoracolumbar disc protrusions were Dachshunds, though a total of 17 breeds were represented among the patients. German Shepherd Dogs represented only 3.3 percent of the cases. It was also found that among the 61 dogs, 32 were males and 29 were females.

Muir et al. (1995) found that among 98 Dachshunds with intervertebral disc extrusions, 56 percent were males, whereas the remaining 44 percent were females.

Scott (1997) reported highest incidence of thoracolumbar disc disease 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 T12/T13 followed by T13/L1 intervertebral discs, together accounting for 65 percent of the cases.
Bray and Burbridge (1998) stated that intervertebral disc disease was one of the most common neurological disorders seen in small animal clinical practice.

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

Necas and Sedlakova (1999) reported the occurrence of thoracolumbar disc disease among various breeds of dogs. 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 ShihTsus, 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.

Olby (1999) stated that intervertebral disc disease is a frequent problem in dogs, accounts for approximately 2% of all diagnoses of canine disease and represents the most common cause of acute spinal cord injury in this species.

Bagley et al. (2000) noted 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.

Lanz et al. (2000) found 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.

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. The authors 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.

Jensen and Arnbjerg (2001) reported a high incidence rate of intervertebral disc calcification at 6 to 18 months of age among Dachshunds.

Montavon et al. (2001) reported that approximately 21% of all pelvic fractures were reportedly associated with sacroiliac luxation.

Breit (2002) measured the dimensions of the vertebral canals from the spinal radiographs of 122 adult, neurologically normal dogs of various breeds and found that the mid sagittal diameters of the caudal vertebral foramen limits of T10 to T12 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 L1/L2 and this agreed with the clinical findings of spinal cord compression most commonly observed in this region in non-chondrodystrophic large breeds of dogs. The author noted that in Dachshunds and other disproportionate dwarf breeds, clinical signs of spinal cord compression were most commonly related to intervertebral disc disease between T11 and T13. This could be attributed to biomechanical indicators, since the trunk at the region around the 10th thoracic vertebra was the most mobile.

Davis and Brown (2002) stated 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.
Macias et al. (2002) found that among 99 dogs with thoracolumbar disc disease 69 percent of the affected discs were located between T12/T13 and L2/L3.

Sanders et al. (2002) reported an unusual case of spinal cord disease in a dog due to a spinal cord hamartoma, which is a nonneoplastic overgrowth of cells or an improper proportion of cells that are normally seen in the involved tissue. The authors 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. The authors opined that intramedullary extrusion of intervertebral disc material was a rare complication of intervertebral disc disease and was typically associated with fibrocartilaginous emboli.

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 T3-L3 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) studied 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) found that the body weight of 22 dogs and 16 cats with spinal injury, 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. The authors also noted 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) opined that acute spinal cord injuries in dogs and cats might result from 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.

Jones et al. (2005) found that degenerative myelopathy (DM) commonly affects German shepherds, Siberian huskies, adult miniature Poodle, welsh Corgies and a cat, based on the available literature.

Kinzel et al. (2005) stated that herniation of the intervertebral disc was the most common cause of neurological trauma in the dog.

Phua and Heng (2005) reported flaccid paralysis and loss of patellar reflexes in 15-month old spayed female mongrel dog as a result of motor vehicle accident.

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.

Gonzalez and Olby (2006) reported fecal incontinence associated with epidural spinal haematoma consequent to intervertebral disc extrusion at thoracolumbar region in a 7-year old castrated male Great Dane.
Levine et al. (2006) conducted a study in 75 Dachshund dogs to determine whether body weight, body condition score or various body dimensions were associated with acute thoracolumbar intervertebral disc extrusion or protrusion and whether any of these factors were associated with severity of clinical signs. The results showed that mean distance between first thoracic vertebra and first sacral (T1-S1) and median tuber calcaneus-to-patellar tendon (TC-PT) were significantly shorter in affected animals than in unaffected animals. A 1-cm decrease in T1-S1 distance was associated with 2.1 times greater odds of being affected and 1-cm decrease in TC-PT distance was associated with 11.1 times greater odds of being affected. Multivariable logistic regression also indicated that affected dogs were taller at the withers and had a larger pelvic circumference than unaffected dogs. Results of original logistic regression indicated that longer T1-S1 distance, taller height at withers and smaller pelvic circumference were associated with more severe spinal cord injury.

Matiasek et al. (2006) reported compressive myelopathy due to subfacial seroma following dorsal laminectomy to treat stenotic myelopathy due to congenital malformation of the C2/C3 articular processes in an 11-month old Rottweiler.

Stiffler et al. (2006) reported the prevalence of urinary tract infection (UTI) in dogs with surgically treated type-I thoracolumbar intervertebral disc extrusion as 27% (25 dogs). Prevalence of UTI was 15% (13/89) before surgery, 12% (11/91) at 2-3 days, 16% (12/76) at 4-5 days and 20% (8/41) at 7 days after surgery. Female dogs that could not ambulate or voluntarily urinate, in dogs not administered preoperative cefazoline and dogs whose body temperature fall < 35°C during anesthesia had higher incidence of UTI.

Voss et al. (2006) reported cervical instabilities in 13 cases (12 dogs and one cat) of different origin. Out of 13, six were with cervical spinal instabilities secondary to disc associated wobblers syndrome, four were with traumatic, iatrogenic and disc associated. Cervical spinal fractures in one dog and one cat and congenital atlantoaxial instability in one dog.

Wheeler et al. (2007) reported traumatic vertebral column injuries with age range of 6-72 months and weight of 10-54 Kg in five dogs.
2.2 Complications of posterior paralysis

Griffiths (1972) observed localized myelopathy and extensive necrosis, affecting about two to four cord segments in the majority of dogs with thoracolumbar disc protrusion, on post-mortem examination of eight dog’s spinal cords.

Moore and Withrow (1982) reported gastrointestinal haemorrhage in 15 percent of 155 dogs with intervertebral disc herniation and found that approximately 2% of all dogs with intervertebral disc disease would die from gastrointestinal complications.

Carberry et al. (1989) reported other injuries associated with vertebral trauma in dogs and cats, which includes abrasions and lacerations; fractures of ribs, pelvic bones and femurs; sacroiliac and coxofemoral luxations; lung contusions and pneumothorax; and radial paralysis.

McKee (1990) reported coxofemoral luxation (3 cases) and fractured ribs (2 cases) among 11 cases (21.6%) as additional injuries out of 51 cases of traumatic spinal injury in cats and dogs.

Yovich et al. (1994) reported severe haemorrhagic diarrhoea in three out of 61 dogs (5%) affected with thoracolumbar disc protrusion. 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 meglumine for two days.

Chan et al. (1999) reported gastrointestinal hemorrhage, ulcers and colonic perforations in dogs with intervertebral disc hernias that were treated with dexamethasone.

Rohrer et al. (1999) conducted a study to determine whether healthy dogs given high doses of methylprednisolone sodium succinate (MPSS) develop gastrointestinal ulcers and haemorrhage. Out of 19 male hound type dogs, 10 received intravenously high doses of MPSS at the rate of 30 mg/Kg of body weight initially, then 15 mg/kg at 2 and 6 hours later and subsequently
every 6 hours for a total of 48 hours. While 9 dogs received equal volume of saline (0.9% sodium chloride) solution.

