UNIVERSIDADE DE LISBOA

FACULDADE DE MEDICINA VETERINÁRIA

POST-SURGICAL OUTCOME OF THE VENTRAL SLOT PROCEDURE FOR CERVICAL INTERVERTEBRAL DISC DISEASE IN DOGS

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Dr. Ricardo Miguel Pedroso Medeiros

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Relatório do Estágio Curricular

O Estágio curricular iniciou-se no dia 9 de Setembro de 2019 e terminou no dia 1 de Março de 2020, totalizando cerca de 800 horas, tendo sido realizado no Hospital Veterinário do Restelo (HVR) sob a orientação do tutor Dr. Ricardo Medeiros. O Estágio constou de rotações pelas várias especialidades disponíveis no HVR, acompanhando um médico da respectiva área durante 2 semanas. As rotações participadas incluíram: Cirurgia, Cardiologia, Medicina geral/interna, Neurologia, Oncologia, Diagnóstico por Imagem, Dermatologia, Oftalmologia, Exóticos, Internamento e Laboratório. Durante a participação nas rotações clínicas referidas, tive a oportunidade de participar numa panóplia de atividades de índole clínico, tais como:

- Administração de fármacos por diversas vias (parenterais e enteral) bem como a administração de vacinas;

- Participação no posicionamento do paciente e apoio na realização de exames de diagnóstico como Radiografia, TAC, Ecografia, Endoscopia (estômago, cólon e bexiga);

- Participação e assistência em diversas cirurgias como OVH, Orquiectomia, Mastectomia, Laparotomia exploratória, Ventral Slot, Hemilaminectomia, Gastropexia e Enterectomia, por exemplo;

- Colocação de catéter endovenoso e urinário;

- Realização de sedação, anestesia, intubação pré-cirúrgica e monitorização cardiorrespiratória;

- Realização de colheitas de sangue e outros fluidos e análises laboratoriais como hemograma, bioquímicas, ionograma e provas de coagulação, bem como a interpretação das mesmas;

- Recolha de amostras como raspagens cutâneas ou esfregaços de sangue e recolha de fluidos orgânicos por zaragatoa, bem como o seu processamento, coloração e visualização ao microscópio;

- Monitorização de pacientes no internamento em várias vertentes, incluindo exame físico geral, maneio da dor e administração de fluidoterapia e fármacos;

- Participação em exames de cardiologia como ECG e Ecocardiografia;

- Participação em consultas de oftalmologia e cirurgia oftalmológica como a cirurgia da catarata por facoemulsificação ou enucleação do globo ocular, por exemplo.

Abstract

The medical records of 18 dogs, including 12 Chondrodystrophic breed dogs and 8 Non-Chondrodystrophic dogs with Cervical Intervertebral Disc Disease (CIVDD) that were submitted to Ventral Slot decompression surgery and posterior rehabilitation physiotherapy were analyzed. Patients were diagnosed using CT Myelography and subsequently classified as having either Hansen Type I or Hansen type II disc herniation. The most frequent clinical presentation was non-ambulatory tetraparesis (33%). The most frequently affected site for CIVDD were the vertebral segments C3-C4 for Hansen Type I (28%) and C4-C5 for Hansen type II (11%). The patient's neurological status was graded using the Modified Frankel Scale and the difference between their pre-surgical and post-surgical neurological grading was calculated to determine the treatment outcome. The short term post-surgical outcome was positive in 100% of dogs, including 72% with an excellent outcome. A significant correlation was found between the site of lesion and the outcome. Hansen Type I CIVDD patients also showed a more favorable improvement compared to Hansen Type II patients.

KEYWORDS: CERVICAL INTERVERTEBRAL DISC HERNIATION, VENTRAL SLOT DECOMPRESSION, DOG

Resumo

As histórias clínicas de 18 cães, incluindo 12 de raças condrodistróficas e 8 de raças não condrodistróficas com hérnia cervical da coluna vertebral que foram submetidos à técnica cirúrgica Ventral Slot e posterior fisioterapia de reabilitação foram analisados. Os pacientes foram diagnosticados através de TAC com mielografia e subsequentemente classificados como afetados por hérnia do disco hansen tipo I ou tipo II. A apresentação clinica mais frequente foi tetraparésia não-ambulatória (33%). O local mais afetado da coluna cervical foi o segmento C3-C4 nos casos de hérnia hansen tipo I (28%) e C4-C5 nos casos de hérnia hansen tipo II (11%). O estado neurológico dos pacientes foi classificado utilizando a escala de Frankel modificada, sendo que a diferença entre as classificações pré e pós-cirúrgicas foi comparada para determinar o outcome do tratamento. O outcome pós-cirúrgico a curto prazo foi positivo em todos os cães, incluindo 72% com um outcome excelente. Foi encontrada uma correlação significativa entre o segmento afetado e o outcome. Os pacientes com hérnia hansen tipo I mostraram uma melhoria mais favorável comparando com os que sofreram de hérnia hansen tipo II.

PALAVRAS CHAVE: HÉRNIA CERVICAL DO DISCO INTERVERTEBRAL, VENTRAL SLOT, CÃO

Chapter I

1.Introduction

Intervertebral disk disease (IVDD) is one of the most common causes of neurologic deficits in dogs (Amsellem et al., 2003). The disease develops due to intervertebral disk degeneration, which might result in extrusion (classified as Hansen type I herniation) or protrusion (Hansen type II herniation) (Hansen, 1952). Consequently, herniated intervertebral disks can affect the spinal cord, resulting in spine compression and inflammation, which can lead to major neurological complications such as tetraplegia, paraplegia, or even result in death due to respiratory complications (Sharp & Wheeler, 2005; Delauhunta & Glass, 2009).

Cervical disc disease affects 14 to 25% of dogs with IVDD, in which the most frequent cause is disk extrusion (Cherrone, 2004; Coates, 2000). Small dogs are frequently affected, specially chondrodystrophic breeds. Large breeds can also develop this disease, although it manifests more frequently as Wobbler Syndrome. Clinical signs commonly appear after 2 years of age, with a mean onset at 6 years (Sharp & Wheeler, 2005). Clinical presentation is variable and depends on the lesion location, volume of material inside the vertebral canal and its ejection speed (Sharp & Wheeler, 2005; Amsellem et al., 2003).

Treatment can either be medical or surgical, although the most effective treatment is still a controversial subject, since some animals recover by solely using anti-inflammatory and analgesic drugs along with confinement (Sharp & Wheeler, 2005). However, a non-surgical approach is reported to show a high recurrence percentage (Seim III, 2002; Sharp & Wheeler, 2005). Therefore, for many authors and clinicians the ideal treatment should be surgical, regardless of the neurological signs displayed. A recent study in 2019, with a 3-year case follow up, reported that surgical treatment was more successful than conservative treatment, especially in cases of severe spinal cord compression (Kim, et al., 2019). Ventral decompression is usually the preferred surgical approach which might be combined with disk stabilization in caudal disc extrusions (Sharp & Wheeler, 2005).

2. Neuroanatomy & physiology

2.1 Spinal cord

The spinal cord, which lies inside the vertebral canal, is an elongated structure which belongs to the central nervous system (DeLahunta, 2013). Its function is to transport both sensorial and motor information to and from the brain. It extends from the caudal portion of the brainstem, at the foramen magnum, until the conus medullaris, within the sixth lumbar vertebra (L6) in most dogs. The spinal cord fits snugly within the thoracolumbar spine but has a wider residual space in the cervical spine, which is filled by epidural fat (Sharp & Wheeler, 2005; DeLahunta, 2013).

This neurologic structure is divided into five segments: Cervical C1–C8, Thoracic T1–T13, Lumbar L1–L7, Sacral S1–S3 and Caudal, which has a variable number of vertebrae. Cervical and lumbar intumescences are the widest areas of the spinal cord, since they originate the lower motor neurons (LMN) that supply thoracic and pelvic limbs, which correspond to segments C6–T2 and L4–S3, respectively (Sharp & Wheeler, 2005; Dyce, et al., 2010).

The spinal cord is composed of central gray matter and peripheral white matter, divided by a dorsal sulcus and ventral fissure into two halves (Dyce, et al., 2010). From each segment of the spinal cord, ventral and dorsal nervous roots arise, each joining the dorso-lateral and ventro-lateral portion of the segment, respectively. Ganglions are located into the dorsal root before joining the ventral root, at the intervertebral foramen, from which the spinal nerve arise, posteriorly dividing into 2 branches, a dorsal and a ventral branch. The dorsal branch innervates epaxial tissues, while the ventral branch supplies hypaxial tissues, which include the limbs (DeLahunta & Glass, 2009).

2.1.1. Spinal cord tracts

The peripheral portion of the spinal cord is composed of **white matter** divided into three funiculi, which are: The **Dorsal funiculus**, composed of ascending tracts, mostly proprioceptive; The **Lateral funiculus**, which contains both ascending (proprioception and sensory information pathways) and descending (motor pathways) tracts; and the **ventral funiculus**, containing only descending motor tracts (Simon R. Platt, 2014).

The spinal core of **grey matter** contains cell bodies of sensory neurons, interneurons and LMNs (Lower motor neurons). The cell bodies of the LMNs are located in the **ventral and lateral grey columns**. The cell bodies of afferent (sensory) neurons lie on the **dorsal root ganglions** (Simon R. Platt, 2014).

2.1.1.1 Ascending Sensory Tracts (afferent tracts)

These tracts carry sensory information, which is gathered from the peripheral sensory axons, passing the dorsal root ganglia, then ascending through the spinal cord to the brain. These tracts essentially include: **Proprioception** axons, which project from the dorsal and lateral funiculi to either the somesthetic cerebral cortex or to the cerebellum; **Temperature and superficial pain sensation** which are transmitted by myelinated fibers of several tracts, such as the lateral spinothalamic in the lateral funiculus; **Nociception** (deep pain sensation), carried by non-myelinated fibers, particularly in the propriospinal and spinoreticular tracts. These tracts are closely located to the junction of gray and white matter. Consequently, a lesion must be extensive in order to impair all deep pain fibers at a given area. Therefore, the absence of nociception indicates a worse prognostic in Spinal Cord Disease. In addition, **The degree of urinary bladder filling** is also a prognosis indicator, as it is controlled by the spinothalamic tract (Sharp & Wheeler, 2005; Simon R. Platt, 2014).

2.1.1.2. Motor tracts (efferent tracts)

There are two main efferent systems controlling motor function—**the upper motor neuron (UMN) and lower motor neuron (LMN) systems**. UMNs connect the brain to a spinal cord segment, whereas LMNs connect the spinal cord segment to somatic or visceral muscle, which are known as myotomes. (Sharp & Wheeler, 2005; Simon R. Platt, 2014).

The **UMN** are responsible to initiate voluntary movements and regulate their intensity, through their inhibition or activation. They lie in the cerebral cortex and brainstem and establish the connection with the LMN using two distinct pathways: the pyramidal pathways, responsible for fine motor skills, and the extrapyramidal pathways, which are responsible for voluntary movement initiation and locomotion (Dyce, et al., 2010; DeLahunta & Glass, 2009).

The **LMN** cell bodies are present in the grey matter of the cervicothoracic intumescence, which supply the brachial plexus, in the thoracic limbs, and the lumbosacral intumescence, supplying the lumbosacral plexus in the pelvic limbs. In addition, LMNs are the effector neurons of the reflex arc. Therefore, stimuli will be transmitted by sensory fibers towards the spine, triggering a LMN response, in normal conditions (Sharp & Wheeler, 2005).

The **vestibulospinal and reticulospinal tracts**, located in the ventral funiculi, also play a role in motor function, as they facilitate muscle extension. In particular, vestibulospinal tracts facilitate extensors while inhibiting flexors ipsilaterally, while having the opposite effect on the contralateral limbs (Sharp & Wheeler, 2005; DeLahunta & Glass, 2009).

In dogs, there is an **ascending motor tract** that projects from the border cells of the dorsolateral gray matter of the L1–L7 spinal cord segments. These axons ascend laterally through the spine to inhibit the extensor muscles of the thoracic limbs. Disruption of this pathway, as seen in severe thoracic spinal cord lesions, results in marked thoracic limb extension, known as Schiff– Sherrington sign, which will be further described (Sharp & Wheeler, 2005; DeLahunta & Glass, 2009).

2.1.2 Spinal cord nerve fibers and the effect of compression

The white matter tracts of the spinal cord have nerve fibers of different sizes. Proprioception fibers are the largest ones, followed by intermediate-sized motor fibers, while the smallest in diameter are nociception fibers. The largest fibers are more prone to injury than lesser diameter fibers, which are more resistant. The later statement justifies the progression of clinical signs in spinal cord disease. Consequently, the progression of the lesion usually starts with proprioception loss, then the ability to support weight, followed by loss of voluntary movement and, finally, absence of deep pain sensation (Sharp & Wheeler, 2005; DeLahunta & Glass, 2009).

Likewise, the location of the spinal cord tracts also influences the progression of signs. Therefore, proprioceptive tracts, which lie superficially in the spinal cord are the most affected by compression. On the other hand, spinothalamic and ascending propriospinal pathways, which transmit nociception are more deeply located in the spine and cross the spinal cord at certain levels. Thus, a lesion must involve much of the diameter of the spinal cord to inflict deep pain sensation loss (Olby et al., 2003).

2.2 Meninges

The CNS is surrounded by three fibrous membranes, known as meninges. Dura mater, the outer membrane forms a tube along the vertebral canal, where underneath lies the epidural space which stands above the vertebrae and is occupied by epidural fat, fluids and a venous plexus. The inner layers, arachnoid and pia mater (together named leptomeninges) contain a space in between, called the subarachnoid space, where the cerebrospinal fluid (CSF) flows. In addition, the subarachnoid space contains the arachnoid trabeculae, which, along with the denticulate ligaments, suspend the spinal cord within the CSF. The CSF is formed in the brain and is usually a clear fluid with a very low protein and cellular content. It supports and protects the brain and spinal cord against shock as well as providing nutritional properties. Since CSF flows caudally, its collection caudal to a lesion is more likely to aid in diagnosis. (Sharp & Wheeler, 2005; DeLahunta, 2013). The meninges caudal to the conus medullaris form the filum terminale, reaching the sacrocaudal vertebrae (Dyce, et al., 2010; DeLahunta, 2013).

2.4 Relationship of spinal cord segments to vertebrae

Neurological lesion localization refers to spinal cord segments, so it is important to note that spinal cord segments do not always correspond to the vertebra of the same annotation.

Despite regional nerves of the brachial and lumbosacral plexuses being usually constant in their distribution their origins might vary. The plexuses arise from C6 to T1 and from L5 to S3 spinal cord segment in most animals. Nevertheless, the brachial plexus arises from C5 to T1 in about 20% of dogs and from C6 to T2 in another 20%. Likewise, the lumbosacral plexus arises from L3 to S1 in 20% and from L6 to S3 in 20% (Sharp & Wheeler, 2005).

2.5 Vertebral Column

The vertebral column, which protects the spinal cord, is composed of a series of vertebrae, most of which are joined by the intervertebral discs and by synovial joints between the articular processes. The vertebrae are divided into 5 regions, which can be represented by the following formula: C7, T13, L7, S3, Cd20-23 (Dyce, et al., 2010). Variations are possible, especially in the transitions between thoracic to lumbar, and lumbar to sacral vertebrae. In immature animals, the vertebral bodies have cranial and caudal growth plates, which close by about 11 months of age in dogs (Hare, 1961).

Most vertebrae have transverse processes projecting laterally from each side of the junction between the vertebral body and arch, spinous processes projecting dorsally from the lamina, as well as cranial and caudal articular processes. These processes vary in length, shape and orientation, according to the vertebral region, and allow the insertion of ligaments and muscles. Vertebral bodies have dorsal articulations (except for C1/2 where the articulations are ventral, as well as between the fused sacral vertebrae), these joints consist of a capsule, articular cartilage and synovial fluid (DeLahunta, 2013).

Between each pair of vertebrae there is an intervertebral foramen, which allows the passage of spinal nerves and blood vessels (Sharp & Wheeler, 2005; Dyce, et al., 2010).

There are four main ligaments within the vertebral column. Firstly, there is the **nuchal ligament** which extends from the dorsal arch of the axis to the spinous processes of the cranial thoracic vertebrae. This large ligament lies deep in the dorsal cervical musculature but can be sectioned surgically without any major complications. Then, there is the **supraspinous ligament** which unites the tips of the spinal processes and contributes to spinal stability and mobility. Furthermore, there is the **ligamentum flavum**, which is located on top of the vertebral canal and in the space between adjacent vertebral articulations and frequently thickens in some spinal diseases such as cervical spondylomyelopathy. Finally, there is the **dorsal longitudinal ligament** which merges with the anulus fibrosus' fibers inside the intervertebral disk (Sharp & Wheeler, 2005; Dyce, et al., 2010).

2.5.1 Cervical Vertebrae

Since the theme of this dissertation is cervical disk disease, the particular characteristics of the cervical segment will be explored in greater detail.

Within the vertebral column, there are seven cervical vertebrae, where the first two are distinct: the atlas (C1) and axis (C2). Thus, the vertebral body of C1 is smaller, the bulk of the vertebra displays lateral masses and caudally there are two articular processes which allow articulation with the axis. There are lateral vertebral foramina in the vertebral arch, through which pass the C1 spinal nerves. The axis has a wide spinous process, that extends cranially over the atlas, which is connected to it via the dorsal atlantoaxial ligament. There is also multiple ligaments and synovial joints between the articular processes, which are located ventrally to the vertebral canal, and there is no intervertebral disk between these two vertebrae (Sharp & Wheeler, 2005; DeLahunta, 2013).

The remaining cervical vertebrae are similar to each other. Thus, the spinous processes are small, and the transverse processes project laterally, there is also a transverse foramen, through which pass the vertebral arteries (except in C7) and the articular processes lie in an oblique dorsal orientation. Exceptionally, the wide transverse processes of C6 are particularly large and project ventrally. They are important surgical landmarks due to a large vascular channel passing through the center of these vertebrae, which makes it prone to extensive hemorrhages or other complications (Sharp & Wheeler, 2005; Dyce, et al., 2010).

It is important to highlight that, there are eight cervical segments, but only seven cervical vertebrae. Therefore, C1 spinal nerves leave through the atlas lateral foramina, while the remaining cervical spinal nerves exit the vertebral canal cranial to the vertebrae of the same annotation, apart from C8 nerves, which leave between C7 and T1 vertebrae. In contrast, the thoracic and lumbar spinal nerves exit caudally towards the same-named vertebrae (Sharp & Wheeler, 2005).

2.5.2 Intervertebral Discs

The vertebral bodies are connected by intervertebral discs, apart from C1, C2 and the sacrum. They guarantee flexibility, and act as impact absorbers for the spine. The capacity to absorb shock decreases with age and degenerative alterations. Intervertebral discs have poor blood supply, which depend on nutrient absorption by diffusion (Sharp & Wheeler, 2005; DeLahunta & Glass, 2009).

Vertebral discs are composed of an outer fibrous ring of obliquely oriented fibers (annulus fibrosus) and a central gelatinous center (nucleus pulposus), which is a hydrated mesodermal leftover from the embryogenic notochord (DeLahunta, 2013). These discs provide a means for the transmission of stresses and strains required for the animal to move laterally and upwards. Intervertebral disks often undergo degenerative changes which can result in in IVDD (intervertebral disk disease). An example of this is calcification of the nucleus pulposus, which frequently occurs in chondrodystrophic breeds at an early age, where sometimes the disk suffers extrusion, compresses the spinal cord, resulting in pain and neurological signs (Stephen J. Ettinger, 2017).

