Cervical pain is a common presentation to our neurology service. The term “hyperesthesia” is more appropriate as pain is a symptom and therefore an interpretation vs. the defined noxious response to a non-noxious stimulus. Cervical hyperesthesia is without other neurologic deficits are frequently encountered mostly because of the large vertebral canal: spinal cord ratio when compared to the thoracolumbar spine. Causes of cervical hyperesthesia run the gamut of the VITAMIN D list, stressing the importance of a thorough history and physical examination. Signalment, Acuteness of clinical signs, progression of disease and presence of spinal hyperesthesia will be essential in prioritizing the differential list. For example, vascular diseases will be acute in non-chondrodystrophic breeds, non-painful after 24 hours and non-progressive as opposed to atlantoaxial luxation, which will be subacute, progressive and painful in young toy breed dogs. The following is a list of potential causes of spinal hyperesthesia.

**Intervertebral disc disease (IVDD)**
IVDD presents as an acute-chronic, progressive disease seen in mostly chondrodystrophic breeds. Cervical IVDD typically affects dogs more than three years of age. Survey radiographs have a reported overall accuracy of only 35% for the diagnosis of the site of disc extrusion in dogs with cervical IVDD.\(^1\) Conservative therapy should consist of appropriate analgesia and strict cage confinement. The success rate associated with conservative management of dogs with neck pain only from cervical IVDD is 50–90%, but nearly half of conservatively managed dogs will have a recurrence of clinical signs. The authors experience is that these conclusions are high and cervical hyperesthesia cases of IVV responded quicker and more completely when treated surgically. Surgical correction with ventral slot is the procedure of choice in most cases with cervical hemilaminectomy and alternative in lateralized discs inaccessible by the slot due to venous sinus borders.

**Atlantoaxial subluxation (AAS)**
Congenital AAS typically causes clinical signs of C1–C5 myelopathy in immature small and toy breeds of dogs, although it can occur in any age or breed. It should be a primary differential consideration in any young small breed dog with neck pain or cervical myelopathic signs. Developmental abnormalities of the dens (hypoplasia or aplasia) or malformations of or trauma to the supporting ligaments are responsible for the development of clinical signs, which results in instability of the atlantoaxial joint and contusion and/or compression of the spinal cord. During the examination, extreme care should be exercised when manipulating the neck of AAS patients as even normal motion, especially flexion, can exacerbate clinical signs.

Survey radiographs will be diagnostic for AAS in the majority of cases, but accurate positioning is crucial. On the lateral projection, an increase in the space between the dorsal arch of C1 and the spinous process of C2 (> 4 mm) is diagnostic for AAS. Congenital absence or hypoplasia of the dens can be seen on the ventrodorsal or rostrocaudal open mouth views. Occasionally a flexed lateral view may be required to demonstrate instability.

AAS may be managed conservatively (cage rest and external coaptation) or surgically. Conservative management can be associated with very good outcomes in some cases, but is only chosen because of financial limitations or if the patient is too young for implant fixation. Often, the finances of conservative management approach those of surgical therapy once the multiple bandage changes have been done. The approach and choice of surgical fixation is primarily based on surgeon personal preference, but ventral approaches using transarticular fixation are the most common, and are associated with lower complication rates compared to dorsal techniques.