Gastroduodenoscopy was performed before and after treatment and found hemorrhage in all dogs after MPSS administration and was severe in 9 of 10 dogs but not visible in any dog after the saline treatment. Occult blood was detected more commonly (9/10 vs. 2/9), median gastric acidity was greater (pH 1 vs pH 3) and food was retained more commonly (7/10 vs. 1/9) in the stomach of MPSS treated dogs. Hence advocated mucosal protectants or antacids in dogs treated with high dose of MPSS to prevent gastric hemorrhage.

Rohrer et al. (1999 b) opined that administration of misoprostal (4-6mg, PO, q 8h) did not prevent gastric hemorrhage caused by high doses of MPSS.

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.

Voss and Montavon (2004) reported concomitant injuries in 20 out of 38 dogs and cats with thoracolumbar injury. 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.

Chandy and Vasanth (2006f) reported concurrent injuries and complications in 47 dogs presented to the college hospital with traumatic posterior paralysis. Hemorrhagic gastroenteritis was observed in 5 dogs. Cystitis was present in two female dogs. Bilateral quadriceps contracture, luxation of the left hip and priapism and subsequent penile trauma were seen in one dog. Among dogs subjected spinal fixation, seroma formation at the site of surgery was a common finding. However, seromas were larger when decompressive procedures were done as adjuncts to spinal fixation. Implant failure due to inability of the vertebrae to hold the implants on the day of surgery itself was seen in a five months old dog with osteodystrophia fibrosa. Implant failure was observed in a dog with a highly unstable oblique fracture of the L5 vertebral body on the day of surgery itself. One dog in which hemilaminectomy was performed developed paralysis of the abdominal wall on the side on which the procedure was performed.
Gonzalez and Olby (2006) reported upper motorneuron fecal incontinence in a castrated male Great Dane as result of epidural spinal haematoma at thoracolumbar region (T13-L1).

Levine et al. (2006) observed the complications like urinary incontinence, paraplegia, paraspinal hyperesthesia and long term disabilities in dogs affected with intervertebral disc extrusion in thoracolumbar region.

2.3 Clinical examinations and grading of patients

Gage (1968) observed 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 39ºC (102.2ºF).

Trotter et al. (1975) evaluated motor function based on scale of paresis and ataxia as follows.

- Grade 5 – normal
- Grade 4 – animal walked with minimal paresis-ataxia
- Grade 3 – animal walked but frequently stumbled moderate paresis-ataxia
- Grade 2 – animal walked with assistance, stumbled and fell
- Grade 1 – animal could not walk, slight movement when supported by tail

Griffiths (1982) graded 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) graded the dogs with spinal cord injury with 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 the dogs with intervertebral disc disease into five 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) categorized the dogs with thoracolumbar disc disease on the basis of severity of the neurological deficit as follows:

Grade I - hyperaesthesia only
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. The authors 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 and graded the 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

Wheeler and Sharp (1994) explained how physical, and neurological examination of a patient with spinal cord injury had to be performed to localize lesions and to help prognostication. The authors 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. It was also explained the evaluation of spinal reflexes like panniculus reflex, patellar reflex, flexor reflex, perineal reflex etc.

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

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) stated 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. The authors 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.

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. The authors 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. The authors 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
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) found 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) found 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.

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).
Rossmeisl et al. (2005) used a scoring system modified by Rusbride et al. (1998) to objectively grade each dog’s neurologic status. A numerical grades (0-5) was assigned, where

Grade 0 – equivalent to a normal neurologic status
Grade 1 to 3 – ambulatory dogs with proprioceptive motor that were mild, moderate, severe.
Grade 4 – non-ambulatory tetraparesis or tetraplegia with out respiratory compromise
Grade 5 – tetraplegia with respiratory compromise

Reported excellent outcome in 16 dogs (3/4\textsuperscript{th} dogs with caudal cervical spondylomyelopathy, 1/2 dogs with spinal neoplasia and one with vascular anomaly), which were subjected to a modified lateral surgical approach to the cervical spine. None of the dogs had showed post-operative deterioration in neurologic status.

Tartarelli et al. (2005) subjected the 23 dogs for extensive hemilaminectomy involving all the compressed spinal segments. Out of 23 dogs, 21(91 %) recovered and regained ambulatory function, while the two dogs with out deep pain perception before surgery did not improve. Further they also reported disc extrusion recurrence in two dogs (9 %) at two and twenty months after surgery and 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

Chandy and Vasanth (2006\textsuperscript{d}) subjected 18 dogs presented to the college hospital with traumatic posterior paralysis to detailed clinical and neurological evaluation. The means of heart, rectal temperature and respiratory rates were 113.3 ± 1.60, 27.72 ± 0.80 and 102.3 ± 0.13 respectively. The dogs were studied for changes in attitude, posture and gait. They were examined
for presence or absence of conscious proprioception and deep pain sensation in hind limbs. Status of bladder function was evaluated and they were subjected to tests for panniculus reflex, patellar reflex, anal sphincter reflex and flexor reflex. The dogs were graded on a scale of 1 to 5 based on the findings of neurological examination. Among the 18 dogs, two, fourteen and two were graded 3, 4, and 5 respectively. Detailed neurological examination and grading of the patients was useful for localization of the spinal lesions and to indicate the prognosis of the patients.

Da Costa et al. (2006) performed physical and neurological examination daily and gait monitoring hourly from about 4-12 hours post surgery and then once daily in dogs which underwent a modified thoraco-lumbar dorsal laminectomy for creation of laminectomy defect to evaluate the effectiveness of cellulose membrane (CM) or free fat graft (FFG) on laminectomy membrane formation.

Gonzalez and Olby (2006) observed in a 7-year-old castrated male Great Dane, mild muscle atrophy in both hind limbs, 132 beats/minute heart rate and rectal temperature of 101.8°F on physical examination. Neurologic examination revealed abnormal posture at rest with a wide based hind limb stance and mildly paraparetic with hind limb ataxia during walking. Postural reactions including conscious proprioception were decreased in the left hind limb and were normal in all other limbs. Mild hyperesthesia was detected on palpation of the lumbosacral junction of the vertebral column.

Levine et al. (2006) used modified Frankel spinal cord injury scale to grade severity of neurologic dysfunction. They were

Grade 0 – paraplegia with no deep pain sensation
Grade 1 – paraplegia with superficial nociception
Grade 2 – paraplegia with nociception
Grade 3a – non-ambulatory paraparesis with weight bearing
Grade 3b – non-ambulatory paraparesis with non-weight bearing
Grade 4 – ambulatory paraparesis and ataxia
Grade 5 – spinal hyperesthesia
Stiffler et al. (2006) graded the ambulatory and urine status of the dogs affected with type-1 thoracolumbar intervertebral disc extrusion as follows.