3. Neurological Examination

3.1 Patient History

In order to suspect the cause of such clinical signs, it is important to access evidences of trauma, progression of the disease (acute versus chronic), previous episodes of the disease, pain signs, state of vaccination, travel history, urinary function, access to toxics, previous/current medications and lifestyle (Sharp and Wheeler, 2005; Chrisman, et al., 2005).

Acute neurological signs are commonly associated with traumatic, vascular, and infectious processes, whereas progressive development of signs is linked with neoplasic and degenerative diseases. In addition, static processes are associated with congenital affections (Chrisman, et al., 2005; Oliver, et al., 1997).

3.2 Physical examination

A complete physical and ophthalmic exam should be performed when there is suspicion of neurological disease.

During the physical exam, vital signs should be evaluated - such as respiratory and cardiac frequency, pulse, temperature, mucous membranes, capillary refill time – as well as all organ systems. It is important to obtain a minimal laboratory database, including biochemical analysis, hemogram and urine analysis (LeCouteur and Grandy, 2004). Palpating the abdomen and verifying bladder size and tension is also of great importance, since urinary incontinence is frequent in spinal cord disorders. Therefore, assessment of urinary function should be obtained through the patient’s history (Sharp and Wheeler, 2005).

If neurogenic urinary incontinence is present, the following step should be to determine if it is LMN or UMN related. Therefore, the LMN bladder is usually large, flaccid, and easily expressed. Commonly associated with lesions of the sacral spinal cord segments or nerve roots.In opposition, The UMN bladder is tense and difficult to express unless grossly distended, since there is an increase in the urethral sphincter tone, which is associated with lesions cranial to the sacral segments, commonly affecting the T3–L3 spinal cord segments (Sharp and Wheeler, 2005).

3.3 Neurological Exam

The neurological exam should be performed in order to determine the presence of nervous system lesions, establish their location and, in some situations, provide a decisive prognosis (De Lahunta, 1983).

Examination of all of these is necessary to determine whether a lesion is confined to the spinal cord and at what level. According to Sharp & Wheeler, 2005 these are the essential parts to the neurologic examination (the order can be arbitrary): examination of attitude, posture and gait, postural reactions, palpation (abdomen, spine and muscles), spinal reflexes, nociception and cranial nerves.

3.3.1 Examination of attitude, posture and gait

3.3.1.1 Attitude

For an animal to stay alert to its surroundings, two main CNS components are essential: the cerebral cortex and the ascending reticular activating system (ARAS) within the brainstem. The latter receives information from the spinal cord and cranial nerves which is transported to the cerebral cortex via thalamus to maintain a state of consciousness. As a result, altered conscience levels (such as depression, stupor or coma) might occur due to metabolic deficits, cerebral cortex disease, disturbances of the brainstem or the connection between the cerebral cortex and brainstem (DeLahunta & Glass, 2009; Platt & Olby, 2014).

Disruptions of the state of consciousness are classified, in order of severity, as depressed/obtunded, stuporous (semi-coma) and comatose (Classification present in attachment 2). These states can be related to either a cerebral cortex disease or a focal lesion affecting the brainstem (where ARAS is localized). In addition, behavioral changes, such as delirium or headpressing, might indicate cerebral cortex disease or neurological conditions secondary to metabolic disturbances (i.e hepatic encephalopathy) (Couto, 2013; Platt & Olby, 2014).

3.3.1.2 Posture

The posture and body position at rest should be observed and classified as normal or defective. Frequently observed abnormalities can be encountered, such as: head tilt, head turn, ventroflexion of the neck, spinal curvature, decerebrate rigidity, decerebellate rigidity, schiff–Sherrington posture, wide-based stance. Certain abnormalities referred can be particularly related to spinal cord disease, such as ventroflexion of the neck, a frequent sign of cervical disk disease (Platt & Olby, 2014; DeLahunta & Glass, 2009)

3.3.1.3 Gait

Gait should be examined in a place where the patient can move freely, leashed or unleashed, on a non-slippery surface. The examiner should evaluate the state of motor function, the gait (noting any asymmetries) and the general attitude. It is important to access if the patient is still able to stand, by pressing down on the shoulders and hips (Platt & Olby, 2014). Also, deficits in proprioception may cause the animal to scuff the dorsal surface of its paws or to overreach on protraction (DeLahunta & Glass, 2009).

After gait and posture are observed, the patient's locomotor status can be classified. The terms paraplegia and tetraplegia indicate complete absence of voluntary movement in the pelvic limbs or in all four limbs, respectively. Occasionally, patients that appear paraplegic at rest may show some voluntary movement if supported by a sling or if held by the base of their tails. On the other hand, patients who show no voluntary movement while supported but present some voluntary limb movement when recumbent are classified as nonambulatory paraparetic or tetraparetic (DeLahunta & Glass, 2009; Platt & Olby, 2014).

Most gait abnormalities show a combination of UMN (spastic paresis) and GP (ataxia) clinical signs due to their anatomic proximity. A patient affected in both tracts mentioned can still walk unassisted, however, protraction (swing phase of the gait) is delayed. The trunk may also seem unstable and sway as the patient walks, especially on turns. A grading system can be used to evaluate the degree of pelvic limb function, which aids prognosis determination and evaluation of therapy response. According to this system, Grade 0 refers to a patient with no voluntary movement in the pelvic limbs and therefore is paraplegic while Grade 5 refers to a patient with normal pelvic limb function (DeLahunta & Glass, 2009). The detailed grading system is cited in Atachment 1.

3.3.1.4 Postural Reactions

Postural reactions aim to access proprioception, as well as other aspects such as motor function and vision. Proprioception can be evaluated in the standing animal by the paw replacement test or the reflex step (Platt & Olby, 2014).

The **paw replacement test** consists of placing the limb over the dorsal aspect of the paw while observing the velocity of the paw returning to its normal position. In normal situations, this should happen fast. Thus, a slow or absence of this movement might indicate defective proprioception (DeLahunta & Glass, 2009). In the **reflex step test**, a piece of paper is placed under the foot and pulled laterally. The animal should readily return the foot to its initial position. In addition, using the **placing test**, visual placing can be assessed as the animal visualizes the table edge, which validates vision and motor function, while tactile placing evaluates sensation, proprioception and motor function (Platt & Olby, 2014).

It is also important to individually test **thoracic and pelvic limb hopping**. The consultant should support the patient with only one limb placed on the ground, and then move the patient laterally. An impaired proprioception or motor function will result in an abnormal hopping response. In a larger breed, the same can be performed by simply raising one thoracic limb and then moving the dog sideways (Platt & Olby, 2014).

In cooperative patients and with cases of uncertainty regarding thoracic limb function, it may help to **wheelbarrow** the patient with its neck held in extension. This consists of lifting the patient’s pelvic limbs of the ground and make him walk in one direction using his front limbs. This test can reveal thoracic limb paresis and exacerbates asymmetrical lesions. A similar technique can be used to evaluate pelvic limb function, which is named **extensor postural thrust**, where the patient is held up with only the hindlimbs supporting its weight (Platt & Olby, 2014; DeLahunta & Glass, 2009)

3.3.1.5 Palpation

Palpation of the spine is useful to determine the presence of spinal hyperesthesia and pain signs by pressing the vertebral column and evaluating the patient's response. Spinal pain can signal discogenic pain, dorsal longitudinal ligament damage, nerve root irritation, inflammation of the meninges and bone pain (Platt & Olby, 2014).

In a dog with cervical disc disease related neck pain, it is advisable to palpate the cervical muscles gently. In this condition, the animal presents an extended neck and shows reluctance to movement (Couto, 2013; Platt & Olby, 2014). In addition, the examiner should **palpate the abdomen**. It is important to determine the degree of bladder filling, and the ease with which urine is expelled by its compression.

Muscle palpation should then be performed with the patient in upright position and then lateral recumbency, to evaluate the limbs. The clinician should palpate the patient's neck, trunk, and limb muscles starting cranially towards caudal direction to evaluate size and tone. After palpating, flexing and extending the limbs, it is essential to determine both the muscle tone and the range of motion of the joints, as it is relevant to rule out muscle, bone or articulation related pain (Couto, 2013; DeLahunta & Glass, 2009).

One frequent finding is muscle atrophy, which usually indicates LMN pathology and/or muscle disuse. On the other hand, an increased muscular tone indicates UMN lesions, in which there is notable resistance to limb flexion (Sharp & Wheeler, 2005; Platt & Olby, 2014).

3.3.1.6 Spinal Reflexes

As Delahunta 2009 cites, spinal reflexes require only the specific peripheral nerves and the spinal cord segments with which they connect, whereas postural reactions depend on the same components as the spinal reflexes plus the cranial projecting general proprioceptive (GP) pathways. As a result, spinal reflexes are much more accurate in localizing a lesion in the spinal cord.

There is plenty of local reflexes available for examination, however it is frequent to focus on the **patellar**, **flexor (withdrawal)** and **perineal reflexes**. Other reflexes such as the triceps, biceps, and gastrocnemius can be tested as well. Nevertheless, they are found inconsistent in normal patients, so their main purpose is to confirm hyper reflexive responses in UMN disorders (Sharp & Wheeler, 2005).

To examine the spinal reflexes, the patient should be placed in lateral recumbency, usually with an assistant's help. The **patellar reflex** serves as an assessment of both the femoral nerve and spinal cord segments L4, L5, and L6. These tests should be performed before testing the flexor reflexes, in which a noxious stimulus is used. Then, the examiner should perform **flexor reflexes** using a noxious compressive stimulus at the base of the digits, in which the purpose is to obtain a flexor response or pain signs. The flexor reflexes mentioned test both the reflex arc and the integrity of the nociceptive pathway to the cerebral cortex. The latter is relevant in evaluating the severity and prognosis of focal spinal cord lesions (Platt & Olby, 2014; Sharp & Wheeler, 2005).

The Perineal reflex consists of the contraction of the anal sphincter and tail flexion as a response to a perineal nociceptive stimulus. The sensorial and motor nerve roots that supply the anal sphincter are localized in the S1 – S2 region. In case the reflex is weak or absent, a rectal digital exam should be performed to evaluate the anal sphincter contraction more accurately (Platt & Olby, 2014; Sharp & Wheeler, 2005).

Once the previous tests are completed and the patient is returned to standing position, the clinician should perform the **cutaneous trunci reflex** (DeLahunta & Glass, 2009; Sharp & Wheeler, 2005). According to Sharp & Wheeler, "the cutaneous trunci reflexes are tested by pinching the skin along the dorsal surface of the trunk with fine forceps and observing the twitch of the cutaneous trunci muscle on both the ipsilateral and, to a lesser extent, the contralateral side." This is verified due to the crossing of the pathways within the spinal cord, leading to a bilateral response after unilateral stimulation. It is important to consider that, in many normal animals, this reflex may not occur until about the midlumbar region, and more rarely, it might not even occur. Therefore, when suspecting of the lesion location, it is vital to consider that each spinal nerve supplies the skin for a distance of approximately two vertebrae caudal to the intervertebral foramen. This reflex is lost in injuries that affect the C8 and T1 spinal cord segments (which supply the brachial plexus). As a result, compression of the skin at any level along the trunk will only result in trunci reflex on the contralateral side of the lesion, since the affected side won't respond (DeLahunta & Glass, 2009; Sharp & Wheeler, 2005).

In addition, thoracolumbar lesions may also interfere with the cutaneous trunci reflex, which can only be intact in regions supplied by segments cranial to a spinal cord lesion and will be absent in the segments caudal to it (Sharp & Wheeler, 2005).

Moreover, the cutaneous reflex is particularly helpful to determine the severity and prognosis of certain transverse spinal cord lesions such as injuries due to vertebral fracture or an intervertebral disk extrusion. As well as identifying pain in less nociception responsive animals (DeLahunta & Glass, 2009).

3.3.1.7 Nociception

In order to perceive pain consciously, the sensory peripheral nerves, their associated spinal cord segments, the spinal cord, brainstem and the related thalamocortical system must all be functional. The nociceptive fibers are located deep inside the spinal cord white matter and project bilaterally from the spinal cord. Therefore, only severe spinal cord lesions can impair nociception, which justifies testing this function as a prognosis indicator for this condition (Platt & Olby, 2014).

It is important to highlight that it is very rare for animals with cervical injuries to display nociception deficits. This is justified because patients with severe cervical injuries are severely tetraparetic or tetraplegic which easily results in asphyxiation. Therefore, it is vital to access hypoventilation in tetraplegic patients. In particular situations, post traumatic unilateral loss of deep pain can be found after a dorsolateral disk extrusion, which results in asymmetrical neurological signs (Sharp & Wheeler, 2005).

Nociception should be **assessed in all four limbs, tail and perineal region**. When testing the withdrawal reflex, the examiner must note if there is any behavioral response to the noxious stimulus applied, such as turning the head, trying to bite or vocalization. If no pain response is observed, higher pressure should be applied to the digits. It is important to note that withdrawal of the limb only tests the flexor reflex, thus it isn’t evidence of pain sensation (Platt & Olby, 2014; Sharp & Wheeler, 2005).

Deep pain sensation loss should be confirmed by absence of response over pinching a line on the patient’s flank. The animal responds to pinching of the dermatomes cranial to the lesion but doesn’t respond to the same stimulus caudally (Sharp & Wheeler, 2005).

3.3.1.8 Cranial Nerves

When presented with a patient that exhibits clinical signs of spinal cord disease, the cranial nerve examination is important for determining whether the spinal cord signs are part of a multifocal disease process (DeLahunta & Glass, 2009). The examiner should determine if the spinal cord lesion interferes with the sympathetic pathway to brain causing Horner syndrome, which can be observed when the cranial nerves are examined (DeLahunta & Glass, 2009). The cranial nerve assessment is present on attachment 3.

Horner's syndrome is associated with loss of sympathetic innervation, it can present signs such as miosis, enophthalmos, protrusion of the third eyelid and ptosis (drooping) of the upper eyelid and decreased tone of the lower eyelid (Platt & Olby, 2014). Avulsion of the brachial plexus nerve roots commonly results in a partial Horner's syndrome (when miosis is the only feature), which happens since only the T1 nerve root of the T1-T3 sympathetic path is affected by this lesion. Partial Horner's syndrome may also occur in dogs with acute and severe lateralized cervical spinal cord disease, however with the majority displaying complete Horner's syndrome (Platt & Olby, 2014).

3.3.2 Location of the lesion in the spinal cord

The purpose of the neurological examination is to identify the location of the lesion within the spinal cord while considering the correlation of signs and lesion location. Hence, if signs of paralysis or ataxia are observed in both front and hind limbs, the examiner should suspect of brain, cervical spinal cord lesions or, more rarely, peripheral neuropathies. On the other hand, if ataxia is only present in pelvic limbs without any thoracic limb abnormalities, we can suspect of a spinal cord lesion caudal to the brachial plexus, or less commonly, a peripherical neuropathy. Finally, if monoparesia or monoplegia are presented we should suspect of peripheral disease only affecting that limb. Once it is assumed that a neuromotor deficits present, it is crucial to determine if it is UMN or LMN related (SW). The signs of each are displayed on table 1, below.

	LMN	UMN
Motor function	Paresis/paralysis	Paresis/paralysis
Reflexes	Absent or reduced	Normal or increased
Muscle tone	Reduced	Normal or increased
Muscle atrophy	Severe, early - neurogenic	Late, mild - disuse

Table 1: LMN and UMN clinical signs. Adapted from Sharp & Wheeler, 2005.

Functionally, the spinal cord may be divided into four regions: A (C1–C5), B (C6–T2 - cervical intumescence), C (T3–L3) and D (L4–S3 - lumbar intumescence).

It is important to consider these regions, as their functional anatomical analysis facilitates the interpretation of UMN or LMN signs. (A synthesis of signs associated with spinal cord affected segment is presented on table 2).

Hence, areas A and C, which correspond to the cervical and thoracolumbar spinal cord, convey primarily the UMNs. As a result, damage to these areas will result in UMN signs to the limbs caudal to the respective areas. Therefore, if area A is affected all limbs can show UMN deficits, possibly resulting in tetraplegia or tetraparesia. On the other hand, if area C is injured, only hind limbs are supposed to show UMN signs. Thus, the patient might be paraplegic or paraparesic (Platt & Olby, 2014; DeLahunta & Glass, 2009).

Areas B and D, which represent the cervicothoracic and lumbosacral spinal cord, provide innervation to the thoracic and pelvic limbs respectively, thus they represent LMN pathways to the limbs. As a consequence, lesions in these areas will produce LMN signs on the limbs innervated by the region affected. Therefore, if area B is affected it is expected to see LMN signs on thoracic limbs - and UMN signs on the pelvic limbs due to disruption of the UMN pathway that supplies them. Likewise, a lesion present on area D will provoke hind limb LMN signs (Platt & Olby, 2014; DeLahunta & Glass, 2009).

However, variations are possible, for instance, in cases of myelopathy affecting the caudal cervical segments, the thoracic limbs often display both UMN and LMN signs. This can be explained since there is an UMN effect on the elbow and carpal extensor muscles which provokes an increased limb muscle tone, which is associated with LMN weakness of the elbow flexors which results in a poor withdrawal reflex (Sharp & Wheeler, 2005).

General proprioceptive (GP) tracts might also be affected, reflecting ataxia of the limbs caudal to the lesion. Likewise, GSA tract lesion might result in hypalgesia or in severe cases, analgesia of the limbs caudally located (DeLahunta & Glass, 2009).

Site of injury	Motor		Sensory	
	Thoracic Limb	Pelvic Limb	GP	GSA
C1 -C5	UMN	UMN	Ataxia – All limbs	Hypalgesia – All Limbs
C6-T2	LMN	UMN		

T3-L3	Normal	UMN	Ataxia –Pelvic limbs	Hypalgesia – Pelvic limbs
L4-S3	Normal	LMN		

Table 2. Limb neurologic signs per injury in each spinal cord region. GP, General proprioceptive; GSA, general somatic afferent; LMN, lower motor neuron; UMN, upper motor neuron. Adapted from Sharp & Wheeler, 2005 and DeLahunta, 2009.

3.3.3 Assessing the severity of the lesion

Determining the severity of the lesion is a crucial part of the diagnosis since it aids in evaluating and obtaining a prognostic for the lesion. Thus, some clinicians use classification systems in order to estimate the prognosis of spinal cord disease, as well as to help monitoring its treatment. For instance, the modified Frankel scale (Attachment 2) can be used for this purpose (Levine, et al., 2007; Platt & Olby, 2014)

The severity of lesions is accessed based on the degree of functional deficit, which might not always be a static parameter, since it can increase or diminish as the lesion progresses or heals.

Generally, LMN deficits result in a worse prognosis compared to UMN signs, except for thoracolumbar lesions , as lesions at this level usually damage both white and gray matter, due to the smaller vertebral foramen diameter. Despite being difficult to identify, parameters such as the duration, occurrence and severity of lesion are crucial for UMN lesion prognosis. Thus, a rapid progression of clinical signs might evolve into decompensation, however, if treated early it can lead to a positive outcome, unless irreversible damage develops (Sharp & Wheeler, 2005).

Generally speaking, greater neurological deficits indicate a worse prognosis, as it usually indicates more severe spinal cord injury. However, neurological deficits do not always illustrate the degree of severity of the lesion, therefore prognosis should be accessed using more accurate parameters, such as nociception. As previously mentioned, the absence of nociception indicates a guarded prognosis, especially if for more than 48 hours, as this condition is associated with 50-60% of recovery post-surgery (Platt & Olby, 2014).