- Non-ambulatory – unable to bear own body weight
- Weakly ambulatory– able to bear own body weight with minimal assistance
- Strongly ambulatory– able to walk with out assistance

Urine status was categorized as

- Voluntary– able to empty the urinary bladder with out assistance
- Non Voluntary– required complete or partial evacuation of the urinary bladder

Voss et al. (2006) performed pre-operative neurological status in 13 cases (12 dogs and one cat) with cervical spinal instabilities of different origin and graded as follows

- Grade 1 – animals with neck pain only
- Grade 2 – animals with ambulatory tetraparesis
- Grade 3 – non-ambulatory tetraparesis and intact deep pain sensation
- Grade 3a – paretic animals with normo/or hyperreflexia of the fore limbs
- Grade 3b – paretic animals with hyperreflexia of one or both fore limbs

2.4 Diagnostic imaging

2.4.1 Plain radiography

Carberry et al. (1989) evaluated the patients with thoracolumbar fractures or fracture/dislocations under sedation or general anaesthesia, radiographically. 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.

The authors 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. The authors 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. The authors 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.
The authors 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) conducted radiographical 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) took 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) performed radiography, 16 months after vertebral fixation with Steinmann pins and orthopaedic wires which showed that all the implants were still in place and the alignment was the same as it was post-surgically.

Bagley et al. (2000) stated 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) stated 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) noted 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. The authors could not identify any soft tissue tumour on plain radiography. The authors 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. The authors 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) performed survey radiographs for identifying spinal lesions associated with posterior paralysis in dogs and to evaluate the stability of implants post-operatively. He was able to identify implant failure in postoperative radiographs in one dog.
Loughin et al. (2005) subjected 48 dogs with type-1 thoracolumbar intervertebral disc extrusion for lateral and ventrodorsal survey radiographs followed by myelogram to diagnose spinal cord compression. The myelography was performed with lohexol injected at L5-L6 at the rate of 0.5 ml/Kg.

Penderis et al. (2005) observed similar radiographic appearance in all four cases, with aplasia or hypoplasia of the caudal articular facet at one or more intervertebral joints in the thoracolumbar region. Bone proliferation was evident secondary to an associated degenerative joint disease. While the myelography and magnetic resonance imaging revealed compensatory hyperplasia of the adjacent cranial articular facets and ligamentum flavum protrusion in to the vertebral canal resulting in a compressive myelopathy.

Chandy and Vasanth (2006) subjected 47 dogs with posterior paralysis to survey radiography for determining the site and type of spinal injury and opined that plain radiography was often adequate to diagnose subluxations, luxations, fractures, fractures-luxations of the vertebral column. However, mild cases of subluxations were often less appreciable in survey radiographs.

## 2.4.2 Myelography

Wright and Jones (1981) performed myelography in 68 dogs by cisterna magna or lumbar route using metrizamide (160mg l/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) noted 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. The authors stressed that failure to recognize this basic difference might be cause for erroneous myelographic diagnoses in Dachshunds.

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

McKee (1990) considered myelography in 51 dogs and cats with traumatic spinal injury, as helpful tool 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) used iohexol or metrizamide for myelography in 60 dogs with thoracolumbar disc protrusion by lumbar puncture. 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)** 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)** opined 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 20º. The authors described in detail the procedure for cisterna magna puncture for collection of cerebrospinal fluid and administration contrast agent for myelography.

**Yovich et al. (1994)** performed 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)** observed 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) stated that myelography could 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) noted 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.

The authors 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) opined 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) performed 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
Gopal and Jeffery (2001) stated 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 weights. It was 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 cerebellomedullary 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) performed 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) not reported any adverse effect in dogs following myelography using iohexol.

Amritveer Kaur and Singh (2004) performed myelography in 13 dogs suffering from various spinal affections, by using Iohexol (300mg I/ml) at 0.45mg/Kg body weight and opined that this quantity of Iohexol was sufficient to produce good quality myelograms up to the cauda equina, in cases where there was no damage to the spinal cord. Partial impairment to the flow of the agent indicated partial compression, while the complete obstruction to the flow indicated complete severance of the spinal cord.

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) performed 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 45º 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) observed 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.

Chandy and Vasanth (2006c) subjected 47 dogs with posterior paralysis to survey radiography for determining the site and type of spinal injury. Of these, 20 were subjected to myelography and opined that myelography was efficient in identifying spinal cord compression in all cases studied.

Da Costa et al. (2006) performed lumbar myelogram at L5-L6 or L4-L5 using 22 gauze (0.73 mm), 6.35 cm spinal needle and 0.3 ml /Kg of Iopamidol. Radiographs were taken immediately after contrast injection and graded myelographic abnormalities as follows
- Grade 4- marked attenuation: spinal cord compression was evident
- Grade 3-moderate attenuation; loss of the dorsal contrast column without spinal cord compression
- Grade 2- slight attenuation; thin narrowing of the contrast in the dorsal subarachnoid space
- Grade 1-normal; neither narrowing nor spinal cord compression

Riaz et al.(2006) performed myelography in twelve cases of posterior paralysis in dogs, which did not show gross lesions such as fracture or dislocations on survey radiographs to diagnose stenosis of spinal canal in three animals at the level of intervertebral space between L1-L4, L3-L5 and L3-L5 vertebra and opined that myelography was effective for diagnosis of spinal compression in cases of posterior paralysis.
2.4.3 Advanced diagnostic techniques

Sharp et al. (1995) opined that computed tomographic (CT) myelography had been found to be more sensitive than myelography for characterizing morphology of the spine in humans, horses and dogs.

Bagley et al. (2000) opined 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) noted 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) stated that the 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.
The authors 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) used 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. (2002a) 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. It was 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. The authors 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) used 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). The authors 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. The authors also performed computed tomography in five dogs with spinal arachnoid cysts after intrathecal administration of iohexol (240 mg l/ml) at the rate of 0.3 ml/kg body weight.

Ito et al. (2005) observed the prognostic value of magnetic resonance imaging in dogs with paraplegia caused by thoracolumbar intervertebral disc extrusion. It was 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. The authors 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.

Jones et al. (2005) described computed tomography (CT) characteristics of the thoracolumbar spine in 8 large breed dogs with degenerative myelopathy (DM) and three large breed dogs that were clinically normal. In all dogs, CT myelography identified morphologic abnormalities that were not suspected from conventional myelograms. Characteristics observed with higher frequency in DM versus normal dogs were: spinal stenosis, disc protrusion, fecal attenuation of the subarachnoid space, spinal deformity, small spinal cord and paraspinal muscle atrophy. Mean spinal cord: dural sac, spinal cord: vertebral canal, dural sac: vertebral canal and vertebral canal: vertebral body ratios were smaller in DM versus normal dogs at more than one disc level.

Ness (2005) opined 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.

Phua and Heng (2005) used computed tomographic (CT) to diagnose comminuted fracture of the body of T12 with dorsal displacement of the right caudal segment in a 15-month-old spayed female mongrel dog.