The etiology of the disease has major implications on the prognosis as well. Since an oncological condition such as a spinal tumor generally will have a much worse prognosis than a thoracolumbar disk extrusion, especially if metastasis are present. Incontinence is also a major prognosis indicator, as it reflects more severe spinal cord injuries. This condition is usually seen between grade 4 or 5, although slighter signs can start to appear from grade 2.

Unless the lesion is acute or peracute, which happens in trauma or vascular lesions, the evolution of clinical signs will be consistent with chronic disease, as they will progress according to the classification presented in attachment 2. Once the lesion starts to heal, the recovery will evolve in the reverse order of signs mentioned. As sharp & wheeler cites “Recovery after spinal injury is usually defined as recovery of continence and of the ability to walk unaided.”

Cervical spinal cord lesion shows a similar progression of signs described, however urinary incontinence and loss of deep pain sensation are notably rare. Respiratory failure is also possible in severe cervical lesions, despite of being uncommon (Sharp & Wheeler, 2005).

On a final note, it is imperative to consider spinal shock, which represents a state of temporary loss of spinal reflexes below the lesion, therefore having the potential to confound the injury location. As this state lasts for a few hours post-injury, it is imperative to re-examine trauma patients a few hours later (Walmsley and Tracey, 1983; Gopal and Jeffery, 2001).

4.Intervertebral cervical disk disease

Degeneration (or disease) of the intervertebral discs occurs with age, due to general loss of water content and proteoglycans, which might result in disk herniation. There are two main types of disc degeneration in dogs, which are classified as chondroid and fibroid metamorphosis. It is also not uncommon for dogs to be affected in multiple vertebral column sites (Platt & Olby, 2014; Jeffery, et al., 2013).

Each of the mentioned degeneration types will, respectively, lead to either extrusion or protrusion (both considered herniation) of disc material into the vertebral canal, resulting in clinical signs due to spinal cord compression and/or contusion (Toombs & Waters, 2003). Therefore, generally speaking, the classification of IVDD can either be Hansen Type I, if it corresponds to the extrusion of the disk, or Hansen Type II when protrusion occurs (Hansen, 1952). Nevertheless, the pathophysiology of the injury doesn’t always illustrate the degree of neurological disfunction (Henke, et al., 2013).

4.1. Pathophysiology of the different IVDD types

Type I IVDD is commonly associated with chondrodystrophic breeds. These types of breeds are characterized as having shortened limbs in comparison to the trunk, a condition also known as dwarfism (Batcher, et al., 2019). Chondrodystrophy is a dominant autosomal trait, recently associated with fibroblast growth factor 4 (FGF4) retrogenes, which were identified in both chromosome 12 (12-FGF4RG) and chromosome 18 (18-FGF4RG). It was proven that the most severely disproportionate dwarf breeds are carriers of both FGF4 retrogenes, such as Dachshunds, Bassey hounds and Corgis (Batcher, et al., 2019; Heidi, et al., 2009).

Chondrodystrophic breeds are also known to undergo chondroid metaplasia of the nucleus pulposus which leads to premature degeneration and further calcification of the intervertebral discs (Smolders, et al., 2013). This process usually occurs during the first 2 years of life, as the nucleus pulposus is invaded by hyaline cartilage and dehydrates, which decreases the hydrostatic shock absorbing capacity of the nucleus pulposus, as well as the consistency of the anulus fibrosus (Sharp & Wheeler, 2005). This dehydration weakens the IVD, as the normal movements of the dog will provoke additional friction in the disc, which predisposes the animal to develop Hansen type I disk herniation (Toombs & Waters, 2003). As previously mentioned, type I disk herniation corresponds to the extrusion of the nucleus pulposus, which passes through the annular fibers and invades the spinal canal, usually provoking acute clinical signs. The onset of the disease is usually between 3 and 6 years for chondrodystrophic breeds (Platt & Olby, 2014).

On the other hand, large non- chondrodystrophic breeds of dog such as the Doberman pincher and Labrador retriever can also be affected by type I IVDD, especially post-trauma. Furthermore, congenital vertebral abnormalities can also result in early intervertebral disc degeneration. In addition to dwarfism, other characteristics such as long backs and excess of weight are proven to increase the risk of type I IVDD (Costa & Platt, 2017).

Regarding the cervical spinal segment, C2-C3 disks are reported to be the most affected in small breeds with the incidence decreasing caudally in the cervical spine, whilst large breeds suffer most frequently from disc herniations between C6-C7 (Platt & Olby, 2014). Nevertheless, this disease affects the thoracolumbar region more frequently (Sharp & Wheeler, 2005).

On the other hand, **Hansen type II IVDD** is defined by protrusion due to the shifting of central nuclear material and is associated with senile fibroid disc degeneration (Costa & Platt, 2017).

Contrarily to Type I IVDD, the nucleus pulposus is dehydrated and is invaded by fibrocartilage instead of hyaline cartilage. This process occurs significantly later than in chondroid metamorphosis as the discs are usually normal during younger years (Platt & Olby, 2014). This process causes the annulus fibrosus to slowly protrude into the spinal cord resulting in spinal compression, which can lead to focal ischemia, contributing to spinal progressive disfunction. This type of herniation is frequently identified at the most mobile sites of the spinal column and is more frequent in older, non-chondrodystrophic dog breeds (Costa & Platt, 2017).

Finally, there is a rare type of herniation, known as **Hansen Type III**, which is also cited as "missile discs" which represent low volume, high velocity disk herniations. This type is very rare and is usually secondary to trauma. They are caused by extrusion of the liquid nucleus pulposus which hits the spinal cord at high impact, therefore causing contusive injury without spinal compression. Therefore, treatment of this cases is non-surgical (Widmer & Thrall, 2013). Moreover, a 2012 study described the existence of an acute, **compressive hydrated nucleus pulposus extrusion** (HNPE). This type of herniation is similar to Hansen type III, apart from causing compressive damage. As such, the preferred treatment for HNPE was surgical, as the ventral slot approach was proven to be successful (Beltran, et al., 2012)

4.2 Cervical Disk Disease

Cervical disk disease accounts for 14% to 25% of IVDD in dogs, from which most develop disc extrusion instead of protrusion (Cherrone, et al., 2004; Coates, 2000).

Small and chondrodystrophic breeds belong to the top risk group. As such, Dachshunds, Toy Poodles and Beagles are documented as the most affected breeds. Nevertheless, larger breeds such as Labrador retrievers, Dalmatians and Dobermans can also be affected by the disease, although in a smaller proportion, representing 24% of cases (Toombs & Waters, 2003; Cherrone, et al., 2004).

The onset peak of cervical disk disease is between 4 and 8 years of age, with a mean ranging from 6.3 years to 8.6 years. Moreover, it is very rare for dogs with less than 2 years of age to be affected. Most studies conclude that both sexes are equally affected (Costa & Platt, 2017).

The majority of cervical disc disease cases in chondrodystrophic breeds affect the cranial cervical spine, where 80% affect C2-C4 spaces, from which 44-59% affect C2-C3 alone (Coates, 2000). On the other hand, most large breed dogs are affected by the disease at the C6-C7 intervertebral disc space, as most protrusions are located more caudally (Cherrone, et al., 2004).

4.2.2 Acute cervical disk disease (ACDD) - Hansen Type I

Acute cervical disc disease is a reported to be a common problem in dogs. It is frequently observed in condrodystrophoid dog breeds such as Dachshunds, Shih tzus, Pekingese, Beagles or Cocker spaniels, despite being able to affect any other breed (Heidi, et al., 2009).

As previously mentioned, chondrodystrophic breeds suffer from premature degeneration and mineralization of the nucleus pulposus, which increases susceptibility of manifesting type I disk herniations. Regarding ACDD, C2-C3 disks are the most affected in small breeds, as the disease usually targets the cranial portion of the cervical spine, as opposed to wobbler syndrome, which commonly affects the vertebral caudal region (Platt & Olby, 2014).

Clinical signs can appear from 18 months, with a peak of onset between 3 and 7 years (Platt & Olby, 2014). Usually, the presenting sign is acute or chronic severe neck pain. The patient frequently presents a typical stance with the head held down, rigid neck (easily palpable) and cifosis, as the weight is shifted to the pelvic limbs (Platt & Olby, 2014).

Another frequent finding is nerve root signature, which corresponds to pain on traction of the limb, this may appear as an orthopedic lameness, which can be ruled out by neck palpation (neck is rigid) or limb traction, during the neurological exam. This sign frequently signals that the affected discs are located caudally, but it can also occur in C2/3 disc lesions (Sharp & Wheeler, 2005).

This condition is one of the few that can prompt the patient to spontaneously scream. The patients are usually reluctant to eat food unless it is raised off the floor. In addition, this pain is generally unremitting and does not respond to medication (Sharp & Wheeler, 2005).

Neurological deficits are less common due to the large space within the vertebral canal which makes the spinal cord less prone to be compressed. However, when compression is present, the following clinical signs may be present: teraparesis/hemparesis, tetraplegia/hemiplegia, ataxia and conscious proprioceptive and postural reaction deficits (Platt & Olby, 2014; Coates, 2000).

Nevertheless, neurological deficits are more commonly seen in C4/5 to C6/7 injuries, whereas neck pain without deficits is more common with lesions at C2/3 and C3/4. This might illustrate the greater degree of space in the cranial vertebral canal compared to the caudal cervical segments (Coates, 2000). In addition, Dogs with severe C6–T2 signs also present a shortstrided thoracic limb gait and a long-strided, ataxic pelvic limb, known as “two-engine gait”. Whereas dogs with C1–C5 signs usually develop a long-strided or ‘floating’ thoracic limb gait together with a long-strided, ataxic pelvic limb gait (Sharp & Wheeler, 2005).

4.2.3 Cervical spondylomielopathy (Wobbler syndrome) associated with Hansen type II

Cervical spondylomyelopathy (CSM), also known as Wobbler syndrome, is a syndrome affecting the cervical spinal cord associated with large and giant breed dogs (Platt & Olby, 2014). The most affected regions are C5–C6 and C6–C7, which justifies the denomination of caudal cervical spondylomyelopathy (Fitzpatrick & Fingeroth, 2015). Lesions affecting both levels simultaneously have been recognized in approximately 20% of affected dogs (Trotter, 2009).

This syndrome was first described in 1967 by Palmer and Wallace in young Bassey hounds, suggesting that the inheritance of the disease was sex-linked (Palmer & Wallace, 1967). This disease is known for affecting large breeds such as Dobermans (which are the most reported to date), Dalmatians and giant breeds like Great Danes, Mastiffs and Bernese Mountain Dogs, although similar changes can be identified in toy and small breed dogs such as Chihuahuas and Yorkshire Terriers (Platt & Olby, 2014; Da Costa, 2010). Despite the lack of proper prevalence studies, CSM is still considered to likely be the most frequent disease of the cervical spine in dogs of large and giant breeds (Da Costa, 2010).

Even considering the most recent studies about the disease, the pathogenesis, diagnosis, and treatment of CSM are still somewhat controversial (Da Costa, 2010). The etiology of these changes is suspected to be multifactorial, as genetic, congenital, body conformation, and nutritional are proposed factors (Da Costa, 2010; Platt & Olby, 2014).

Many authors have proposed a genetic origin, as the disease is identified in specific breeds of dog. A diversity of studies proposed a pattern of inheritance, but the results were most often inconclusive (Da Costa, 2010). For example, two studies with a sample of 370 Dobermans couldn’t accurately prove the inheritability of the trait (Burbidge, et al., 1994; Lewis, 1991). It was also proposed, in a study in Borzoi dogs, that CSM was inherited in an autosomal recessive pattern, also suggesting that females were more predisposed to the disease (Jaggy, 1988). In addition, congenital abnormalities in Dobermans, such as stenosis of the cranial vertebral canal and asymmetry of C5- C7 vertebral bodies, were found in a CT study conducted in neonatal Dobermans (Burbidge, 1999).

Overfeeding and excessive calcium supplementation in the first year were suggested to be related to the disease in Great Danes, however normal dietary conditions did not avoid the occurrence of the disease (Fitzpatrick & Fingeroth, 2015). Also, it has been proposed that head and neck conformation influence the development of lesions. Therefore, abnormal forces applied by a large head on a long neck, associated with a rapid growth rate may result in increased tension between vertebral bodies, inciting vertebral changes and spinal cord compression. (Fitzpatrick & Fingeroth, 2015). Nevertheless, in a large study with Dobermans, no correlation was found between radiographic changes associated with CSM and the body dimensions mentioned (Burbidge, 1999).

It is also believed that vertebral instability may predispose to chronic degenerative disc disease, but it is unclear whether this instability is the primary cause of the development of CSM or an exacerbation factor (Fitzpatrick & Fingeroth, 2015).

This syndrome is associated with compression of the spinal cord due to degenerative and congenital alterations in the cervical spine. CSM is linked to a collection of pathologic alterations, such as (Platt & Olby, 2014):

- Hypertrophy and protrusion of the annulus fibrosus (Hansen type II IVDD);
- Hypertrophy of the ligamentum flavum and dorsal longitudinal ligament;
- Degenerative joint disease associated with remodeling of the articular facets, resulting in synovial membrane hypertrophy and synovial cysts;
- Stenosis of the vertebral canal.

According to Da Costa, the pathophysiology of the wobbler syndrome can be divided into two distinct types, although they may also overlap. The first one is **Disc Associated Compression**, which is typically linked with Doberman pinchers and is frequently presented in middle aged large breed dogs (Da Costa, 2010). This type of compression combines three main key factors: relative vertebral stenosis, an intensified torsion motion in the caudal cervical spine and protrusion of a larger volume of disc material. The latter is supported by evidence that intervertebral discs are larger in CSM affected Dobermans (Da Costa, et al., 2006).

The other cause for wobbler syndrome is classified as **Osseous Associated Compression**, which is more frequent in young adult giant breed dogs, therefore a congenital etiology seems probable. This type of compression is a result of severe absolute vertebral canal stenosis due to vertebral malformations, such as: proliferation of the dorsal arch (compressing the spinal cord dorsally), articular facets and/or pedicles (which compress the spine dorsolaterally). Both of these types may also be accompanied by compression due to hypertrophy of the ligamentum flavum or the dorsal longitudinal ligament (Da Costa, 2010).

Most giant breed dogs reveal degenerative changes of the articular facets and synovium, as well as stenosis of the vertebral canal within the first 3 years of age, commonly affecting C3-T1 (Platt & Olby, 2014). However, most dogs only start developing signs around middle age due to protrusion of the annulus and ligamentous hypertrophy of the caudal cervical vertebrae. These changes can be classified as static or dynamic (Fitzpatrick & Fingeroth, 2015). It is important to note that compressive lesions may be present in more than one site, as this is verified in approximately 50% of large breed and 80% of giant breed dogs (Platt & Olby, 2014).

Traditionally, there is a history of chronic progressive evolution (several weeks to months), however acute presentations can also occur, which are often associated with neck pain (Da Costa, 2010). Frequently reported clinical signs include ataxia, tetraparesis and neck pain (Platt & Olby, 2014). Neck pain signs account for approximately 65% to 70% in Dobermans, whereas in other breeds it is only verified in about 40 to 50% of cases. Despite being relatively common, only 5 to 10% dogs display neck pain as the main reason for consult presentation (Da Costa, et al., 2008).

It is crucial to evaluate the patient's gate, since it allows the identification of proprioceptive ataxia, which is seen in most CMS affected dogs (Costa & Platt, 2017). Of note, proprioceptive ataxia can still occur in the absence of conscious proprioceptive deficits, since conscious and unconscious proprioception pathways are carried by different tracts (DeLahunta & Glass, 2009).

Typically, pelvic limb signs are usually more severe than those in the thoracic limbs. However, patients with cranial or midcervical spine lesions are more likely to present a more homogeneous four limb ataxia (Da Costa, 2010). In caudal cervical lesions, thoracic limb gait is usually short and stilted and associated with a disconnected pelvic limb gait (Platt & Olby, 2014). Tetraparesis is relatively rare, as only about 10% of dogs with CSM present this sign (Morgan, et al., 1986; Da Costa, et al., 2008).

Facilitated palpation of the scapular spine can be an indicator of atrophy of the supraspinatus and infraspinatus muscle, which is a sign of suprascapular nerve compression. This compression is usually linked with C6 nerve root entrapment and can also result in limb lameness (Platt & Olby, 2014; Da Costa, 2010).

5. Imaging Diagnosis

After the neurological examination, it is essential to perform imaging exams to obtain a definitive diagnosis (Coates, 2000). These exams will allow an accurate determination of the lesion location, the type of herniation present and, in some even the tridimensional orientation of the herniated disk material (Griffin, et al., 2009). However, before proceeding with these exams, it is important to perform a pre-anesthetic evaluation which includes a complete blood count (CBC), chemistry profile and urinalysis in all patients before nonemergency procedures. This screening exams are also relevant to rule out other concurrent disorders, such as infectious conditions, for example. During emergencies, the analysis should include at least packed cell volume, total protein, serum glucose and urea concentrations (Sharp & Wheeler, 2005).

CSF analysis should also be carried out in order to rule out neurological inflammatory diseases. It is relevant to take into account that elevations of protein and cell content are usually mild (Sharp & Wheeler, 2005; Stephen J. Ettinger, 2017). On the other hand, in cases of urinary incontinence, a microbiological culture should be performed, as well thorax radiographs, especially in geriatric dogs (Griffin, et al., 2009).

5.1 Radiography

Survey radiographs can be taken to rule out other causes for the detected signs, as well as to access degenerative changes compatible with disc herniation (Platt & Olby, 2014). This exam can be used to exclude specific diseases such as discospondylitis, neoplasia, vertebral fractures or malformations (Da Costa, 2010). Of note, radiographic features of chronic disease are commonly found in older dogs and might not always translate into clinical signs. (Sharp & Wheeler, 2005).

Despite being very suggestive of disc extrusion, radiographic features like intervertebral space narrowing and dorsal displacement of mineralized disc material are not reliable enough to provide a definitive diagnosis, since their estimated accuracy rate is only about 35%. Therefore, other imaging tests such as myelography, CT or MRI are needed to reach a definitive diagnosis (Somerville, et al., 2001; Sharp & Wheeler, 2005; Mohammed, et al., 2016).

5.2.Myelography

For many years, myelography was considered the method of choice to diagnose spinal cord lesions. However, nowadays, CT and MRI are considered the preferred alternatives for diagnosis of IVDD. Myelography allows the identification of the herniation site and the respective direction (ventral, dorsal, lateral) of the spinal cord compression, as well as allowing stress myelographic studies (Da Costa, 2010).

During this exam, a contrast medium is injected into the subarachnoid space, forming a spinal cord outline with the positive contrast. The contrast medium should be a non-ionic and water-soluble substance such as iohexol (Sharp & Wheeler, 2005). It is advised to obtain both lateral and ventrodorsal views, as well as oblique views, which may increase the diagnostic sensitivity of myelography (Da Costa, 2010).

Until early 2000s, traction myelographic views have been regularly used to distinguish dynamic from static lesions (Seim & Withrow, 1982). However, recent comparative myelographic and MRI studies have shown that the concept of static and dynamic lesions can be highly subjective. Therefore, a lesion that might appear dynamic on myelography can also appear static on MRI, in addition to the fact that any compressive lesion seems to improve with traction. This observations indicate that this lesion classification is not only dependent on personal opinion, but also infers that the very concept of static and dynamic lesions might as well be questionable (Costa, et al., 2006; Da Costa, 2010).