Boudrieau (2006a) used computed tomography (CT) and magnetic resonance imaging in 4-month old male moderately ataxic and tetra paretic Border collie pup with a history of collapsing episodes. Which revealed a severe malformation and malalignment of cervical spine with six
cervical vertebrae with a portion of C₂ and C₃ absent. Severe cord compression was present in the region of C₁₂ by adjacent soft tissue.

Bruecker (2006a) opined that advancements in diagnostic imaging has made cross sectional imaging modalities (CT and MRI) and three dimensional reconstruction software invaluable tools in the diagnosis, assement and treatment of spinal conditions. Fluoroscopy and digital radiography could be useful tool in the operating room when placing implants.

Chandy and Vasanth (2006c) subjected 47 dogs with posterior paralysis to survey radiography for determining the site and type of spinal injury. One dog was subjected for digital radiography, Computed tomography (CT) and magnetic resonance imaging (MRI) and opined that CT helped to visualize fractures better compared to conventional radiography. MRI was helpful in determining the actual status of the spinal cord and appeared to be the best technique for studying the spinal cord compared to any other technique.

Gonzalez and Olby (2006) used magnetic resonance imaging (MRI) unit to diagnose epidural spinal haematoma and intervertebral disc extrusion in thoracolumbar portion of vertebral column in a dog. The sagittal T₂ weighted and short T₁ inversion recovery images revealed subtle narrowing of T₁₃-L₁ intervertebral space and hypo intensity of corresponding intervertebral disc. On sagittal and transverse T₂ weighted, an area of signal void that was overlaid dorsally by an isointense epidural mass was detected in the vertebral canal above T₁₃-L₁ intervertebral disc space.

Matiasek et al. (2006) used magnetic resonance imaging to diagnose subfascial seroma in dogs following cervical dorsal laminectomy, as a measure to decompress spinal cord compression at C₂/C₃. It allowed detection of high signal intensity material on T₂ weighted images and low signal intensity in T₁ weighted images.

Platt et al. (2006) used 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 Laboratory examination
2.5.1 Haematology

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

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

Wheeler and Sharp (1994) observed 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) conducted a complete blood count and urinalysis in a nine-month-old dog with intradural extramedullary nephroblastoma in the L2-L3 region the results were within the normal reference ranges.

Sanders et al. (2002) found the results of 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) not found 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) noted 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.

Gonzalez and Olby (2006) found, in a dog suffering with upper motor neuron fecal incontinence as a result of secondary epidural spinal haematoma and intervertebral disc extrusion in thoracolumbar region, a mild thrombocytopenia (183 x 103 platelets/µL) on routine blood analysis.

2.5.2 Serum biochemistry

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

Simesen (1980) noted no changes in serum calcium or phosphorus in animals with paraplegia.

Chaudhari (1997) found 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) observed values within normal reference ranges with regard to complete blood count, serum biochemistry profile and coagulation profile 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) found 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 observe any changes in serum alanine aminotransferase or aspartate aminotransferase in animals with paraplegia. Even serum calcium, phosphorus and potassium levels were also not expected to change in animals with paraplegia.

Tidwell *et al.* (2002) observed 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. The author 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.

Chandy (2006) reported no change in the values of serum calcium, phosphorous and potassium values, aspartate aminotransferase and alanine aminotransferase were within the normal physiological range in 18 clinical cases of posterior paralysis on the day of presentation as well as on the specific days of study period.

Levine *et al.* (2006) conducted a study to detect the presence of matrix metalloproteinase-9 (MMP) in serum and cerebrospinal fluid (CSF) and to determine its relationship with severity of disease, duration of clinical signs and duration of hospitalization in 35 dogs with intervertebral disc disease (IVDD) and 8 normal dogs. The activity of MMP-9 in CSF was detected in 6 of 35 dogs with IVDD, activity was significantly more common in dogs with duration of signs < 24 hours.
Paraplegic dogs were more likely to have MMP-9 activity in CSF than nonparaplegic dogs. No significant difference in hospitalization time was detected in dogs with IVDD between those with and without activity of MMP-9 in the CSF. Serum MMP-9 was detected more frequently in dogs with IVDD than in control dogs.

2.5.3 Cerebrospinal fluid analysis

Indrieri et al. (1980) studied 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. The authors 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) found 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) observed 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) analyzed 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) collected cerebrospinal fluid from the cisterna magna and the lumbar subarachnoid space in 97 dogs with thoracolumbar disc disease using a 22 gauge spinal needle. The authors 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) collected and analzed lumbar cerebrospinal fluid 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) examined cerebrospinal fluid in four dogs with cervical intervertebral disc prolapse and found they were normal.
McKee (2000) indicated cerebrospinal fluid analysis 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) collected cerebrospinal fluid 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 the cerebrospinal fluid cells 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) analyzed 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) found 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 on routine cisternal cerebrospinal fluid analysis.

Macias et al. (2002) observed xanthochromic in 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, the authors did not mention the site from which the cerebrospinal fluid was collected.

Sanders et al. (2002) found that in the cerebrospinal fluid from the lumbar cistern contained a high protein concentration (121.9 mg/dl; reference range, < 35 mg/dl) without evidence of pleocytosis albuminocytologic dissociation) in a dog with paraparesis due to intramedullary spinal cord hamartoma.

Gnirs et al. (2003) found 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.

Bohn et al. (2006) conducted a retrospective study to assess and compare the diagnostic information contributed from magnetic resonance imaging (MRI) and cerebrospinal fluid analysis
(CSF) in 256 dogs affected with neurologic disease. Results showed that MRI abnormalities were found in 89% and CSF abnormalities in 75% of dogs. CSF abnormalities were more common than MRI abnormalities only in inflammatory CNS disease. Hence the authors opined that the majority of CSF abnormalities were nonspecific, an etiologic diagnosis was determined only in 2% of CNS samples. MRI excelled in detecting structural disorders, revealed 98% of vertebral abnormalities. In confirmed cases 76% of MRI and 9% CSF samples were diagnostic. Therefore concluded that CSF analysis might not be necessary when MRI findings of IVDD (intervertebral disc disease) or vertebral malformation instability were obvious, however when the cause of neurologic disorder was uncertain, concurrent MRI and CSF analysis provides the greatest assistance in establishing a clinical diagnosis.

Chandy (2006) observed that the colour, clarity and cell type of cerebrospinal fluid obtained from the cisterna magna in all dogs were normal. Mean values of specific gravity, cell count and total protein were also within the normal range in all 18 clinical cases of posterior paralysis.

Fry et al. (2006) conducted a study to determine the effects of time, protein concentration and presence or absence of exogenous stabilizing agents on standard cerebrospinal fluid (CSF) analysis. Thirty abnormal CSF samples from 26 dogs were evaluated for total nucleated cell count (TNCC), differential cell count (DCC) and cell morphology for all groups and protein concentration for selected groups. The results of the study concluded that delayed analysis of canine CSF by 4-8 hours was likely to alter diagnostic interpretation, especially for samples with protein concentration > 50 mg/dL. The likelihood of misinterpretation was higher for samples with low cellularity or low protein concentration. Adding of either fetal calf serum or hydroxy ethyl starch was found to improve sample stability.