The imaging features vary according to the type of herniation present. Therefore, extrusion herniations are related to signs such as: lateral or dorsal deviation of the contrast outline, narrowing of the contrast outline and asymmetric distribution of the extruded material. On the other hand, in protrusion herniations, signs such as dorsal or dorsolateral deviation of the contrast outline and slight outline narrowing can be observed in the affected sites (Macias, et al., 2002).

Myelography is an invasive exam which might result in artefacts, as well as a variety of adverse reactions due to the contrast medium, which include convulsion, cardiac arrythmia, apnea and deterioration of the patient’s neurologic status (Barone, et al., 2002). Due to these factors, myelography is rarely indicated, unless CT or MRI aren’t available (Tidwell & Kent, 2013).

5.3 CT

CT is a diagnostic exam that allows the clinician to rapidly obtain multiple transverse sections of the vertebral column without the layering of other anatomic structures (Robertson & Thrall, 2011; DaCosta & Samii, 2010). This exam has notable advantages when compared to myelography, since it is much faster to perform and allows a much more accurate location of the lesion (Olby, 1999).

This method ensures the possibility to generate tridimensional, high resolution anatomical reconstructions which show the exact location and orientation of the extruded disc material (Robertson & Thrall, 2011). These advantages are useful for the surgeon to plan the ventral slot procedure and to identify lateralized or foraminal lesions. CT is considered the preferred imaging method to confirm the diagnosis of cervical disc disease in chondrodystrophic breeds (Sharp & Wheeler, 2005).

Contrast enhancement using myelography is often used, especially in indicated cases such as mineralized disc extrusions, vertebral tumors or CSM. CT myelographies require a much lower dose of contrast medium, which is an advantage over conventional myelograms. Therefore, if a CT study is properly planned, the dose of contrast medium can be reduced in about one quarter of the dose used in conventional myelography (Sharp & Wheeler, 2005; Robertson & Thrall, 2011).

A recent 2016 study has shown that CT Myelography has 100% accuracy in determining spinal cord lesion sites and a 93,9% accuracy in detecting the side of the herniation. This study also inferred that CT Myelography was also the most accurate technique at locating spinal cord lesions when compared to neurological examination, plain radiography, CT alone and traditional myelography (Mohammed, et al., 2016).

The resulting image of a mineralized disc extrusion is a heterogenous, hyperattenuating, extradural mass with loss of epidural fat around the affected area (Olby, et al., 2000). Regarding CSM, CT myelography is considered a standard for the diagnosis of the disease. The technique is advantageous to evaluate the disease, since it allows the identification of spinal cord atrophy, which is a possible feature of CSM. The corresponding image can be identified using CT myelography as a widening of the subarachnoid space which surrounds the spinal cord in a triangular shape (Sharp, et al., 1995; Costa, et al., 2009).

Even without contrast, CT is still considered to provide higher precision rates than traditional myelography in the determination of the extrusion site (Olby, et al., 2000; DaCosta & Samii, 2010). However, if the disc material is not mineralized, it may be difficult to identify a compressive lesion without the use of contrast. Therefore, iohexol should be administered into the subarachnoid space, in order to visualize the compression site more precisely (Olby, et al., 2000; Robertson & Thrall, 2011).

5.4 MRI

Nowadays, MRI is considered to be the best exam to evaluate the cervical spinal cord, as it allows a non-invasive obtention of high-resolution images, without the side effects attributable to other imaging methods, such as CT or myelography (Levitski, et al., 1999). However, the higher cost and duration of the exam when compared with CT, might not always provide the most cost-effective option (Sharp & Wheeler, 2005). In addition, MRI provides a notably detailed image of the spinal cord parenchyma and intervertebral discs, which can aid prognosis (Mashita, et al., 2015).

MRI allows the detection of IVD degeneration, even before its mineralization, which is an advantage when compared with CT (McConnell, 2012). The detection of disc degeneration is possible since the nucleus pulposus dehydrates, therefore in T2 Weighted images (T2WI) , the nucleus appears isointense or hypointense in comparison to the annulus fibrosus, as opposed to its normal hyperintense magnetic signal (Griffin, et al., 2009; DaCosta & Samii, 2010).

T2 Weighted images allow the differentiation of extrusion and protrusion herniations. Therefore, extrusion herniations appear as hypointense, amorphous, extradural masses, located dorsally to the IVD, compressing the spinal cord or epidural fat. Moreover, traumatic extrusion herniations will show an increased magnetic signal in the injury site, while presenting a hyperintense nucleus pulposus, despite having a slightly diminished intensity when compared to other IVDs, since the NP is not degenerated in these cases. In addition to these characteristics, traumatic disc extrusions tend to show absent to slight compression of the spinal cord (McConnell, 2012). On the other hand, a 2012 study showed that acute, compressive hydrated nucleus pulposus extrusion (HNPE) is also a possibility, displaying a “hydrated signal intensity immediately above the affected disc space, often with a seagull shape on transverse images” (Beltran, et al., 2012).

In cases of protrusion herniation, the image is characterized by hypointense nodules located in the vertebral canal associated with spinal cord ventral compression (McConnell, 2012).

Regarding CSM, MRI is the gold standard test for evaluation of the disease typical lesions (Da Costa, 2010). This method is advantageous since it is able to detect spinal cord parenchymal alterations with notable detail (Lipsitz, et al., 2001). MRI is proven to be far more accurate at identifying the site, severity, and nature of spinal cord compression in CSM than Myelography. As such, in a 2006 study, it was shown that Myelography revealed 83% accuracy in identifying the lesion parameters referred, whereas MRI imaging detected 100% of those lesion parameters (Costa, et al., 2006).

MRI imaging CSM features depend on the etiology of the disease (Da Costa, 2010; Fitzpatrick & Fingeroth, 2015). Therefore, osseous compressions show hypointense vertebral proliferation in articular processes, lamina and pedicles in both T1 and T2 weighted images. Whereas, in disc associated CSM, affected IVD appear hypointense or isointense relative to the vertebral bodies in T2WI, depending on the degree of protrusion (Costa, et al., 2006). In addition, it is important to consider that the degree of spinal compression does not always match the severity of clinical signs. Thus, in the presence of minimal image features of spinal cord compression accompanied with severe clinical signs, a dynamic spinal cord compression should be considered (da Costa, 2007).

Despite not being properly cited in veterinary medicine, there is a well-documented correlation between spinal cord signal changes on MRI and histopathologic alterations in CSM affected humans. This evidence infers that multilevel hyperintensity in T2WI and hypointensity in T1WI are indicators of a worse prognosis (Ohshio & Hatayama, 1993; Chatley, et al., 2009; Yagi, et al., 2010).

Finally, MRI has the advantage of prioritizing the relative importance of multiple lesions (Fitzpatrick & Fingeroth, 2015). As such, transcranial magnetic stimulation is suggested as a method to differentiate clinically relevant spinal cord compressions using MRI imaging (De Decker, 2011).

6. Treatment

There is some controversy regarding the most suitable treatment for CVIDD since the treatment can either be conservative or surgical (Jeffery, 1995; Seim III, 2018; Sharp & Wheeler, 2005). As a result, the decision to treat medically or surgically should be based on a variety of factors, such as neurological severity, chronicity, recurrence, response to medical treatment, systemic health of the patient and financial status of the owner (Costa & Platt, 2017). Therefore, patients can be classified into three groups: group I, first episode involving neck pain only; group II, repeated episodes of neck pain only; and group III, neck pain with concurrent neurological deficits. As such, medical therapy is usually recommended for group I dogs, whether a surgical approach is most suitable for group II and group III patients (Toombs & Waters, 2003).

In opposition, other authors defend that even in patients with a mild onset of the disease, it might be a risk to treat the patients medically, since there might be a great amount of disc material inside the vertebral canal contributing to severe neurological deterioration. Therefore, these authors defend that the ideal treatment for all degrees should be surgical (Sukhiani, et al., 1996; Sharp & Wheeler, 2005). Regardless of the treatment choice, many authors consider the association of physiotherapy to be beneficial for a faster and complete recovery of cervical injury in IVDD patients (Ramalho, et al., 2015; Fossum, et al., 2007; Brisson, 2010).

6.1. Medical/ Conservative treatment

The Non-surgical treatment entails rest and use of anti-inflammatory drugs and can be tried in any patient, unless severe neurological deficits are present (Sharp & Wheeler, 2005; Seim III, 2018; Jeffery, et al., 2013).

Cage rest for 4 to 6 weeks, followed by gradual incremental walks over the next month is considered the most relevant factor in conservative CIVDD. This period of rest facilitates the resolution of the inflammation and stabilization of the of the injured disc by fibrosis, preventing further herniation (Toombs & Waters, 2003; Costa & Platt, 2017). It is important to consider that a lack of response to treatment or worsening of clinical signs is an indicator of recurrence due to treatment failure (Sharp & Wheeler, 2005). Moreover, a favorable response to conservative treatment implies the maintenance of cage rest for at least 6 weeks after the resolution of clinical signs. Post recovery, during the periods of exercise, it is important to replace a leash for a harness, in order to minimize neck tension (Toombs & Waters, 2003).

Non-steroidal anti-inflammatory drugs (NSAIDs) or low-dose prednisolone can be recommended for a few days during the resting phase. In addition, analgesic medication may be associated to the treatment if needed (Costa & Platt, 2017; Sharp & Wheeler, 2005). Since most cases are related to neck pain, it is advisable to combine the anti-inflammatory treatment with muscle relaxants such as diazepam and methocarbamol. Gabapentin can also be used as an adjunctive medication if signs of nerve root involvement, such as nerve root signature, or foraminal herniation, identified via imaging exams (Costa & Platt, 2017).

Chondroprotectors containing glicosamine sulphates and condroitine, can also be included in the treatment protocol, since they stimulate hyaline cartilage synthesis, preventing joint degeneration (Rosa & Kataoka, 2019). Other complementary approaches, such as acupuncture can also be beneficial, as acupuncture is associated with an initial recovery of 69% of studied cervical disc disease cases (Janssens, 1985; Costa & Platt, 2017).

Conservative approaches were reported to have recurrence rates of 33 to 36% (Levine, et al., 2007; Janssens, 1985; Russell & Griffiths, 1968). In one study assessing the effectiveness of the conservative treatment for cervical intervertebral disc herniation, 49% had a successful outcome, whereas 33% recurred and 18% showed therapeutic failure (Russell & Griffiths, 1968). The latter, also verified that increasing onset duration and severe neurological deficits are associated with a less successful conservative management (Russell & Griffiths, 1968; Costa & Platt, 2017). In addition, a 2003 study on the disease showed that, in dogs with deep nociception loss, medical treatment only represents a 7% rate of success (Amsellm, et al., 2003).

As previously stated, physiotherapy is shown to be beneficial as an adjuvant for either treatment option. Physiotherapy aims to aid recovery of injured nervous tissue, prevent the development of muscle atrophy, improve limb function, avoid the development of soft tissue fibrosis and stimulate limb sensibility to stimuli (Ramalho, et al., 2015; Fossum, et al., 2007). As such, during conservative treatment, it is advised to start the physiotherapy sessions after a minimum of 2 weeks in confinement, due the risk of further extrusion of disc material stimulated by the dog's motion (Pedro & Mikail, 2009; Lecouteur & Grandy, 2004). On the other hand, post-surgical physiotherapy can be initiated as soon as 48 hours after the procedure (Ramalho, et al., 2015; Pedro & Mikail, 2009).

6.2. Surgical Treatment

As previously stated, the eligible surgical treatment cases include recurrence of the onset of CVIDD, unremitting pain (both included in group II) and severe or progressive neurological deficits (Group III) (Sharp & Wheeler, 2005; Toombs & Waters, 2003). The aims of the surgical treatment for IVDD are to diminish compression of the spinal cord, to remove the material inside the spine, to reduce the associated edema and to promote pain relief and prevention of further extrusions (Sharp & Wheeler, 2005).

Although a diversity of procedures can be used, the most practiced surgical methods to treat IVDD are decompressive techniques (Jeffery, 1995; Sharp & Wheeler, 2005). Amongst these techniques, ventral decompression is considered to be the gold standard procedure by many authors for CIVDD (Jeffery, et al., 2013). This technique can also be combined with stabilization for caudal disc extrusions. However, in extrusions that cannot be accessed by ventral slot or in case of doubt regarding the herniation site, it is advisable to opt for dorsal or dorsolateral decompression procedures, such as hemilaminectomy or laminectomy (Sharp & Wheeler, 2005; Chambers, et al., 1986).

Regarding CSM surgery, it is important to classify the cause of the disease in order to choose the most appropriate technique. Therefore, in Disc-Associated CSM, ventral slot is generally the preferred method to stabilize the injured site. CSM ventral slot surgery consists of removing disc protrusion and ligament hypertrophy to decompress the spinal cord. Of note, in the presence of dynamic compressions or multiple compression sites, distraction-stabilization techniques are advisable (Jeffery & McKee, 2001; Da Costa, 2010). In addition, dorsal approaches, such as laminectomy or hemilaminectomy, may be preferable if multiple disk spaces are injured, or when the compression is predominantly dorsal or lateral (Fossum, 2013). Post surgically, osseous fusion is encouraged in order to allow long-term fixation, which shouldn't solely depend on implants. This process usually takes 8 to 12 weeks after the procedure (Sharp & Wheeler, 2005; Da Costa, 2010).

On the other hand, Osseous Compressions are typically treated with dorsal laminectomy or hemilaminectomy. Despite not diminishing compression, distraction-stabilization techniques can also be applied in Osseous CSM, since they may allow the healing of ligamentous and/or bone lesions over time (Da Costa, 2010; Rossmeis, et al., 2005; Jeffery, 1995).

Ventral slot decompression in Hansen Type I extrusions was associated with the complete recovery of 90% of dogs within 1 month and 98% of dogs within a year (Seim & Prata, 1982). In another ventral slot decompression study, using large breed dogs with disc protrusion associated wobbler syndrome, a 66% success outcome was registered, along with the conclusion that dynamic lesions should be associated with stabilization (Chambers, et al., 1986). Moreover, the post-surgery recurrence rate for CIVDD ventral slot was observed to be 5 to 10% (Cherrone, et al., 2004; Russell & Griffiths, 1968). Furthermore, recent studies reveal roughly 100% success rates post VS surgery (Santini, et al., 2010; Arias, et al., 2007; Cherrone, et al., 2004). In sum, it is relevant to consider that CSM ventral slot outcomes are notably less successful when compared to Hansen type I-disc herniation outcomes of the same surgical approach.

Moreover, a recent study on the use of ventral slot, for the treatment of cervical compressive hydrated nucleus pulposus extrusion (HNPE), revealed a favorable outcome in all dogs except one, despite the presence of severe onset neurological deficits (Beltran, et al., 2012).

6.2.1 Preoperative care

If vertebral instability is suspected, the patient needs to be as immobilized as soon as possible (e.g., neck brace or secured to a rigid surface). It is important to be extremely careful with neck manipulation, and to consider that after anesthesia, voluntary contraction of the cervical muscles will no longer be a protective mechanism in response to trauma. For patients displaying neck pain, which is one of the most frequent signs in CVIDD, oral prednisolone is recommendable for pain relief. In animals with severe neck pain, analgesia should be initiated immediately, which can include injectable opioids (e.g. fentanyl) (Fossum, 2013; Sharp & Wheeler, 2005).

6.2.2 Ventral slot decompression

This technique allows the removal of ventral displaced disc material and usually provides the fastest resolution of clinical signs, when compared to other techniques (Sharp & Wheeler, 2005). Despite allowing a more direct access to ventrally herniated disc material, without the amount of dissection practiced in dorsal methods, VS decompression has the caveat of a limited working space. To counteract the latter, magnification and proper lighting can be beneficial (Fauber, 2015).

Ventral slot decompression can be combined with stabilization if vertebral instability or subluxation are potential risks, which are usually related with CSM and/or caudal disc extrusions (C4/5–C6/7). Stabilization is defined as fixation of the vertebral interspace subject to ventral decompression (Lemarie, 2000; Fitch, 2000). Several distraction-stabilization methods can be used for fixation after ventral slot, the most effective include pin or screw insertion into vertebral bodies with a polymethylmethacrylate (PMMA) bridge and PMMA “plug” placement into the opened ventral slot (Fossum, 2013).

6.2.3 Postoperative Care

Postoperatively, the patient should be hospitalized and kept under observation for 24 hours. Post operatory critical care should include monitoring of vital signs, pain relief medication and observing for gastric dilation, seizure activity and blood gas analysis if dyspnea is present (Fossum, 2013).

Analgesia should consist of low doses of opioids, fluids in maintenance rate and the patient should be turned every 2 hours while hospitalized, until voluntarily acquiring sternal recumbency. Corticosteroids should be discontinued after the procedure, and only given in case of neurologic deterioration signs (Fossum, 2013; Sharp & Wheeler, 2005).

Ambulatory dogs should be discharged 3 to 5 days post-surgery. At home, they should be confined for 4 weeks, consisting of 2 weeks of strict confinement followed by 2 weeks of gradual controlled exercise with a harness. On the other hand, patients with neurological deficits require additional postoperative care, which includes passive range of motion exercises, hydrotherapy, physiotherapy, massages, frequent turning and bladder emptying. These patients should be frequently cleaned to avoid decubital ulcers (Fossum, 2013; Platt & Olby, 2014).

6.2.4. Complications

The Ventral Slot procedure is associated with complications such as respiratory compromise, cardiac dysrhythmias, vertebral subluxations, and venous plexus hemorrhage (Da Costa, 2010; Sharp & Wheeler, 2005). In a recent study of 546 dogs who underwent ventral slot decompression surgery, 9.9% manifested adverse events (AE), which were significantly associated with perioperative hypotension, C7–T1 disc extrusions, surgeon experience, and NSAID administration. This study also suggested that significant postoperative AE is an indication for urgent diagnostic imaging studies, since 50% of the patients required reoperation (John, et al., 2013). Weeks prior to surgery, there are still possible severe complications such as aspiration pneumonia, cardiac arrthytmias and vertebral luxation (Platt & Olby, 2014).

Chapter II

1. Objectives

The present retrospective study uses data obtained from a sample of 18 animals of the species *Canis lupus familiaris* diagnosed with Cervical Intervertebral Disc Disease (CIVDD) and submitted to Ventral Slot Decompression Surgery in Restelo Veterinary Hospital, a referral hospital which includes the specialty of orthopedics and neurology.

The data relative to these cases was obtained from the Hospital's clinical database, by accessing the patient's history using the veterinary software program QVet. The cases were observed and registered between late 2018 and early 2020.

The aim of this study is to report the short-term surgical outcome of the Ventral Slot Procedure for the treatment of Cervical Disc Herniation and to compare the surgical outcomes of different types and sites of herniation.

Within the studied population, the following objectives were defined:

1. Characterization of the studied population (breed, sex, age);
2. Characterization of the severity of the lesions and clinical signs;
3. Characterization of the lesion location and type of herniation (Hansen Type I, Hansen type II);
4. Evaluation of the post-surgical outcome;
5. Comparison between Hansen type I and Hansen type II post-surgical outcome;
6. Comparison between the different lesion sites post-surgical outcome;
7. Comparison of the obtained results with the bibliographic revision.