2.6 Non surgical treatment

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. The authors reported 14.8 percent recurrence in cases where fenestration alone was undertaken.

Trotter et al. (1988) administered potent glucocorticoid (dexamethasone) systemically 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. The authors 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. The authors 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) used corticosteroids with or without external support to treat vertebral fractures and luxations in 12 dogs and 5 cats. 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 upto three years following surgery.

Brown and Hall (1992) recommended the usage 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. The authors 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 Ca2+
accumulation, reduction of neurofilament degradation and enhanced neuronal excitability and synaptic transmission.

Coughlan (1993) stressed 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. The author 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) used either 2 mg/kg of dexamethasone or 10 mg/kg prednisolone sodium succinate intravenously pre-operatively, in all the 61 dogs with thoracolumbar disc protrusion treated by lateral spinal decompression, except for three dogs that had haemorrhagic diarrhea.

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) adopted a routine nursing care after evaluating magnetic resonance imaging for no extra-parenchymal compression of the cervical spinal cord, to prevent complications of recumbency, manual expression of bladder, removal of faeces from the rectum.
and physiotherapy, in a tetraplegic nine-year-old female crossbred dog, which sustained cervical spinal cord injury following a fall.

Davis and Brown (2002) administered, no corticosteroids in 42 dogs (39%), out of 112 dogs with thoracolumbar disc extrusion. 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 and found that 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. The authors concluded that steroid protocol was not beneficial.

Macias et al. (2002) observed 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) treated tetraparetic three-year-old Doberman pinscher 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 to nonsurgical treatment which involved ultrasound therapy of the back for 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, in cases where owners did not agree for surgical treatment due to financial or emotional reasons. The dogs were also administered B complex vitamin tablets orally daily for a period of six weeks and opined that this method of treatment was better than surgical stabilization of the vertebrae in paraplegic dogs.
Steiss (2004) discussed 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 up to 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.

Having et al. (2005) opined that non-surgical management of atlanto-axial subluxation by use of a cervical splint, was a viable treatment modality for young dogs with a first episode of acute-onset of clinical signs, regardless of the severity of neurologic deficits at admission.

Kinzel et al. (2005) indicated the medical treatment in animals with intervertebral disc disease experiencing back pain or mild paresis or chronic loss of deep pain in pelvic limb, as well as in cases whose owners declined surgical treatment.

Ness (2005) opined that despite controversies about the usage of high dose of dexamethasone therapy in the treatment of canine disc disease, it continued to be used despite the fact that such treatment was found to cause gastrointestinal bleeding in as many as 15 percent of the patients and mortality rates of up to two percent.

Boudrieau et al. (2006a) delayed an occipitocervical fusion until 8-months of age due to skeletal immaturity and successfully managed conservatively by applying neck splint in a 4-month-old male ataxic, tetraparetic Border Collie, with a history of collapsing episodes and at the end of period found that dog was able to walk with minimal support but was moderately ataxic and tetraparetic.

Boudrieau et al. (2006b) described the rationale for medical management based up on the pathophysiology of acute spinal cord trauma (contusion and laceration) which initiates progressive series of pathologic events such as ischemic damage, neurologic deficits. To overcome ischemic damage he suggested methylprednisolone sodium succinate (30 mg/Kg IV plus multiple dosing: 15
mg/Kg at every 2 hours, followed by a continuous infusion at 2.5 mg/Kg at every 1 hour for 48 hours). Treating this ischemia, which resulted from the continued cord compression was the identical rationale for the surgical management.

Chandy and Vasanth (2006a) Evaluated the efficacy of medical and surgical treatment for traumatic posterior paralysis in 18 dogs and observed that 9 out of 12 dogs (75%) treated surgically by modified spinal stapling with tension band wiring with or with out laminectomy, became ambulatory. But only two out of six (33.33 %) dogs treated medically (Epidural methylprednisolone acetate, B-complex vitamins, cage rest and ultrasound therapy) became ambulatory by 60th post-operative day. Hence the authors concluded that surgical treatment improved the chances of recovery in dogs with traumatic posterior paralysis compared to those treated surgically.

2.7 Surgical treatment

Gage (1968) reported the treatment of fracture of the odontoid process and the cranial vertebral body 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) applied small bone plates to the dorsolateral aspect of the vertebral bodies in 20 dogs (11dogs were subjected to hemilaminectomy and vertebral body plating at various locations along the spine and in the rest 9 dogs spinal instability was created and affixed with small bone plates of varying length) to immobilize unstable spinal column. Evaluated the technique for its efficiency in immobilizing simulated spinal luxations. 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.

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 nineyear-old Doberman pinscher. The plate was fixed to the dorsal spinal processes using bolts through holes drilled through them.

Yturraspe and Lumb (1972) described the surgical technique for immobilizing the canine spine by plating the dorsal spinous processes with plastic plates. Plastic plates were attached by placing bolts between rather than through the spinous processes. The authors opined that these plastic plates provide a greater bone-plate contact than was possible with metal plate and plastic being some what flexible, confirm to the curvature of spinous processes.

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.

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) performed minihemilaminectomy to decompress spinal cord and opined that as it preserved the articular processes, resulted in less instability.

Dulisch and Withrow (1979) opined that plastic plates were a rapid and easy method to realign and stabilize the spinal column of dogs. They observed that these plates gave greater bone to plate contact than metal plates. In addition they distributed the pressure on the spinous processes over a larger surface area preventing fracture of spinous processes.
Shores (1985) observed 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.

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. The authors concluded that Steinmann pins and methylmethacrylate would be very useful for the treatment of cervical vertebral fractures and dislocations.

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 was 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. The authors 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 percutaneous discectomy in dogs.

Shores et al. (1989) used 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.

McKee (1992) performed hemilaminectomy in 30 dogs to treat intervertebral disc protrusion 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.

Touliatos et al. (1992) observed the advantages of minimally invasive methods of spinal surgery like faster recovery, lower infection rates and less perineural fibrosis.

Coughlan (1993) recommended a 30 mg/kg dose of methylprednisolone sodium succinate at the time of 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 in view of the risks of iatrogenic cord damage during surgical procedures entering the spinal canal.
Wheeler and Sharp (1994) advised the dog to 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. The authors 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.

Muir et al. (1995) stated that removal of disc material from the spinal canal was the most important objective during decompressive surgery. If the disc material remained in the spinal canal, resulted in residual spinal cord compression, which led to poorer results after surgery.

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 nonambulatory.

Bagley et al. (2000) 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. The authors 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.

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

Kanomori et al. (2001) opined that free fat graft seem to work better than most materials studied and were most popular materials used in spinal surgery of dogs and humans.

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 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) performed hemilaminectomy and fenestration in paraplegic animals and reported 86% success rate in 71 dogs with thoracolumbar and 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) performed dorsal laminectomy to decompress the spinal cord due to T3-T4 disc herniation in a dog and advised to take care not to displace it during dorsal laminectomy. Since the spinal cord was a highly vulnerable tissue.