2. Materials and Methods

2.1. Inclusion Criteria

The medical records of 18 dogs that underwent Ventral Slot Decompression procedure for the treatment of CIVDD at Restelo Veterinary Hospital between 2018 and 2020 were examined.

Registered information included age, breed, sex, pre-operatory and post-operatory neurological status, site of injury, type of disc herniation and hospitalization period. Patients were included if they had undergone ventral slot decompression surgery and had records of at least one post-surgery follow-up consultation. In all affected patients, the diagnosis of CIVDD was confirmed by CT myelography scans of the vertebral column and the correspondent reports were written by the same imaging diagnosis specialist. All dogs were confined during hospitalization and participated in physiotherapy sessions after surgery.

2.2 Exclusion Criteria

For the present study, animals with Cervical Intervertebral Disc Herniation associated with concurrent spinal diseases such as neoplasia, discospondylitis or atlantoaxial instability, were excluded.

Likewise, animals with history of advanced chronic conditions such as Chronic Kidney Disease, for example, were also excluded from the study. In addition, animals with lack of medical records reporting post-surgical follow up consultations.

2.3 History and neurological exam

The dogs included in the sample were graded based on the modified Frankel scale (present on table 3), according to the severity of the neurological disfunction presented.

0	Tetraplegic/paraplegic without deep nociception
1	Tetraplegic/paraplegic without superficial nociception
2	Tetraplegic/paraplegic with nociception
3a	Non-ambulatory tetraparesic without weight support
3b	Non-ambulatory tetraparesic with weight support
4	Ambulatory tetraparesic/paraparesic with ataxia
5	Hyperestesic only

Table 3 – Modified Frankel Scale ***(Levine, et al., 2007)***

However, for the present study, a slightly adapted version of the Modified Frankel Scale was used as represented on table 4 bellow.

0	Tetraplegic/paraplegic without deep nociception
1	Tetraplegic/paraplegic without superficial nociception
2	Tetraplegic/paraplegic with nociception
3	Non-ambulatory tetraparesic
4	Ambulatory tetraparesic/paraparesic with ataxia
5	Hyperestesic only
6	Clinically normal

Table 4 - Adaptation of the Modified Frankel Scale used in the study

As such, grades 3a and 3b were converted into solely grade 3, since the history of tetraparesic animals was often not clear regarding the presence of weight support.

Therefore, the patients were divided into 7 different grades, from which the numeric order is inversely proportional to the severity of the corresponding neurological signs. As such, Grade 0 stands for the most severe onset of CIVDD, which corresponds to tetraplegic patients without deep nociception, followed by Grade 1 corresponding to tetraplegic patients without superficial nociception, while maintaining deep pain sensation. Moreover, Grade 2 corresponds to tetraplegic patients presenting full nociception, followed by Grade 3 which represents nonambulatory tetraparesic patients.

Furthermore, Grade 4 represents ambulatory tetraparesic dogs and Grade 5 is composed of dogs which solely manifested cervical hyperesthesia.

In addition to the Frankel scale, this study uses Grade 6 to represent dogs which did not present any neurologic deficits or clinically related signs with CIVDD, which, therefore were considered normal from a neurological standpoint.

All patients were graded based on their consultation history records. Both preoperative and postoperative neurological evaluations during the respective consultations were used to access the grade attributed to each patient.

2.4 Diagnostic Imaging

CT Myelography was performed in all dogs in order to identify the spinal cord lesion site. Firstly, animals were submitted to a CT without contrast, followed by a CT myelography posterior to an injection of Iohexol contrast (Omnipaque) into the lumbar subarachnoid space.

Lateral scans of the cervical spine were taken with the patient in dorsal recumbency, for the interpretation of sagittal, axial and longitudinal images, as well as a three-dimensional reconstruction of the vertebral column.

2.5 Characterization and Classification of cervical spinal cord herniation

The characterization of the herniation was accessed via imaging diagnosis using CT myelography scan reports written by a specialist in the field. The CT report information was used to list the spinal cord region affected, as well as to classify the herniation into Hansen Type I or Hansen Type II. This information was posteriorly confirmed via visualization of the herniation during ventral slot decompression surgery.

Furthermore, dogs who were not classified as presenting Hansen type I or II herniation were excluded from the study. According to the CT myelography scan, CIVDD was classified as

Hansen type I if hypodense material within the intervertebral disc space or the vertebral canal was identified, along with a narrowing and dorsal or lateral deviation of the contrast columns of the injured intervertebral disc space. On the other hand, Hansen type II herniations were associated with focal, dorsal, or dorsolateral deviation of the contrast columns associated with their discrete narrowing. During the ventral slot procedure, it was possible to confirm the prior imaging diagnosis regarding the site of injury and the type of disc herniation. As such, Hansen type I-disc disease was associated with mineralized nucleus pulposus within the vertebral canal which could be combined with annulus fibrosus material displacement. In opposition, Hansen type II herniations were confirmed by the observation of annulus fibrosus protrusion not associated with sequestration of fibrous material in the epidural space.

2.6. Surgical Procedure

The ventral slot decompression surgery was performed in all dogs. The surgical technique based on observation and the bibliography consulted will be posteriorly described.

Initially, the patients are positioned in dorsal recumbency with the head and neck in extension. Secondly, a dissection is made over the ventral midline to the cervical spine, followed by an incision, which is done between the sternothyroideus and sternohyoideus muscles.

Afterwards, the trachea, carotid sheath and esophagus are deviated to the left to reveal the longus colli muscles. Posteriorly, the intervertebral space of interest is identified by palpation. The longus colli musculature on the midline is then separated at the caudal and cranial aspects of the disc space, and gelpi retractors are placed in the cranial and caudal aspects of the corresponding area, while hemorrhage is controlled using lipostick, for example.

An opening centered over the dorsal aspect of the disc and extended to the dorsal longitudinal ligament is created using a high-speed burr. Following the penetration of the dorsal cortex of the vertebral body, the longitudinal ligament is separated and the herniated disc material can be excised from the spinal canal using a probe and forceps (Fossum, 2013).

2.7 Postoperative Care

Post surgically and while hospitalized, the patients were submitted to the administration of parenteral opioid analgesics. Initially, an LK (Lidocaine and Ketamine) CRI administered for pain relief, followed by methadone (0.2 mg/kg, IV) and then buprenorphine (0.02 mg/kg BID or TID, SC). The duration and frequency of administration of each opioid analgesic was sometimes adapted according to the discomfort/pain signs displayed by the animal (e.g. if the animal was still displaying discomfort while on methadone, there wouldn't be a switch to buprenorphine yet, since it provides a less potent analgesia for dogs).

Post-discharge, the patients were prescribed tramadol (PO 1.5 mg/kg, BID, 8 days) associated with nonsteroidal anti-inflammatory drugs such as robenacoxib (PO 10 mg/kg, SID, 5 days). In addition, prednisolone (PO, 5mg, SID) was admininstered for 3 days, followed by a dosage reduction in half for the next 3 days (PO, 2.5mg, SID), ending with the same 2.5 mg/kg dosage q48h for 4 days.

Antibiotics were also administered post-surgery, therefore Cephalexine (PO, 250mg/kg, BID, 8 days) was used, providing gram-positive and gram-negative anti-bacterial coverage.

In addition, omeprazole (PO, 10 mg, SID) was administered for 8 days as a gastric protectant, due to the administration of gastric damaging NSAIDS and prednisolone.

Additionally, an omega 3 and Vitamin E supplement (PO, SID, 8 days) was prescribed to aid articulation and tissue regeneration.

Strict cage rest, and posterior restricted exercise, along with the use of a cervical collar or harness for at least a month were strongly encouraged to the owners. Moreover, physical therapy was also provided to all patients to facilitate an effective motion recovery.

2.8 Surgical Outcome

The Surgical outcome was calculated using the difference between the presurgical neurologic grading with the post-surgical neurologic evaluation accessed during the first post-surgical follow up examination. The follow up consultations were performed one to two weeks after hospital discharge. The surgical outcome was classified as positive if the patient improved its neurological status at least by 1 grade. Moreover, treatment was considered excellent if the animal improved 2 or more neurological grades. On the other hand, the outcome was classified as good if the animal improved solely 1 grade.

2.9 Statistical analysis

All data was registered and introduced in two different digital softwares for its statistical analysis. The data introduction, organization and processing were executed using the software program Microsoft Office Excel 365. The use of this software resulted in the processing of descriptive graphics, percentages, ratios, one-way ANOVA regressions and other statistic parameters. One-way ANOVA was used to determine the correlation between the following pairs of variables: hospitalization and site of lesion, surgical outcome and site of lesion, outcome and type of herniation, outcome and hospitalization, as well as outcome and age. For these tests, an R squared >70% or a P value < 5% were considered statistically significant.

In addition, a more specific statistical analysis was obtained using the software program IBM SPSS Statistics for Microsoft Windows 64-bit. This program was used to perform nonparametric tests, due to the small sample size and the non-normal distribution of the study population. As such, a Mann-Whitney test was used to determine the correlation between hospitalization time (numeric variable) and Hansen type of herniation (also converted into a numeric variable). Followed by a Fisher exact test to determine an association between Qualitative Outcome (categoric variable) and Hansen type of herniation (categoric variable). Finally, a Chi-Square test was used to determine the association between Qualitative Outcome and Site of lesion. For these tests, a P value < 5% was also considered statistically significant, and a Cramer’s V > 60% was considered to indicate a strong correlation between variables.

3. Results

The case details collected and selected for this study are displayed in table 5 bellow.

Case number	Hansen type	Age (years)	Sex	Breed	Site of injury	Preoperative grade	Postoperative grade	Follow up (days)	Hospitalization (days)	Outcome
1	Type I	8	Male	Labrador Retriever	C7-T1	1	4	15	5	Positive (good)
2	Type II	10	Male	Basset Hound	C5-C6	3	5	40	10	Positive (good)
3	Type I	3	Female	French Bulldog	C3-C4	3	4	7	3	Positive (good)
4	Type II	6	Female	Pug	C4-C5	3	6	15	5	Positive (excellent)
5	Type I	9	Male	Mixed breed	C4-C5	3	6	16	3	Positive (excellent)
6	Type II	9	Male	Yorkshire Terrier	C4-C5	3	4	10	3	Positive (good)
7	Type I	7	Male	Poodle toy	C6-C7	4	6	16	3	Positive (excellent)
8	Type I	8	Male	Mixed breed	C6-C7	4	6	5	3	Positive (excellent)
9	Type I	8	Male	Mixed breed	C3-C4	5	6	15	3	Positive (excellent)
10	Type I	6	Female	French Bulldog	C3-C4	5	6	15	3	Positive (good)
11	Type I	12	Male	Yorkshire Terrier	C3-C4	1	4	3	3	Positive (excellent)
12	Type I	1.5	Female	French Bulldog	C4-C5	5	6	10	3	Positive (excellent)
13	Type I	5	Female	Beagle	C2-C3	5	6	5	3	Positive (excellent)
14	Type I	6	Male	Beagle	C5-C6	4	6	5	3	Positive (excellent)
15	Type I	6	Female	Beagle	C2-C3	3	6	8	3	Positive (excellent)
16	Type I	7	Female	Ibizian hound	C5-C6	4	6	20	6	Positive (excellent)
17	Type I	4	Female	French Bulldog	C3-C4	5	6	12	3	Positive (excellent)
18	Type I	7	Male	Labrador Retriever	C6-C7	4	6	16	3	Positive (excellent)

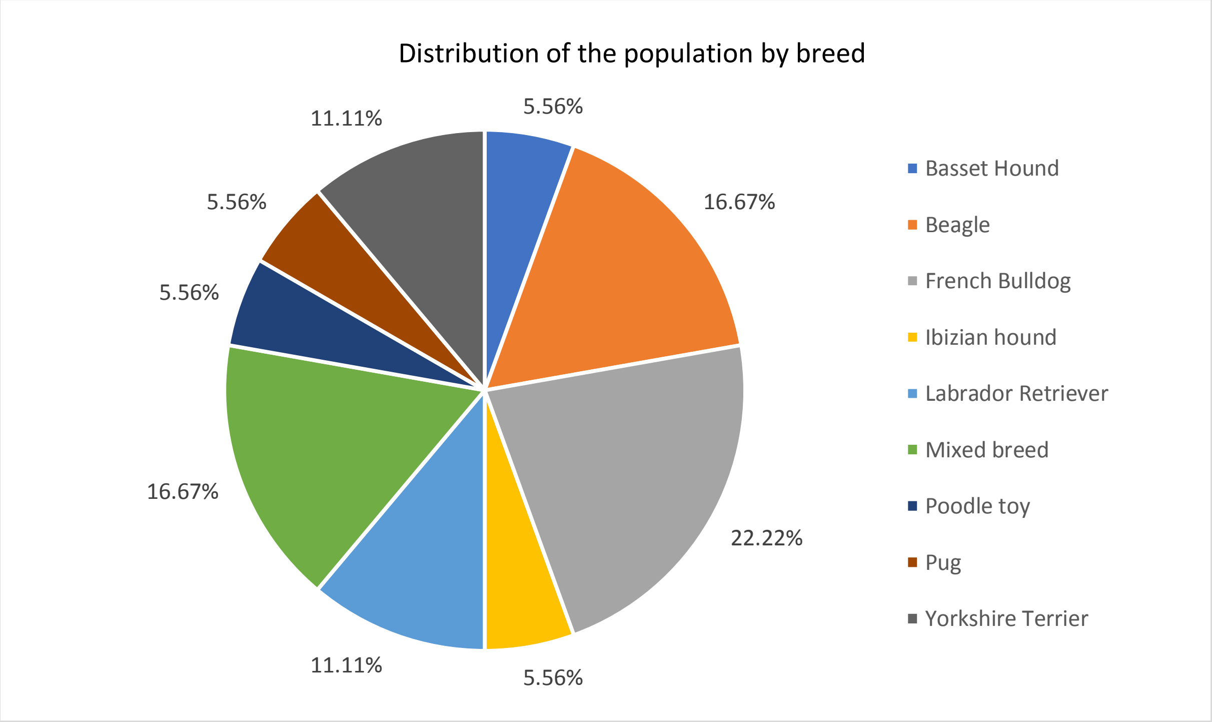
Table 5 – Case details of 18 dogs who underwent Ventral Slot Decompression Surgery

3.1 Characterization of the studied population

As displayed in table 2 above, the studied population is composed of 18 dogs who underwent ventral slot surgery for the treatment of Cervical Intervertebral Disc Disease. The population was divided into different groups for a more detailed analysis of the specific categories studied. As such, groups such as Hansen type I vs II, as well as chondrodystrophic breeds vs non-chondrodystrophic breeds were formed to obtain a more accurate comparison within the studied population.

3.1.1 Breed

Within the sample studied, 9 different breeds were identified. The most commonly affected breed were French bulldogs (22,22%), followed by Beagles (16,67%) and Mixed breed dogs (16,7%). Graphic 1 bellow represents the distribution of the studied population by breed.



Graphic 1 – Distribution of the population by breed

Within the analyzed sample, 66.6% of the population is represented by chondrodystrophic breeds, whereas 33.33% represent non-chondrodystrophic breeds. The most common chondrodystrophic breed is the French Bulldog, followed by the Beagle and the Yorkshire terrier.

3.1.2 Age, Sex and Hansen type of herniation

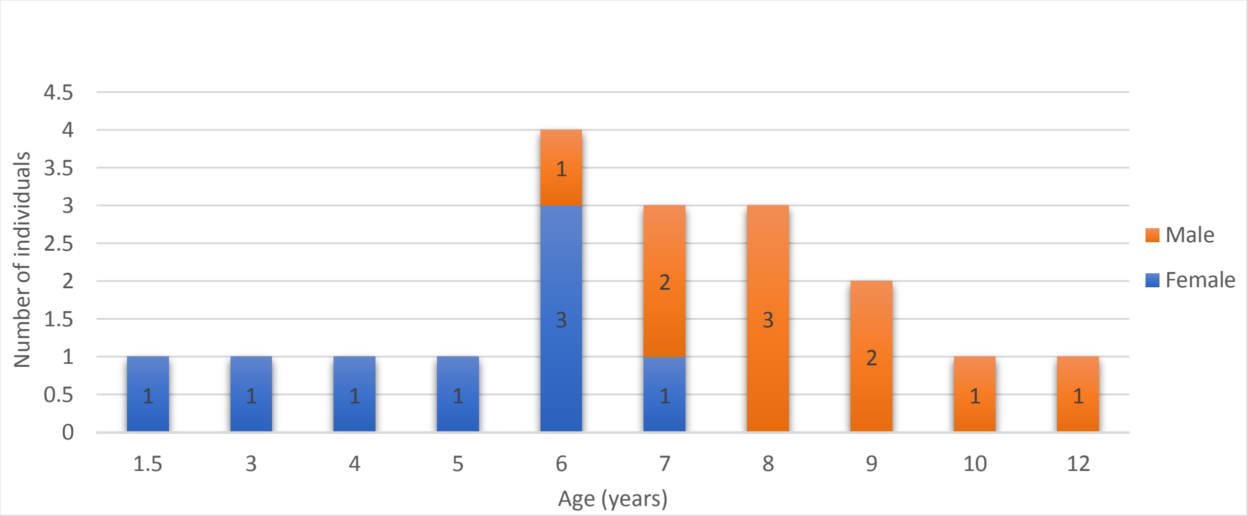
The mean age of the population was 6.8 ± 2,4 years, with a median of 7 years and an amplitude of 1.5 to 12 years. Regarding Hansen types, Hansen Type I registered a mean of 6,5 ± 1,7 years, a median of 7 years and an amplitude of 1.5 to 12 years. On the other hand, Hansen type II herniation patients showed a mean of 8,3 ± 1,7 years, a median of 9 years and an amplitude of 6 to 10 years of age.

		Total population	Hansen Type I	Hansen Type II
Age (years)	Mean ± Standard Deviation	6,8 ± 2,4	6,5 ± 1,7	8,3 ± 1,7
	Median	7	7	9
	Amplitude	1.5-12	1.5 - 12	6 - 10
Sex	Female	8	7	1
	Male	10	8	2

Table 6- Characterization of Age, sex and type of herniation

The most prevalent herniation type of this study is Type I (n=15, 83%), while hansen type II patients represent a much smaller portion of the population (n=3, 17%).

Regarding sex, the studied population was mostly represented by males, as they made up a total of 10 patients, from which 8 were affected by Hansen type I herniation and 2 were diagnosed with Hansen type II herniation. In contrast, females made up of 8 dogs, from which 7 were diagnosed with Hansen type I herniation, whereas 1 was affected by hansen type II herniation.