Macias et al. (2002) treated 72 dogs with thoracolumbar disc disease by hemilaminectomy. Two of these dogs had vertebral body plating as well. The authors 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. It was postulated that vertebral stabilization was more likely to be useful in larger, younger dogs with a single affected disc.

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, the authors 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. The authors 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 the advantages of external skeletal fixation of the canine spine 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. The authors inferred that external skeletal spinal fixation constructs had biochemical properties comparable with polymethylmethacrylate/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.

Moissonnier et al. (2004) performed lateral corpectomy in 15 dogs with signs of chronic thoracolumbar disc herniation and opined that corpectomy permits relatively easy removal of protruded disc material from within the vertebral canal in chronic disc disease with out further iatrogenic injury to the spinal cord.
Voss and Montavon (2004) reported the use of tension band stabilization of fractures and luxations of the thoracolumbar vertebrae in 38 dogs and cats. 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.

Kinzel et al. (2005) performed partial percutaneous discectomy in 331 dogs to treat thoracolumbar disc protrusion. Observed that the 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. The authors 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.

Rossmeisl et al. (2005) suggested a modified lateral approach to the cervical spine for dogs of all sizes to treat caudal cervical spondylomyelopathy, other anomalous conditions of the cervical spine, intervertebral disc disease and spinal neoplasms.
Shales et al. (2005) defined a safe corridor to facilitate screws insertion in lag fashion with in the sacral body for fixation of sacroiliac fracture-luxation injuries in dogs and advocates angle of 97° from the articular surface which avoids penetration of the vertebral canal in all sacra measured but risks ventral exit from the body in 30% of sacra studied.

Tartarelli et al. (2005) observed that extensive hemilaminectomy (from 3-7 vertebrae) could adequately decompress the spinal cord after disc extrusion associated with extensive epidural haemorrhage (DEEH) and may produce a recovery and recurrence rate similar to thoracolumbar disc extrusion not complicated by extensive epidural haemorrhage.

Boudrieau (2006a) made no attempt to alter the orientation of the malformed vertebrae nor was any decompression performed in 4-month old male moderately ataxic and tetraparetic Border Collie, affected with malformation and malalignment of cervical vertebrae (portion of C2 and C3 absent). Through dorsal approach to the caudal half of the skull and the entire cervical spine, applied two 3.5 mm LCP reconstruction plates to each side of dorsolateral cervical spine to stabilize the area. Locking screws were secured in to the area of sagittal crest of the skull and the bodies of the last two cervical vertebrae. A synthetic graft rh BMP-2 /BCP collagen was placed along the length of each plate.

Boudrieau (2006b) described the use of distraction technique using either the Scoville-Haverfield self-retaining laminectomy retractors or a modified gelpi forceps for reduction of C2 fracture/luxation after performing fenestration and partial ventral slot at C2-3. This technique was employed in 13 dogs (8 with Scoville frame and 5 with modified gelpi forceps). The author opined that an approximate 10-fold increase in force generated by the Scoville frame in comparission to the gelpi forceps. The technique of distraction provided a single method to reestablish spinal cord integrity and there by decompress the spinal cord. Inaddition, it also provided a simple method to hold the fracture in reduction during the application of stabilization (screws and methylmethacrylate).
Bruecker (2006a) opined that laminectomies and hemi laminectomies were by nature destabilizing procedures since they mean the loss of important dorsal compartment stabilizers. With the concurrent loss of stability in the ventral compartment due to degenerative disc, hence adopts minimally invasive techniques like pediculectomy and minihemilaminectomy for approaching spinal canal.

Bruecker (2006b) describes methylmethacrylate (PMMA) plug technique to stabilize the cervical spine in the cervical vertebral instability patients (CVI) and also an egress channel for the PMMA in the caudal aspect of the vertebra cranial to the diseased disc to overcome ventral plug migration.

Bruecker (2006a) advocates locking plate/screw implants application to the vertebral bodies, which would improve overall stability of the construct and permit unicortical vertebral body application minimizing potential trauma to the spinal cord.

Da Costa et al. (2006) evaluated the effectiveness of cellulose membrane (CM) or free fat graft (FFG) on laminectomy membrane formation in 16 dogs, which underwent a modified dorsal laminectomy on T_{13}-L_{1}. The results showed that they were partially effective in preventing laminectomy membrane formation but were associated with neurological deficits and spinal cord changes, hence recommended to avoid FFG or CM implants when performing modified dorsal laminectomy in thoracolumbar area in the dogs.

Chandy and Vasanth (2006b) performed modified spinal stapling with tension band wiring for traumatic posterior paralysis in 6 dogs and opined that the technique provided adequate stabilization of the vertebral column.

Chandy and Vasanth (2006c) performed hemilaminectomy in six out of 12 dogs with traumatic posterior paralysis presented to the college hospital as an adjunct to the spinal fixation by modified spinal stapling and tension band wiring. The procedure was performed on the left side if the site of vertebral injury whenever lateralisation of the spinal cord compression could not be made on myelograms. Four out of six dogs (66.67 %) in which hemilaminectomy was not done
became ambulatory whereas five out of six dogs (88.33 %) in which hemilaminectomy was done became ambulatory by the 60th postoperative day. A marginally better clinical outcome resulted when hemilaminectomy was combined with spinal fixation.

Gonzalez and Olby (2006) performed right sided hemilaminectomy to further characterize the lesion and decompress the spinal cord in a dog suffering with upper motor neuron fecal incontinence as result of secondary epidural spinal haematoma and intervertebral disc extrusion in thoracolumbar region T13-L1.

Matiasek et al. (2006) performed dorsal laminectomy to decompress the cervical stenotic myelopathy due to congenital malformation of the $C_2$/$C_3$ articular processes in an 11-month old Rottweiler.

Voss et al. (2006) evaluated clinical application of the Compact Unilock system for ventral stabilization of the cervical spine in 13 cases (12 dogs and one cat) with cervical spinal instabilities secondary to the disc associated wobbler syndrome (6 dogs), traumatic, iatrogenic and disc associated (4 cases), Cervical spinal fractures (one dog and one cat) and atlanto-axial instability (one dog). The authors found that the Compact Unilock system was found to be a suitable implant for treating cervical instabilities of different origin in both small and large patients with lesions from $C_1/C_2$ to $C_6/C_7$.

Watine et al. (2006) defined the characteristics of optimum implantation corridors in vertebral bodies $C_2$ to $C_7$ and $T10$ to $S1$, based on computed tomographic measurements of 207 vertebrae from 35 different adult dogs. Based on the results the authors opined that implantation corridors of the cervical vertebrae are narrow, hence the risk of laceration of the vertebral artery is high. Dorsal implantation should not be used for the last four thoracic vertebrae as they have narrow implantation corridors and major anatomical structures are very close to their emergence point. The implantation corridor is wider for first six lumbar vertebrae than thoracic vertebrae, as the vascular structures are far from the emergence point. The last lumbar vertebra and the sacrum have a broad pedicle, which provides an alternative site for implant placement.
Wheeler et al. (2007) used closed fluoroscopic assisted application of external fixator for the stabilization of vertebral column injuries in five dogs and opined that it provided satisfactory reduction and effective stabilization in five dogs.

2.8 Post-operative care

Bardet et al. (1983) used a combination of cephalixin and gentamicin for the treatment of osteomyelitis in small animals.

Blass et al. (1988) reported the use of 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. Postoperative dexamethasone was not used when blood was present in the stools.

McKee (1990) administered the broad-spectrum antibiotics and corticosteroids until return of voluntary control of urination in dogs and cats with spinal injuries. 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) mentioned the special care that had to be taken to present 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 waterproof 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. The
authors 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 postoperative 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 of 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) used 0.5 mg/kg prednisolone orally once a day for five days after partial percutaneous discectomy, in dogs. 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.
Rossmeisl et al. (2005) administered one or more parenteral opioid analgesics, strict confinement for three or more weeks, avoidance of stairs and cervical collars, post-operatively in all the dogs which underwent modified lateral approach to the cervical spine for the surgical treatment of caudal cervical spondylomyelopathic or radiculopathic lesions. Convalescence of nonambulatory patients was further assisted with cart-facilitated exercise, waterbed usage, physiotherapy and hydrotherapy.

Boudrieau (2006a) used cervical splint up to 12th week post-operatively and took radiographs, which revealed substantial bone formation over the entire dorsal aspect of the caudal skull and cervical spine adjacent to both the implanted plates in a 8-month-old pup affected with severe malformation and malalignment of cervical vertebrae. He opined that loss of neurological function seen immediately after surgery was improved 4 days later and in-hospital follow up at 2, 4, 8, 12 and 22 weeks after surgery revealed reduced neck movement without pain and dog functioned normally with unrestricted activity.

Da Costa et al. (2006) used preservative free morphine epidurally at lumbosacral junction to maintain post-operative analgesia, on induction at a dose of 0.1 mg/Kg, in cases which underwent modified dorsal laminectomy on T13-L1, to evaluate the effectiveness of cellular membrane and free fat graft on laminectomy membrane formation.

Gonzalez and Olby (2006) post-operatively used fentanyl patch (100 µg/h), hydromorphone (0.05 mg/Kg,IV, every 4-6 hours) and carprofen (2.2 mg/Kg,PO every 12 hours) and adopted controlled exercise after right sided hemilaminectomy in 7-year-old dog affected with intervertebral disc extrusion at thoracolumbar region.

Voss et al. (2006) post-operatively took radiographs in 13 cases, which underwent Compact Unilock system bone plating for cervical instabilities of different origin, to evaluate restoration of spinal canal and positioning of implants. In these cases post-operative pain control was achieved with morphine, fentanyl patch or a constant rate infusion of morphine and a combination of lidocaine and ketamine.
Wheeler et al. (2007) used spinal arch external skeletal fixator for stabilization of vertebral column injuries in five dogs. Fixator removal time ranged from 65 to 282 days.

### 2.9.1 Post-operative complications

Swaim (1971) stated the drawbacks of applying plates on the dorsal spinous processes for spinal stabilization based on the available literature. 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 prevent the fracture of the dorsal processes, the application of body cast following spinal plating had been advocated. The use of vinylidine 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 like, lymping, unable to extend stifle properly and lack of knee-jerk reflex in the limb on the side on which the nerve had been cut in one dog and in another 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 hindquarters, 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.
Brown et al. (1977) found in a retrospective study that laminectomy membrane formation after surgery was responsible for 10.2% of recurrences in thoracolumbar disc disease in dogs.

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) reported scoliosis and lateral abdominal wall weakness consequent to fenestration by the dorsolateral muscle separation technique as the possible complications.

Trotter et al. (1988) observed, severe post-operative spinal cord compression (constrictive fibrosis) in dogs, caused by laminectomy membrane formation remained the major factor limiting the exposure and decompression achieved by laminectomy in the thoracolumbar region. The authors 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 the complications of thoracolumbar vertebral bodies plating in 51 cases of traumatic spinal injury in cats and dogs. They include, a dog with 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) observed constrictive laminectomy membrane formation consequent to extensive dorsal laminectomy technique. 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) noted that one dog out of 61-exhibited permanent scoliosis post-operatively, which underwent modified lateral spinal decompression for thoracolumbar disc protrusion. 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) observed 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. The authors 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) encountered 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.

Amritveer Kaur and Singh (2004) observed no other complications except for subdural injection in one case while performing myelography in 13 dogs suffering with various spinal affections.

Miossonnier *et al.* (2004) observed seroma formation in one dog out of 15 that underwent corpectomy as a treatment for thoracolumbar disc herniation.

Voss and Montavon (2004) reported complications in six (16%) out of 22 dogs, following tension band fixation of the vertebral column. 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 L1 and subluxations of L1 and L2. The implants became loose with subluxation of T12-T13 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.
Loughin et al. (2005) documented post-operative complications viz, decubital ulcers, recurrent back pain and loss of voluntary motor function in 8 of 48 dogs (16.7 %), which underwent hemilaminectomy with or without durotomy for the purpose of treating type-1 thoracolumbar intervertebral disc extrusion.

Rossmeisl et al. (2005) reported seroma formation as post-operative complication in one dog, which resolved with short-term conservative treatment without drainage and in another dog aspiratory pneumonia, sepsis and fulminant disseminated intravascular coagulation (DIC) out of 16 dogs which underwent modified lateral approach to the cervical spine, for surgical treatment of cervical myelopathic or radiculopathic lesions.

Tartarelli et al. (2005) observed no complications in any of the 23 dogs that underwent hemilaminectomy for intervertebral disc extrusion.

Chandy and Vasanth (2006) reported post-operative complications in 18 dogs with traumatic posterior paralysis presented to the college hospital by spinal fixation with or without hemilaminectomy or non-surgically (Groups A, B and C respectively of six dogs each) They were subjected to radiological evaluation on 0, 1st, 15th, 30th, 45th and 60th days. Lateral and ventrodorsal view radiographs of the affected part of the spinal column were obtained. Variable levels of callus formation were observed during the healing of spinal fractures in all dogs. Recurrence of subluxation was observed in one dog of Group-A on the 15th post-operative day. Implant migration was observed in one dog of Group-B on the 30th post-operative day. In Group-B, no significant change was visible in plain radiographs at the site of hemilaminectomy.

Matiasek et al. (2006) documented compressive myelopathy in dogs due to subfascial seroma, as a complication in dorsal spinal cord approach, particularly in the region of the cervical spine where multiple soft-tissue layers are dissected. Recommends surgical revision and drainage for quick recovery.

Voss et al. (2006) encountered implant failure on follow-up radiographs in one dog with a healed C2 fracture and screw pullout occurred in one dog with caudal cervical
spondylomyelopathy, out of 13 cases (12 dogs and one cat), which were treated for cervical instabilities of different origin by a versatile implant, the Compact unilock system.

2.10 Surgical anatomy of thoracic and lumbar vertebrae

Traumatic spinal cord injury resulting in disruption of the supporting soft tissue structures, fracture and /or luxation of vertebral column, often requiring surgical intervention is common in small animal practice. An understanding of the regional anatomy of thoracolumbar region has a direct significance in the treatment of these traumatic spinal disorders (Bruecker and Howard, 1992).