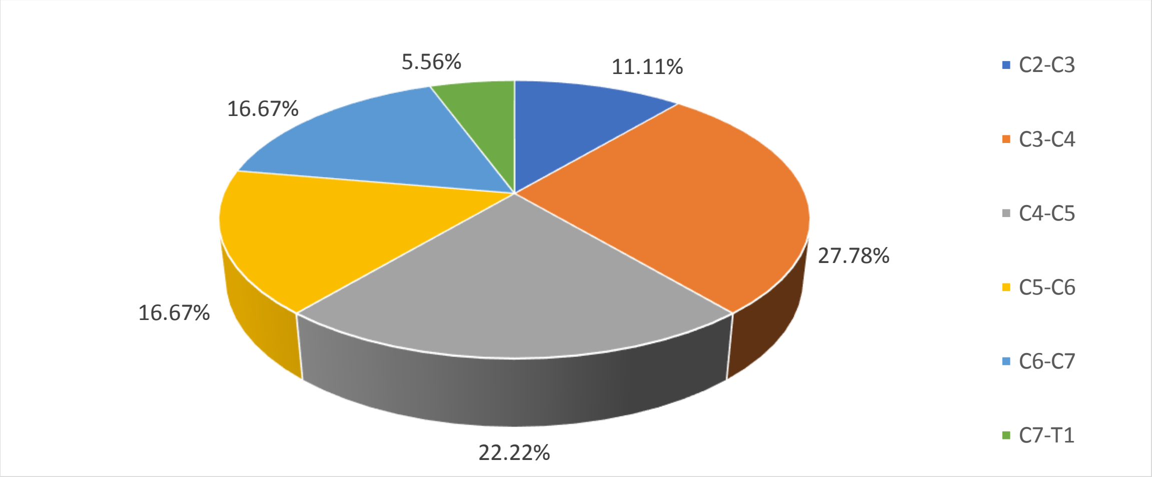


***Graphic 2* – Sex and age sample distribution**

As shown in the graphic 2 above, most patients were between 6 and 8 years of age, which may indicate a prevalence of cervical disc disease in middle aged dogs, within the studied population. Moreover, the great majority of dogs (approximately 77%) were older than 6 years, which also suggests that the disease was more frequent in middle aged and senior dogs.

Interestingly, the sex distribution per age is also notably heterogenous, as most affected females are younger than males. As such, females have shown an average of 4.8 years, contrasting with the male fraction of the population which has an average of 8.4 years.

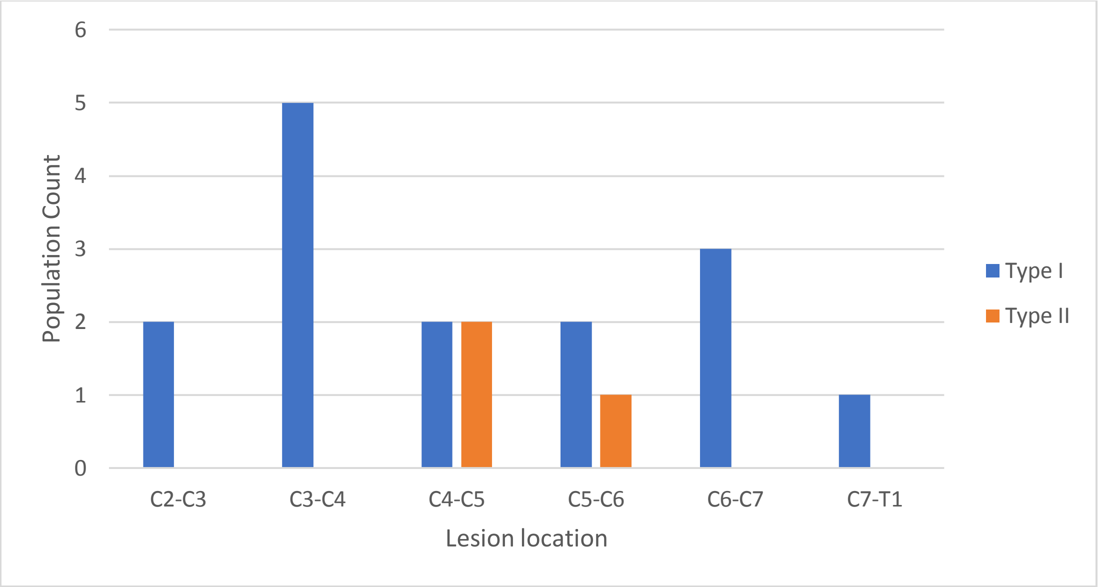
3.1.3 Characterization of lesion location and type of lesion



Graphic 3– Spinal cord lesion location of the studied population

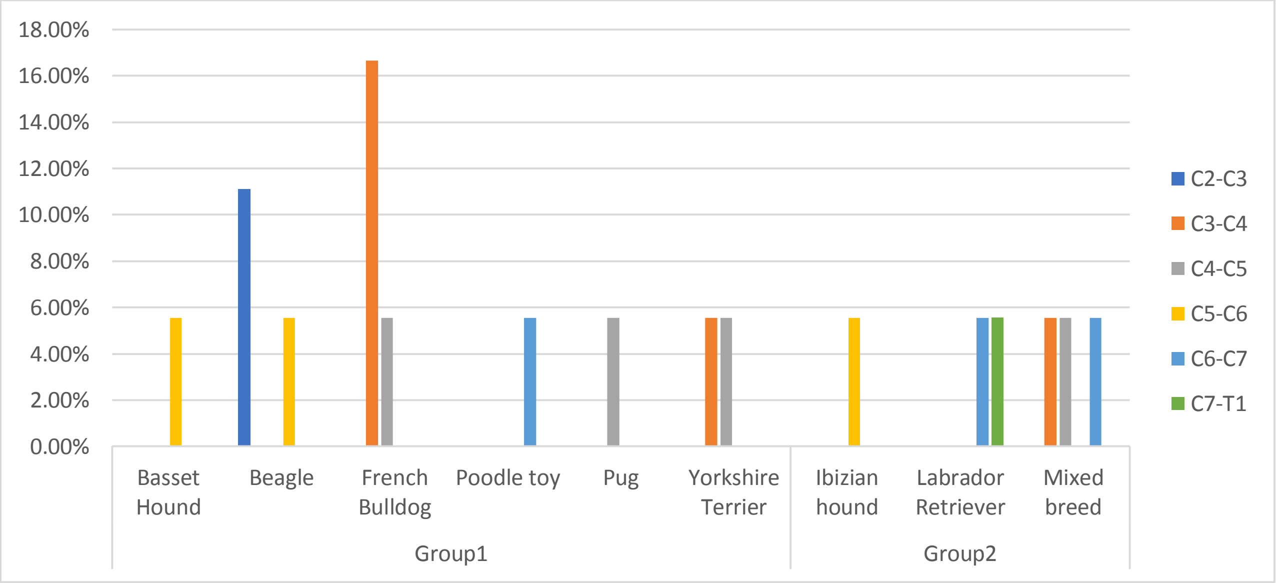
Regarding lesion location, the distribution was relatively homogenous, despite C3-C4 lesions being the most diagnosed, with a percentage of 27.78%. The second most affected area was the C4-C5 segment, representing 22.22% of the studied population, followed by the third most affected site which was C5-C6 and C2-C3, which both accounted for 16.67%, corresponding to the same expression in terms of percentage of the population.

By analyzing graphic 4, which displays the type of herniation per intervertebral space, we can conclude that type I lesions had a more homogeneous distribution, contrarily to type II herniations, which were situated towards the caudal portion of the cervical intervertebral spaces, more specifically between C4-C5 and C5-C6 vertebral segments.



Graphic 4 – Type of herniation per lesion location

Moreover, graphic 5 allows a more specific breed evaluation and comparison of the lesion location tendencies, as such, group 1 is composed of chondrodystrophic breeds, while group 2 represents other breeds.



Graphic 5– Lesion location according to breed

As shown above, the most frequent herniation site in a specific breed was the French Bulldog with C3-C4 herniation, which represented 16% of all cases. It is also possible to observe that group 1 tends to display lesions located more cranially, as most lesions are located between C2-C3 and C5-C6.

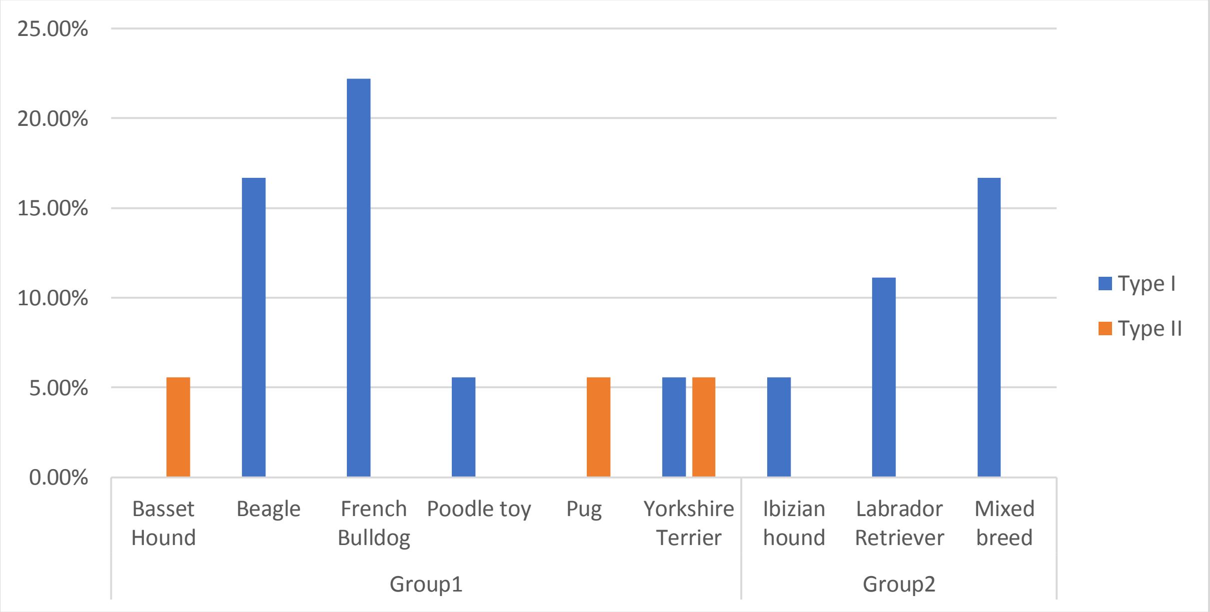
Moreover, the Beagle is the only chondrodystrophic breed suffering from C2-C3 herniations, which represent about 11% of the population.

In addition, the Poodle Toy appears to be an outlier, since all cases studied were diagnosed with lesions located in C6-C7, which belongs to the caudal portion of the cervical vertebral column.

In opposition, group 2 shows a tendency towards lesions located more caudally within the cervical segment of the spinal cord, since most lesions are located between C6-C7.

Furthermore, there is a much more homogenous and diverse distribution of the lesion sites within group 2, which does not seem to highlight any breed tendency.

Regarding Hansen type of herniation per breed, graphic 6 also divides the breeds into group 1 and 2, which also represent chondrodystrophic and non-chondrodystrophic breeds, respectively.



Graphic 6– Type of herniation per breed

As seen in the graphic above, the French Bulldog, followed by the Beagle and Mixed breed, were the most prevalent breed within the population studied, in addition to all being affected by Type I herniations.

Interestingly, type II herniation was only verified in group 1 dogs. However, it is important to reinforce that only a very small fraction of the population was affected by this type of herniation, therefore these results may not be significant.

3.1.4 Complications

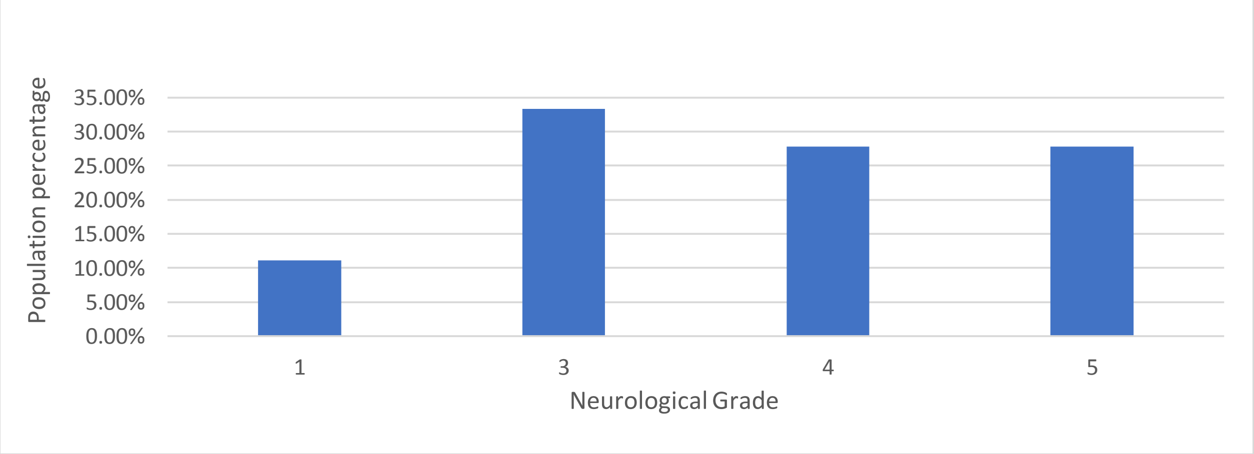
The most commonly registered surgical complication was abundant hemorrhage during the removal of herniated disc material from the vertebral column, which was controlled using cauterization.

Dyspnea due to paralysis of the intercostal muscles was registered in one dog, which was halted after a slight reduction of the anesthetic concentration.

3.4 Neurological grading and respective clinical signs

3.4.1. Preoperative grade

As mentioned in the previous chapter, the patients were graded to describe their neurological status using the Modified Frankel Scale described above in the Materials and Methods section. Graphic 7 bellow describes the neurological preoperative grade of the population, evaluated during the pre-surgical neurology consult.



***Graphic 7*- Preoperative grade of the population**

As illustrated in graphic 7, the distribution of neurological grade is relatively homogeneous, with the exception of grade 1 patients, which represent a significantly lower percentage (approximately 11%), in comparison with the rest of the sample. Of note, grade 1 patients represent a severe degree of neurological disfunction since they are described as tetraplegic with loss of superficial nociception.

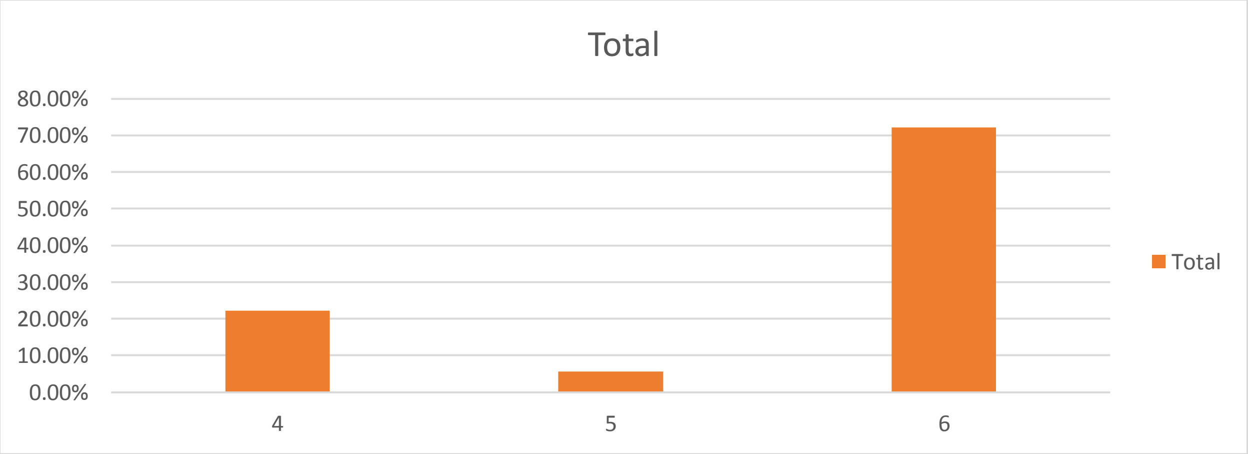
Representing the majority of the studied cases, grade 3 patients, which are described as non-ambulatory patients with tetraparesic ataxia, account for approximately 33% of the population.

Following grade 3 patients, we can observe a "tie" between grade 4 and 5 dogs, since both groups display a percentage of approximately 28%. Grade 4 patients represent ambulatory tetraparesic dogs while grade 5 represents patients in which cervical hyperesthesia is the only described detected neurological disfunction.

In summary, we can conclude that non-ambulatory tetraparesis is the most frequent onset of cervical intervertebral disc disease within the analysed sample.

3.4.2. Postoperative grade

After the ventral slot surgical procedure, the neurological status of the patients was re-evaluated and graded accordingly, as shown in graphic 8.



Graphic 8 **- Postoperative grade percentage**

As graphic 8 demonstrates, all patients were situated between grade 4, which corresponds to ambulatory tetraparesis and grade 6, which represents clinically normal patients.

The majority of patients, which account for 72.22% of the population, were classified as grade 6 by the Modified Frankel Scale, inferring that the majority of them reached complete neurological function post-surgery, which is a very positive indicator.

Grade 4 patients represent the second most relevant percentage, representing 22.22% of the population, implying that these animals displayed tetraparesic ataxia post surgically.

In a significantly smaller portion, stand grade 5 patients, representing only 5.56% of the population, therefore displaying signs of cervical hyperesthesia, according to the grading system adopted herein.

3.5 Surgical outcome

In order to obtain the quantitative surgical outcome, the difference between the preoperative grade and the postoperative grade was calculated.

All animals improved at least one grade after surgery, which qualitatively, translates into a 100% positive surgical outcome of the studied population. Positive outcomes were further classified into excellent and good, as mentioned in the materials and methods section.

The hospitalization period was also measured and characterized in more detailed since it is also an outcome parameter. As such, a shorter hospitalization can be a sign of a faster recovery, therefore meaning a better outcome.

3.5.1 Hospitalization

All animals were hospitalized post-surgery, which is typically planned to last for around three days, in order to grant a proper post-surgical assessment and enhance tissue recovery with minimal movement (Fossum, 2013; Platt & Olby, 2014). Table 2 bellow summarizes the data regarding the hospitalization period of the population and, more specifically, of the groups analysed in this study.

	Total population	Hansen type I	Hansen type II	CD breeds	Non CD breeds
Mean ± Standard Deviation	3.78 ± 2.22	3.33 ± 1.05	6 ± 2.94	4.28 ± 2.57	4.33 ± 1.25
Median	3	3	5	3	4
Amplitude	3-10	3-6	3-10	3-10	3-6

Table 7 – Hospitalization in days

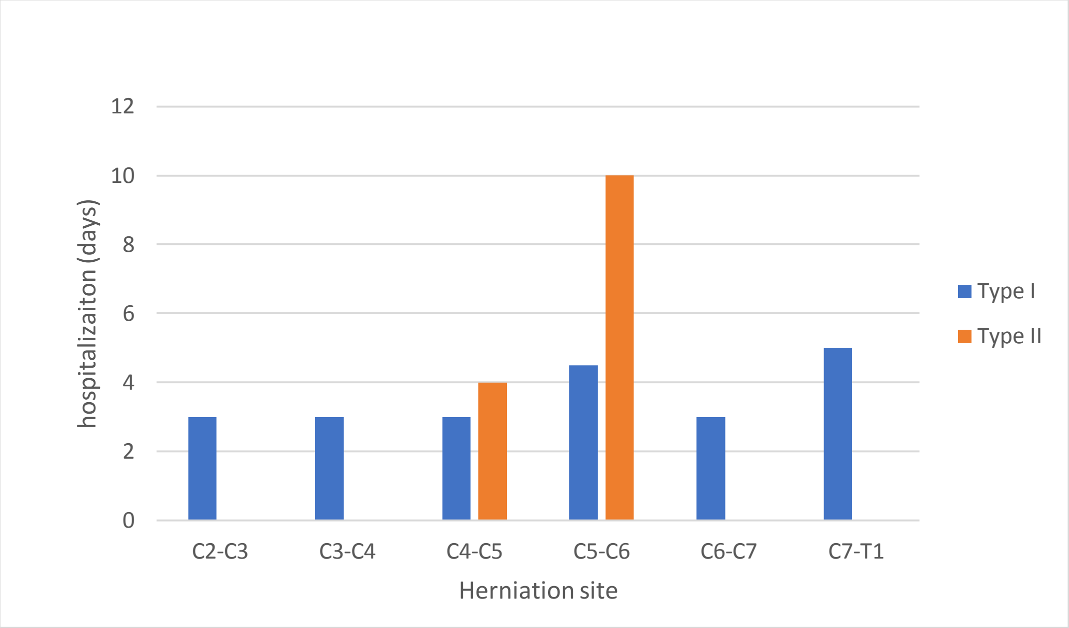
As table 2 demonstrates, the population mean of hospitalization was 3.78 days, with a median of 3 days and ranged from 3 to 10 days. It is relevant to note that only one dog stayed for 10 days and that this prolonged hospitalization was due to logistics of the owner despite the dog being apt to return home after 3 days.

Regarding the Hansen type I patients, the mean was 3.33 days, the median 3 days and the amplitude ranged from 3 to 6 days. These results were also considered within the normal range and slightly reduced when compared with the average of the population.

On the other hand, the Hansen type II group showed a mean of 6 days of hospitalization, with a median of 5 days and an amplitude of 3 to 10 days. When compared to the total population and Hansen type I group these values show a much higher hospitalization time, which could be an indicator of a slower recovery time for these types of herniation. However, it is also important to consider that this sample is very small and that the "10-day outlier" mentioned above is also included in this subdivision, therefore decreasing the statistical credibility of these values.

In relation to the Chondrodystrophic breed group, a 4.28 mean of hospitalization days was registered, along with a median of 4 and an amplitude of 3 to 6 days. On the other hand, the non-chondrodystrophic sample revealed a mean of 4.33 days, a median of 4 days and an amplitude ranging from 3 to 6 days. Despite the CD group displaying higher hospitalization times, both samples showed similar values, which does not allow to identify a tendency towards any of the groups.

3.5.1.2 Hospitalization days per herniation site and type of herniation



***Graphic 9* – Average of hospitalization days per herniation site and type**

As graphic 9 demonstrates, C5-C6 herniations show the highest mean of hospitalization, when compared to other cervical vertebral column segments.

We can also observe that more caudal herniations seem to have a tendency for a slightly longer hospitalization period, contrasting with cranial herniations that display a more reduced average, of approximately 3 days. It is also possible to observe that type II herniations reveal a more prolonged hospitalization period than type I herniations. A possible justification for this finding was previously stated above.

A one-way ANOVA test was performed to test the correlation between Hospitalization and Site of lesion, however the null hypothesis was rejected since the P-value was 0.248, meaning no correlation was found between these two variables.

In addition, a Mann-Whitney Test was performed to test the correlation between Hospitalization and Hansen type. Since the P-value was 0.042 the null hypothesis could be rejected, therefore indicating a possible correlation between these two variables.

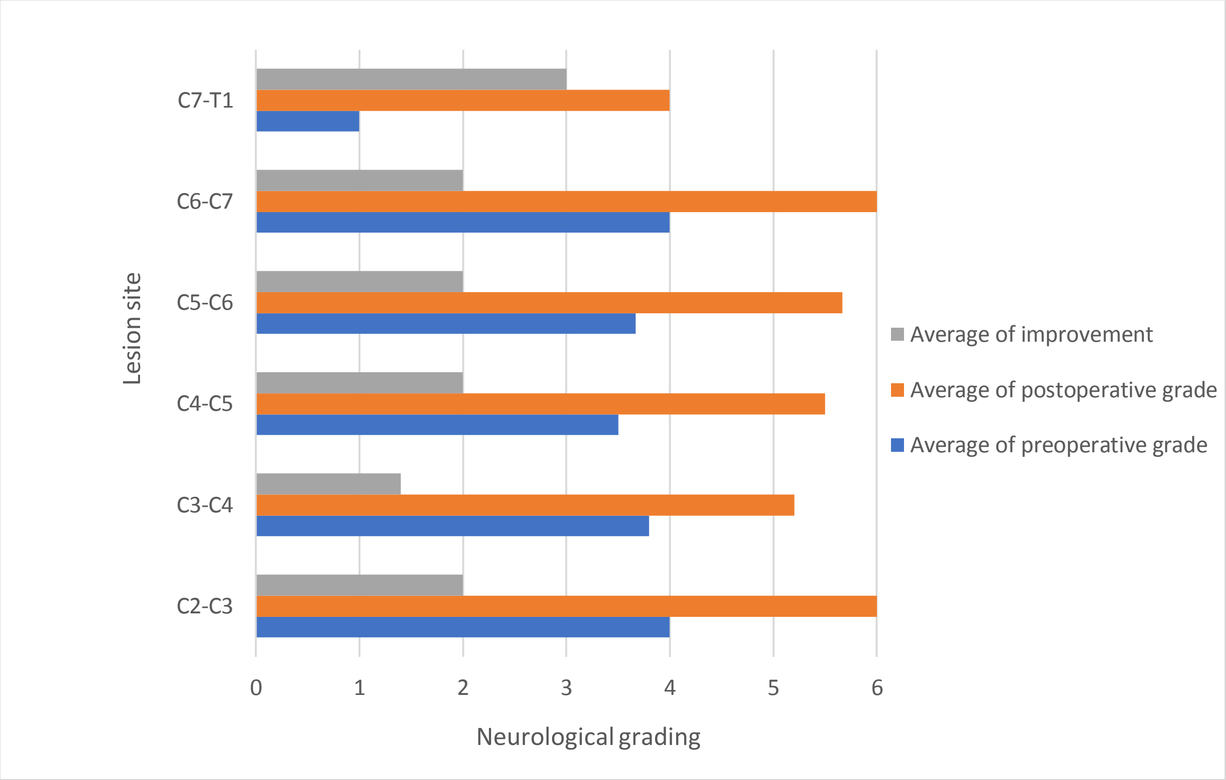
3.5.2 Outcome per lesion site

Table 3 bellow shows the average of preoperative and postoperative grade, as well as the improvement in neurological grading according to the lesion site within the cervical spinal cord segment.

Lesion site	**Average of preoperative grade**	**Average of postoperative grade**	**Average of improvement**
C2-C3	4.00	6.00	2.00
C3-C4	3.80	5.20	1.40
C4-C5	3.50	5.50	2.00
C5-C6	3.67	5.67	2.00
C6-C7	4.00	6.00	2.00
C7-T1	1.00	4.00	3.00
Population average	**3.61**	**5.50**	**1.89**

Table 8– Average of postsurgical preoperative, postoperative grade and improvement per lesion site

As table 8 demonstrates, the average of preoperative grade was 3.61, while the average of postoperative grade was 5.5. Therefore, the difference between these values is 1.89, representing an average of improvement of approximately 2 grades. These values represent, not only a positive outcome, but also a very favorable response to treatment. Moreover, Table 2 was also represented graphically to accurately illustrate the population's clinical improvement per lesion site.



***Graphic 10*- Average of postsurgical preoperative, postoperative grade and improvement per lesion site**

As graphic 10 represents, the less favorable preoperative grade was verified on the C7-T1 herniation, which corresponds to a grade 1 neurological deficit, therefore tetraplegia without superficial nociception. Nevertheless, it is important to note that there was only one patient who suffered from CIVDD in this location, therefore this result cannot be considered statistically representative of the population.

In opposition, C2-C3 and C6-C7 herniations show the most favorable preoperative grading, both with an average grade of 4, therefore translating clinical signs of ambulatory tetraparesis.

Regarding postoperative grade, the lesion site with the least favorable neurological grading was also C7-T8, with an average grade of 3. However, as previously stated, this example is not statistically significant due to the insignificance of the sample size.

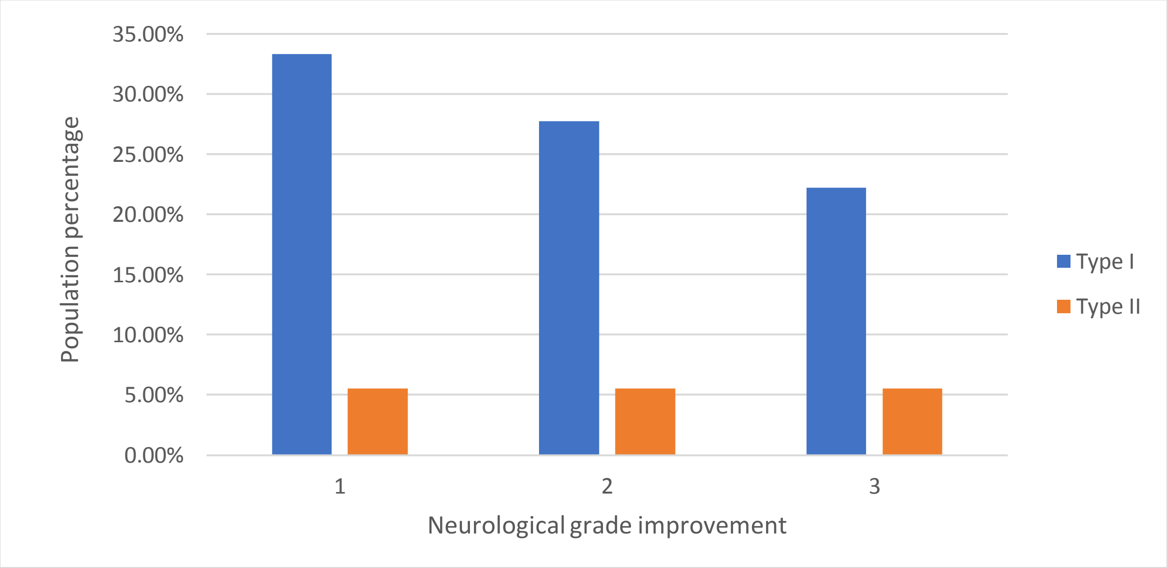
On the other hand, the lesion site with the most positive postoperative grading was C2-C3 and C6-C7, both with an average grade of 6, corresponding to clinically normal patients.

Regarding average of improvement, C7-T1 registered the best improvement average with an improvement of 3 grades post-surgery. As noted, this is not a significant example. Following the latter, C2-C3, C4-C5, C5-C6 and C6-C7 all present an average of 2 grades of improvement post-surgery. Lastly, C3-C4 lesions display an average of improvement of 1.4 grades.

Furthermore, a Mann Whitney test was performed to test the association between the quantitative outcome and herniation site. The results do not allow the rejection of the null hypothesis due to a P value of 0.881. As such, this association is not statistically significative.

3.5.3 Outcome per Hansen type of herniation

The lesions observed in the study were classified as type I or type II herniations and their neurological postsurgical outcome was displayed in graphic 10.



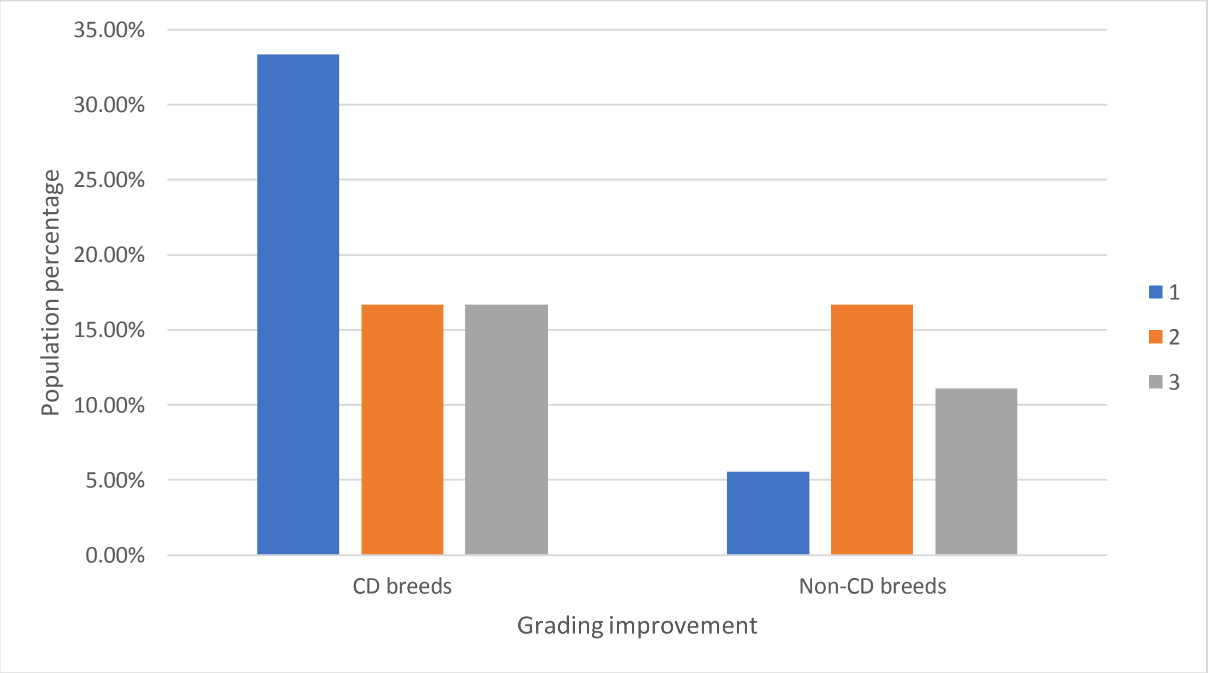
***Graphic 11*– Neurological grade improvement per Herniation type**

As the graphic above illustrates, most type I lesions showed an improvement of 1 grade, accounting for 33.33% of the population, followed by an improvement of 2 grades, which was verified in 27.78% of the population, lastly, 22.22% showed an improvement of 3 grades after surgery. Overall, we can conclude that all type I lesions improved positively by one, two or three grades.

Regarding, type II herniations, there is a more homogenous distribution of improvement, since there are equal percentages for each quantitative outcome. In addition, the improvement is also of 1, 2 or 3 grades, however it is important to consider that the type II lesion sample is very small, therefore not statistically representative.

In addition, a Mann Whitney test was performed to test the correlation between herniation type and quantitative outcome. As such, since the P value was 0.589, this correlation was not considered statistically significative since the null hypothesis could not be rejected.

3.5.4. Outcome per type of breed



***Graphic 12*– Grading improvement per breed type**

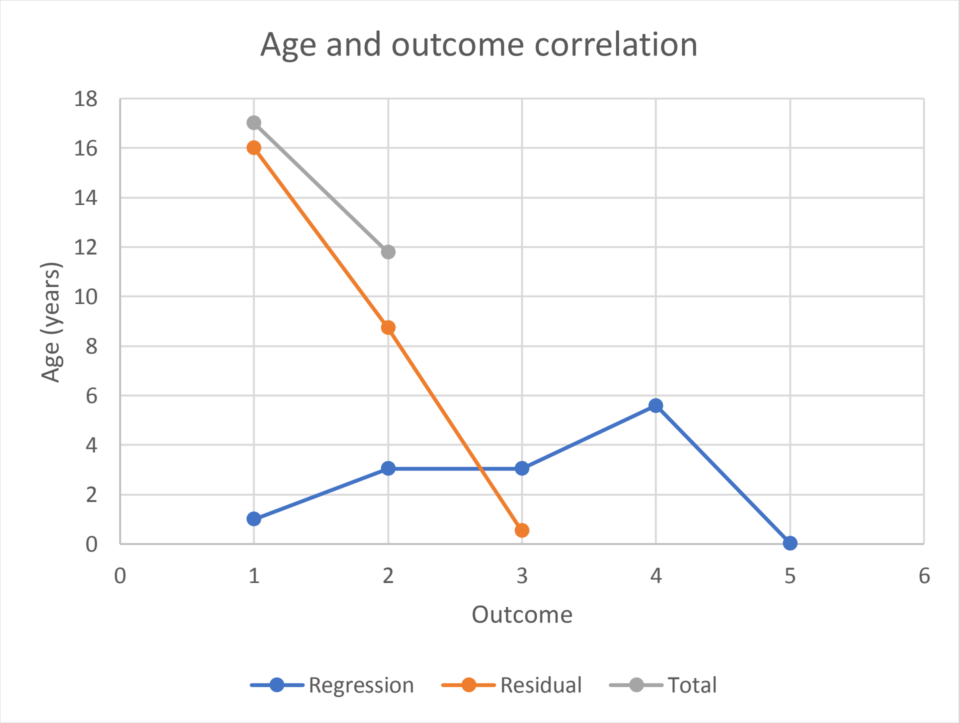
As the graphic above illustrates, CD breeds showed a higher percentage of improvement by solely one grade, representing 50% of the CD population. Secondly, 25% of the CD breeds have improved by 2 grades. Equally, the remaining 25% of the CD sample has also shown a 3 grade improvement.

Regarding non-CD breeds, a more heterogenous graphic displays a higher percentage of dogs who improved 2 grades, representing 50% of the non-CD sample, followed by 33% of dogs who improved 3 grades and lastly 17% who improved just 1 grade.

In conclusion, CD breeds have shown a smaller magnitude of quantitative improvement, when compared with non-CD breeds. However, when statistically tested, the Mann Whitney test showed a P value of 0.885, which does not confirm the statement above.

3.5.5 Outcome and age correlation

A one-way ANOVA test was performed to access the correlation between the variable of age and surgical outcome (treated as a numeric variable) The results are presented in graphic 13 bellow.



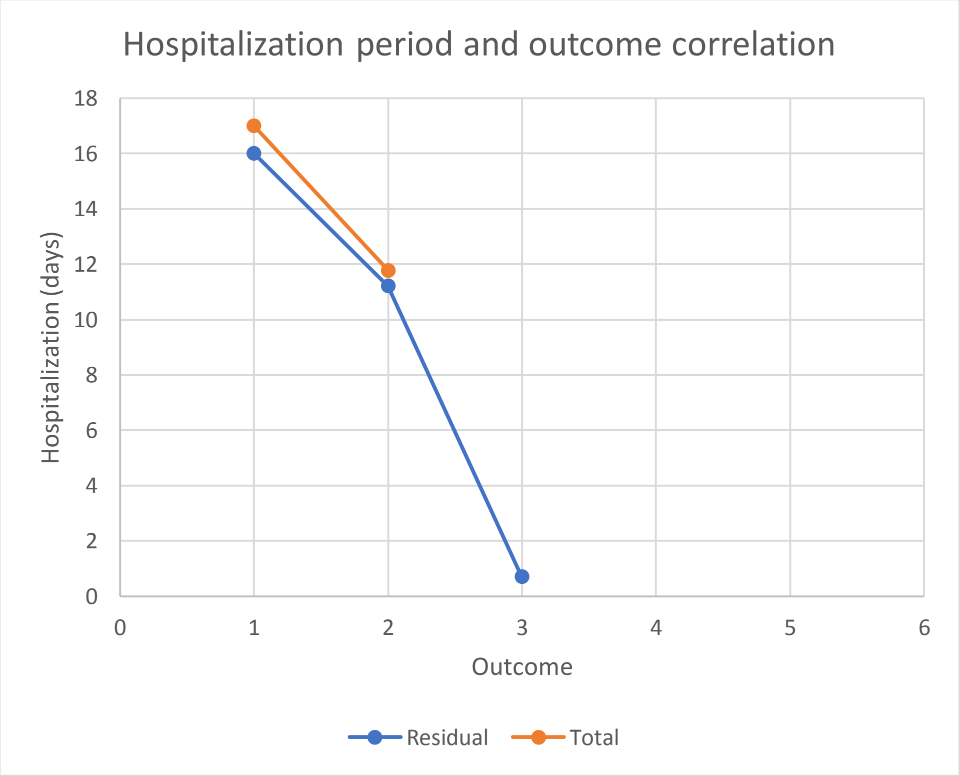
***Graphic 13* – Correlation between age and surgical outcome**

As we can observe, there seems to be a correlation between these two variables, as age is inversely proportional to surgical outcome, which suggests that an older age represents a worse post-surgical prognostic indicator.