Thoracolumbar region has irregular bones, the vertebrae, joints, ligaments and epaxial musculature with spinal innervation and segmental blood supply. A typical vertebra consists of a body, a vertebral arch, consisting of right and left pedicles and laminae and various processes, which include transverse, spinous, articular, accessory and mamillary processes.

2.10.1 Parts of typical vertebrae

The **vertebral body** is roughly cylindrical, its flattened dorsal surface form the floor of the vertebral canal, has convex cranial and concave caudal extremities. The body length of the thoracic vertebrae is shorter than those of the cervical or lumbar vertebrae. Width of the lumbar vertebrae increases gradually from first.

The **neural arch** includes two upright pedicles and from each of these a lamina projects medially to complete a ring called vertebral foramen, the summation of these foramina constitutes the vertebral canal. The base of the pedicles is notched and on successive bone articulation, these notches combine to form inter-vertebral foramen, through which blood vessels enter and spinal nerves exit. The various processes are meant for muscular and articular connections.

**The dorsal spinous process** project dorsally from the laminae. Spine of the first thoracic vertebra is more prominent than the others. The prominence 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 caudally through the ninth and tenth segments. The spine of the eleventh thoracic vertebra
(anticlinal vertebra) is nearly perpendicular to the long axis of the bone, and is the transitional segment of the thoracolumbar region. All spines caudal to the eleventh point cranially whereas the spines of all vertebrae cranial to the eleventh thoracic are directed caudally. In the lumbar region, the spinous processes are short.

The paired **articulate processes** are located at the junction of pedicle and lamina of the vertebra. There are two of these on each side of the vertebra— a cranial pair whose articulating facets point upward and forward and a caudal pair whose facets are directed downward and backward. The cranial pair are nearly confluent at the median plane on thoracic vertebrae, 3 to 10. The caudal facets articulate with the cranial ones of the vertebrae behind, are similar in shape, and face opposite direction. The joints between thoracic vertebrae 10 and 13 are conspicuously modified, since the caudal articular facets are located on the lateral surfaces. This type of interlocking articulation allows flexion and extension of the caudal thoracic and lumbar region, but limits lateral movement.

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

Overlying the caudal vertebral notches are the **accessory processes**. They appear first in the mid-thoracic region and seen as far caudally as the fifth or sixth lumbar vertebra. In the lumbar region, the accessory processes are well developed on the first three or four vertebrae, and absent on the fifth or sixth.

The paired **transverse processes** arise at the level of inter-vertebral foramina at the junction of body of the vertebra and neural arch and divide the trunk muscles into dorsal and ventral group. The transverse processes of the thoracic vertebrae are short, blunt and irregular. All have foveae for articulation with the tubercles of the ribs. In lumbar region, the transverse processes are directed cranially and ventrally. They are longest in the mid lumbar region (Evans and Criestense, 1979). Parts of lumbar vertebrae are shown in Fig.1, 2 and 3.

### 2.10.2 Joints in the vertebral column
They are two sets of joints in the vertebral column. The fibrocartilagenous joints bring about direct connection of adjacent vertebral bodies. The synovial joints appear between the articular processes of the contiguous vertebrae and joints between the ribs and vertebrae.

2.10.3 Ligaments of the vertebral column

Long and short ligaments of the vertebral column stabilize the inter-vertebral articulations and maintain the integrity of the spinal cord. The supraspinous, dorsal and ventral longitudinal ligaments are the long ligaments. The short ligaments includes, inter-vertebral discs, inter-spinous, inter-transverse, yellow and conjugal ligaments.

The supraspinous ligament runs over the summits of the spinous process of the first thoracic vertebra to the third coccygeal vertebra. Bilaterally the dense collagenous lumbodorsal fascia blends with it throughout the thoracic and lumbar regions. These ligaments prevent abnormal separation of the spines during flexion of the vertebral column.

Dorsal longitudinal ligament runs along the floor of the vertebral canal from axis to sacrum. It is narrowest at the middle of the vertebral bodies and widens at the inter-vertebral discs.

The ventral longitudinal ligament is located on the ventral surface of the vertebral bodies. In the middle of vertebral bodies it is narrow and widens at the inter-vertebral discs.

Except between C₁ and C₂ in every inter-vertebral space there is a flexible pad, the inter-vertebral discs, connecting the bodies of the adjacent vertebrae. The thickness of the discs is greatest in the cervical and lumbar regions. Each disc consists of peripheral an annulus fibrosus and a central, the nucleus pulposus. The retention of nucleus pulposus with in the fibrous ring absorbs shock and spreads compressive forces over a wide part of the vertebrae, to which the column is very often subjected.

Interspinous ligaments occur between the spinous processes of the adjacent vertebrae and best developed in the thoracic region. Some of the fibers blend dorsally with the supraspinous ligaments.

Between the transverse processes of the lumbar vertebrae are the intertransverse ligaments. They are not distinct in any other regions of the spine.

The yellow ligaments join the arches of the adjacent vertebrae.
Conjugal ligaments join the heads of the given pair of ribs passing transversely between the annulus fibrosus and the dorsal longitudinal ligament (Fig.4, 5 and 6).

2.10.4 Epaxial musculature

The group of the muscles located dorsal to the transverse processes of the vertebrae on either side of the spinous processes constitutes the epaxial muscles. These muscles are divided into three longitudinal muscle masses, each comprising many overlapping fascicles. They are iliocostalis, longissimus, and transversospinalis on lateral, intermediate and deep medially, respectively. The transversospinalis consists mainly of the multifidus and the interspinale muscles. Mammary, transverse or the articular processes of the caudally lying vertebrae gives origin to the multifidus and attach to the spinous processes of the cranial vertebrae. The interspinale muscle runs between the contiguous edges of the spinous processes (Fig.7).

2.10.5 Blood supply

Vertebral column has got segmental arterial blood supply with a spinal branch entering the vertebral canal via the intervertebral foramen. The origin of the branches varies between the regions of the spine. Vertebral venous plexus, comprising two valveless veins on the floor of the vertebral canal, drains into the vertebral veins via intervertebral veins, these may be single or paired, at each intervertebral foraminae. The intervertebral veins are very fragile and can bleed profusely if damaged. Spinal cord in the lumbar region is supplied by spinal arteries. These enter the vertebral canal through intervertebral foramen and branch in to dorsal and ventral reticular arteries, which form anastomotic network on the surface of the spinal cord. The venous drainage of the cord occurs via vertebral venous plexus (Fig.8 and 9).

2.10.6 Nerve supply

At the level of intervertebral foramen each spinal nerve trifurcates in to dorsal, ventral and communicating (Visceral) branches. The dorsal branch courses dorsally and supplies epaxial muscles, vertebrae, ligaments and duramator and subsequently devides in to medial and lateral
parts. The hypaxial muscles receive the nerve supply from ventral branch. The visceral branch carries the motor and sensory fibers to and from visceral structures (Fig.10).