The R squared of this correlation is 0.26, meaning 26% of the outcome is related with the patient's age. However, since the R square is inferior to 70%, this correlation cannot be considered statistically significant.

3.5.6. Correlation between hospitalization and outcome

A one-way ANOVA test was performed to access the correlation between the variables of age and surgical outcome (treated as a numeric variable). The results are presented in graphic 13 bellow.



Graphic 14 – Hospitalization and outcome correlation

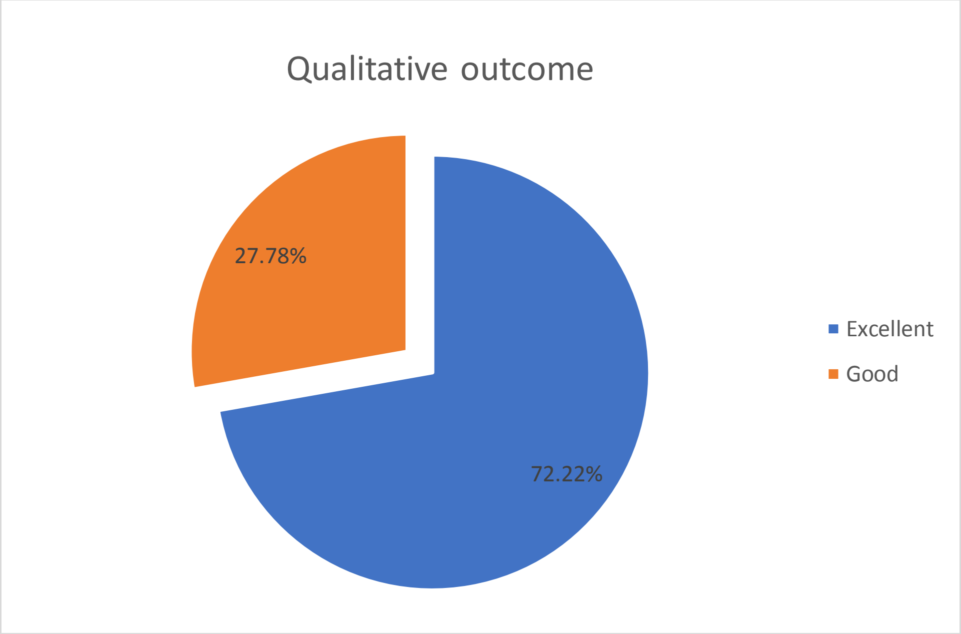
Graphic 14 suggested that generally shorter hospitalization periods are related with a better outcome.

The R squared of the regression is approximately 0.05, meaning only 5% of the outcome is related with the hospitalization period. Therefore, this correlation is not statistically significant.

3.5.7 Qualitative Outcome analysis

Regarding the overall qualitative outcome analysis, all cases were considered to have had a positive post-surgical outcome, since all patients improved by at least one neurological grade post-surgery.

Moreover, positive qualitative outcomes were also classified as excellent when the patient recovered normal neurological status and good when improved at least one grade while still exhibiting a significant degree of neurologic deficits during the first follow up consult. This classification is displayed on graphic 13 bellow.

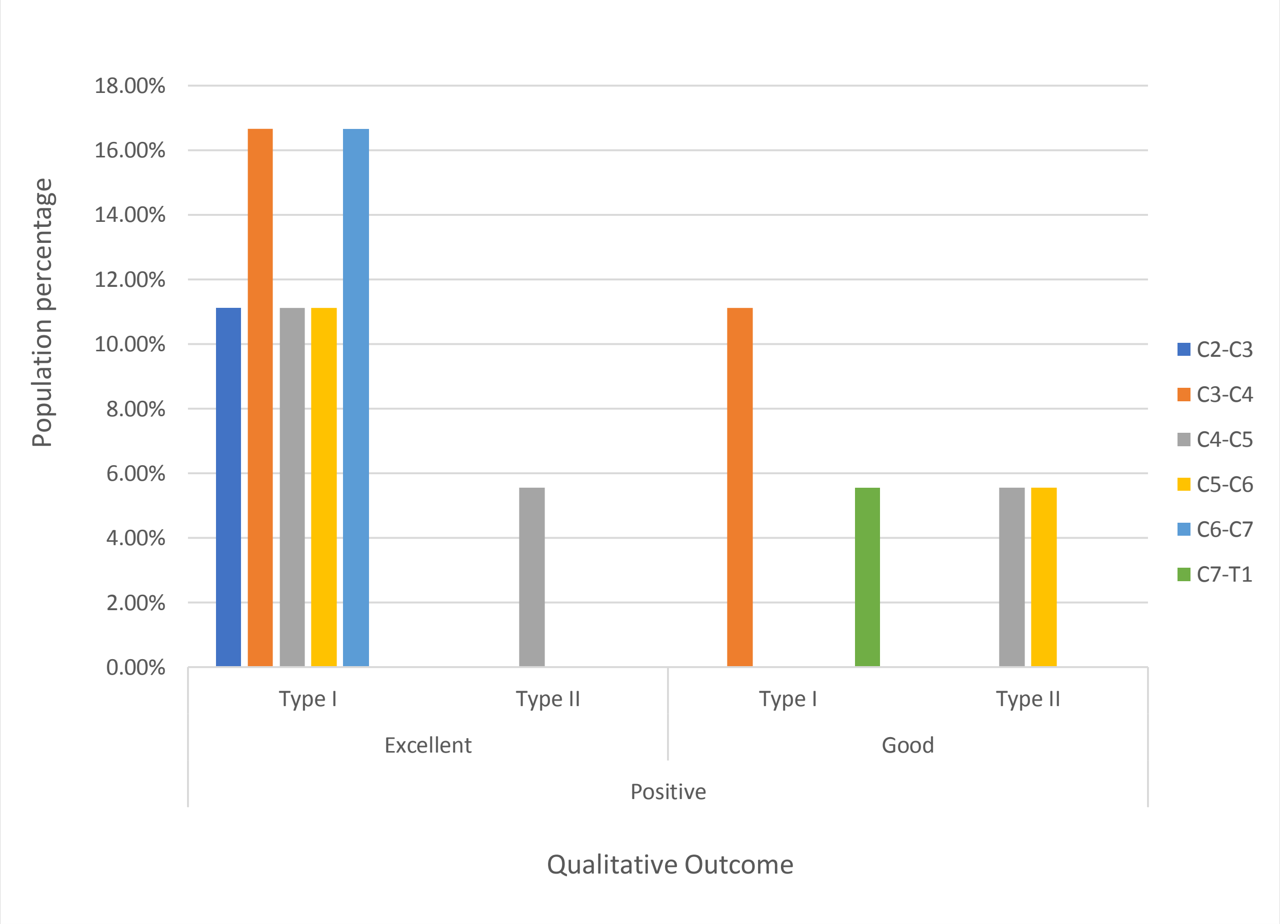


Graphic 15– Qualitative outcome characterization

As noted by graphic 13, 72.22% of the population recovered full ambulatory status and did not display any signs of cervical hyperesthesia. Furthermore, 27.78% exhibited improvements after surgery, despite the presence of neurological deficits during the post-surgery follow up.

3.5.8 Qualitative Analysis per lesion site and Hansen type

In order to evaluate the quantitative outcome of the lesions with more detail, graphic 14 was obtained aiming to characterize the quantitative outcome regarding the lesion site and Hansen type of herniation.



Graphic 16 – Characterization of the qualitative outcome according to lesion site and Hansen type

The graphic above shows a slight tendency towards type C6-C7 and C3-C4 type I herniations within the population, which was already described herein. Furthermore, all patients suffering from C6-C7 type I herniations showed an excellent quantitative outcome, which may be taken as an indicator of great prognosis. These findings are consistent with the bibliographic revision presented since most of the studies mentioned a success rate of nearly 100%.

Furthermore, a Chi-square test was performed to test the correlation between the site of lesion and qualitative surgical outcome. As such, this association was considered statistically significative along with a very strong correlation, due to a P value of 0.00 and a Cramer's V value of 0.799.

On the other hand, despite not being highly statistically significative, type II herniations showed a less favorable improvement when compared with type I herniations, since 67% were classified as good. Nevertheless, these results are also consistent with the bibliography, since caudal cervical type II herniations (frequently associated with wobbler syndrome) are cited as having a significantly less favorable prognosis (Da Costa, 2007).

In opposition, type I herniations showed a 72.22% excellent outcome after around 2 weeks post-surgery Therefore, these results also match the bibliography regarding prognosis since Type I herniations are described as having a very favorable post-surgical success rate in recent studies, which ranged from 80% to 99% (Arias et al., 2007; Cherrone et al., 2004). Of note, it is important to consider the latter results were measured at 1 month to 1-year post-surgery, while the present studies' results were obtained after just 2 weeks. As such, although the comparison is not completely accurate, the results remain a very favorable indicator of recovery.

In addition, a Fisher exact test was used to test the correlation between outcome and Hansen type of herniation. The results obtained indicated a strong correlation between these two variables, with a P value of 0.00 and a Cramer's V of 0.749.

4.Discussion

4.1 Population, diagnosis and clinical signs

Regarding the distribution of the population,Toombs & Waters, 2003 and Cherrone, 2004, state that the most frequently affected dogs are chondrodystrophic, therefore the breed distribution of this study is in agreement with these findings since 66.6% of the population is represented by this category. Moreover, these authors also noted the most affected breeds are Dachshunds, Toy Poodles and Beagles, which are also significantly represented in this sample, except for Dachshunds which were not documented in the present study.

The bibliography presented in the revision above states that there are no significant differences regarding sex distribution of the disease, which was also verified in the study, since there is no significant prevalence of any of the sexes (Costa & Platt, 2017).

The mean of age of the studied population is 6.8 ± 2.4 years which is also in agreement with Ettinger, 2017, which states “the onset peak of CIVDD is between 4 and 8 years of age, with a mean ranging from 6.3 years to 8.6 years”. However, Platt & Olby, 2014 affirm that the onset of Hansen Type I is between 3 and 6 years of age, which is slightly younger than the mean age of 6,5 ± 1.7 years found within the studied population for Type I CIVDD.

In addition, the most prevalent herniation type of this study is Hansen Type I, which is also in agreement with the bibliography, since this prevalence is reported by Cherrone, et al., 2004 to be the most frequent Hansen type herniation of the cervical vertebral column in dogs. Moreover, chondrodystrophic breeds have shown a tendency towards type I herniations, where the French Bulldog, Beagle and Mixed breed were the most affected breeds.

Concerning lesion location, Coates, 2000 states that “the majority of cervical disc disease cases in chondrodystrophic breeds affect the cranial cervical spine, where 80% affect C2-C4 spaces”. Therefore, the lesion location findings are also compatible with the bibliography since the C3-C4 segment was the most diagnosed lesion site. However, a significative percentage of C4-C5 intervertebral disc spaces (22,22%) represented the second most affected area of the cervical vertebral column, which is caudal to the C2-C4 space.

Furthermore, when analyzing the lesion location according to breed in graphic 5, there was a considerable percentage of the population (16%) represented by French Bulldogs with C3-C4 herniations (all Hansen Type I), followed by 11% of the population represented by Beagles affected by C2-C3 herniations (all Hansen type I). These findings are also in agreement with Coates, 2000 and suggest a tendency for Chondrodystrophic breeds to develop upper cranial cervical intervertebral disc herniations. This tendency in location could possibly be related to the considerable weight of the animal’s head when compared with the small caliber of the vertebrae, which may increase tension in the cranial cervical area.

By analyzing graphic 4 in the results section above, we could observe that Hansen type I lesions had a relatively homogeneous distribution, despite targeting the cranial portion of the spine more predominantly, which is consistent with Platt & Olby, 2004.

On the other hand, Hansen Type II herniations were situated towards the caudal aspect of the cervical intervertebral spaces, more specifically between C4-C5 and C5-C6 vertebral segments. Consequently, these findings are partially in agreement with Fitzpatrick & Fingeroth, 2014, which have suggested that the most affected regions are C5–C6 and C6–C7 in Type II herniations. However, it is important to note that the number of individuals suffering from

Hansen type II herniation was only represented by 3 individuals of the population, which may not illustrate this category accurately.

Regarding intra-operative complications, the most frequent finding was abundant venous plexus hemorrhage during the removal of herniated disc material from the vertebral column, which was also a frequent reported complication in Jonh, et al., 2013. Nevertheless, this study lists other complications such as respiratory compromise which was only verified in one patient in the present study. The low prevalence of complications may be justified by the surgeon's high level of experience.

The most frequently registered clinical sign was non-ambulatory patients with tetraparesic ataxia, accounting for approximately 33% of the studied population. These findings are also agreeing with the bibliography since Sharp & Wheeler, 2005 and Platt & Olby, 2014 list tetraparesic ataxia as one of the most frequent presenting signs of CIVDD.

Regarding hospitalization, the mean of post-surgical hospitalization days was 3.78. In spite of this value being considered normal and expected when compared to the bibliography, which states that 3 days is the average recovery time for Ventral Slot Decompression surgery (Seim III, 2018).

4.2 Outcome

Regarding average of improvement post-surgery, in Hansen type I herniations (shown in graphic 4), C7-T1 registered the best improvement average with an improvement of 3 grades post-surgery. However, as noted in the results above, this is not a significant example since this study only has one case of CIVDD affecting this segment.

In addition, C2-C3, C4-C5, C5-C6 and C6-C7 all present an average of 2 grades of improvement post-surgery. Lastly, C3-C4 lesions display an average of improvement of 1.4 grades. In summary, there was no significant tendency towards a better improvement regarding lesion site in Hansen Type I herniations.

Regarding, type II herniations, a more homogenous distribution of improvement was registered, since there are equal percentages for each quantitative outcome. In addition, the improvement is also of 1, 2 or 3 grades, however it is important to consider that the type II lesion sample is very small, therefore not statistically representative.

Furthermore, by analyzing graphic 5 we could infer that chondrodystrophic breeds have shown a smaller magnitude of quantitative improvement, when compared with non-chondrodystrophic breeds, despite this association not being statistically significative.

Regarding qualitative outcome, graphic 13 showed that 72.22% of the population recovered full ambulatory status and did not display any signs of cervical hyperesthesia. Whereas 27.78% exhibited improvements after surgery, despite the presence of neurological deficits during the post-surgery follow up. Therefore, these results are very favorable and in agreement with the bibliography. In a study by Seim & Prata 1982, it was suggested that Ventral slot decompression in Hansen Type I extrusions was associated with the complete recovery of 90% of dogs within 1 month. As such, despite the percentage of complete recovery being 72%, it is important to consider that the average follow up time was 12.9 days, which is less than half of a month.

In addition, although the vast majority of the population was represented by Hansen Type I CIVDD patients, 3 were affected by Hansen Type II herniations which are stated to have a much lower percentage of success, with 72% post-surgical success outcome (Da Costa, 2010). As such, the Hansen type II patient’s outcome has the potential to slightly decrease the percentage of Excellent Outcome.

Despite not being an objective of study, this study also suggests that post-surgical physiotherapy might prompt a faster post-surgical recovery in CIVDD patients, since all patients were submitted to physiotherapy and most of which showed a full recovery after only 2 weeks, representing a very high success rate after such a short period, given that the recovery period is reported to be 5-6 weeks (McCartney, 2007). Furthermore, a recent 2019 study is in agreement with this suspicion, since it proved that rehabilitation therapy after surgical decompression of cervical IVDD can improve the success rate when the preoperative pathological condition is severe (Jeong, et al., 2019).

In addition, when compared with Hemilaminectomy, which shows an 88% short term success rate according to Schmied, et al., 2011, the ventral slot procedure in this study shows an impressive 100% short term success rate in this study. Therefore, mantaining the status of gold standard procedure to solve CIVDD, according to the bibliography (Fossum, 2013; Sharp & Wheeler, 2005).

4.3 Limitations

Limitations of this study include a small sample (18 animals), specially the Hansen Type II affected patients' sample (3 animals), which may affect the statistical significance of the study, especially regarding the comparison between Hansen Type I and Type II groups.

Furthermore, the lack of long-term follow-up information can be considered a limitation, since recurrences could not be properly determined within the sample analyzed. Also, since this is a retrospective study, there is the possibility of lack of information from the follow up consults.

In addition, the surgeries were executed by two different neurosurgeons, despite both being experienced. Similarly, the post-surgical follow up was made by three different veterinarians.

There were also differences in pain relief approaches since certain patients with severe neurological presentations took larger doses of corticosteroids in addition to NSAIDs and opioids. These should be considered since these drugs can affect tissue recovery.

Lastly, the reduced number of patients in each category (Hansen type and type of breed), as well as the retrospective nature of this study are also limitations to consider.

5. Conclusions

Since all patients displayed a positive outcome during the first post-surgery follow-up, we can conclude that the present study shows that different types and locations of CIVDD can be successfully treated with Ventral Slot Decompression surgery. Consequently, this study supports the bibliography, which states that this procedure is the gold standard treatment for cervical disc herniations.

This study also suggests that Hansen Type I herniations are associated with greater prognosis when compared with Hansen type II herniations, despite Type II herniations also showing a favorable post-surgical outcome. Nevertheless, for Type II – wobbler syndrome associated herniations, hemilaminectomy might be a great option for non-ventral herniated material, since the procedure does not remove such large portions of IV disc, therefore reducing destabilization of the cervical column.

Furthermore, this study also suggests that the association of post-surgical physiotherapy is beneficial and may be a catalyst for a faster post-surgical recovery in CIVDD patients, which is in agreement with the bibliography.

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Attachments

Attachment 1: Grading system to access the degree of pelvic limb function

“Patients with functional grades 1 and 2 are unable to stand in the pelvic limbs without assistance. When you hold the patient up by grasping the base of the tail, and only very slight movements of the pelvic limbs occur, this patient would receive a grade of 1 for its function. If voluntary movements readily occur but are delayed, awkward, and poorly placed, the degree of function would be grade 2. A patient with grade 3 function is able to stand up in its pelvic limbs without assistance but has great difficulty and is able to walk but with significant paresis and ataxia. A patient with grade 4 function readily stands up unassisted and exhibits only mild paresis and ataxia in its gait. These are grades of function, not grades of paresis and ataxia.”

0	Tetraplegic/paraplegic without deep nocicption
1	Tetraplegic/paraplegic without superficial nocicption
2	Tetraplegic/paraplegic with nociception
3a	Non-ambulatory tetraparesic without weight support
3b	Non-ambulatory tetraparesic with weight support
4	Ambulatory tetraparesic/paraparesic with ataxia
5	Hyperestesic only

Attachment 2: Modified Frankel Scale (Levine, G. J. et al., 2009)

Classification of consciousness	
Normal / Alert	Normal response to environmental stimuli
Confused/ disoriented	Responding to stimuli inappropriately
Depressed	Drowsiness, less responsive to environmental stimuli
Stuporous	State of unconsciousness with reduced responses to external stimuli, only responds to painful stimuli
Comatose	State of unconsciousness with absence of response to any environmental stimuli, including pain

Attachment 3: Classification of consciousness (Adapted from BSAVA)