**Cervical spondylomyelopathy (wobblers disease)**
In contrast to cervical IVDD, this is predominantly a condition of large and giant breeds of dogs. Wobblers is a generic term used to describe a syndrome of compressive cervical myelopathy that may result from one or more of the following pathological abnormalities: disc protrusion, congenital vertebral canal malformation or acquired osseous stenosis, vertebral instability / subluxation, ligamentous hypertrophy, and joint capsule proliferation / synovial cyst formation. Also in contrast to cervical IVDD, giant breeds of dogs (Great Dane, Mastiff) with congenital vertebral malformations or joint capsule proliferations may show clinical signs at a young age (< 1 year), although many dogs will not develop signs until middle age. The clinical signs of CSM are usually associated with gait dysfunction, with or without signs of neck pain. Signs of neck pain may not be readily apparent in these breeds, but they may carry their heads low, or be reluctant to bend down to eat. Definitive diagnosis of CSM requires advanced imaging, but survey radiographs are useful to rule out other differential diagnoses, and may reveal changes suggestive of CSM, such as proliferative articular facets and vertebral subluxation.
**Diskospondylitis**
This is an inflammatory condition involving the intervertebral disc and end-plates. The infection usually results from hematogenous spread of infection from remote sites in the body, which commonly include the urogenital tract and skin. The most commonly implicated bacterial pathogens include *Staph intermedius*, *E.coli*, *Strep* spp, and *Brucella canis*. Fungal pathogens, particularly aspergillosis, may also cause diskospondylitis. Large breed dogs are most often affected, and the disease most often manifests at the highly mobile regions of the vertebral column (cervicothoracic, thoracolumbar, and lumbosacral junctions). The initial clinical sign is almost always spinal hyperesthesia, which may be associated with systemic signs of illness such as fever, anorexia. Neurologic deficits may develop secondary to epidural or meningeal spread of infection, disc extrusion, or pathologic vertebral fracture.

Survey radiographs are often diagnostic for diskospondylitis, although lesions may be radiographically occult within the first few weeks of the onset of clinical signs. In animal with radiographic evidence of diskospondylitis, a urinalysis and urine culture and *Brucella* screening test should be performed. Blood cultures have been reportedly positive in up to 66% of diskospondylitis cases. Initial treatment is systemic antibiotic therapy, ideally based on culture and sensitivity results, for 6 weeks. Dogs with neurological deficits associated with diskospondylitis may require advanced imaging and surgical therapy.

**Syringomyelia (SM)**
Syringomyelia (SM) is characterized by the development of fluid-filled cavities within the spinal cord parenchyma, and can be caused by numerous congenital (caudal occipital malformation syndrome [COMS]) or acquired (trauma, meningitis, neoplasia) causes of disturbed CSF flow dynamics. COMS is the most common condition associated with the development of SM in dogs. The prevalence of COMS-SM is high in several small and toy breeds of dogs, but most notably the Cavalier King Charles Spaniel. The clinical signs associated with COMS-SM can be quite variable and reflect dysfunction of the vestibular system, cerebellum, cervical spinal cord, or can suggest a multifocal lesion. Dogs with COMS-SM also commonly manifest with signs of maladaptive neuropathic pain, which may include allodynia, such as intolerance to petting or grooming the head and neck, or dysesthesia, which often appears as "phantom" scratching the head, neck, or shoulders without making contact with the skin.

These pain behaviors are theorized to arise from damage to the spinal cord dorsal horn or ascending nociceptive pathways from SM. Clinical signs are more common in dogs with SM associated with COMS, and there appears to be some correlation between the severity of signs and syrinx size. COMS with or without SM may also be an asymptomatic, incidental finding in at risk breeds. MRI is the preferred modality for the definitive diagnosis of COMS-SM.

The primary goals of multimodal medical therapy are to slow the progression of disease by decreasing CSF production and palliate neuropathic pain. Since COMS-SM is a mechanically obstructive problem, corrective surgery, which typically involves a foramen magnum decompression and variably extensive cervical dorsal laminectomy, offers a better chance for long-term control of clinical signs.

**Meningitis / meningomyelitis**
Although there are numerous infectious diseases that can meningomyelitis, the most common etiologies of inflammatory spinal cord disease in dogs that cause cervical pain appear to be variants of immune-mediated diseases such as steroid-responsive meningitis arteritis and granulomatous meningoencephalomyelitis (GME). The index of suspicion for meningitis should be high when a dog presents with cervical pain and fever. Survey radiographs are usually unremarkable in these cases, and the diagnosis requires MRI of the cervical area, CSF analysis, and serology.

**Extradural neoplasia**
Spinal neoplasia is typically a disease of older dogs, with extradural neoplasms accounting for half of all spinal tumors. Primary bone tumors arising from the vertebral bodies, such as osteosarcoma and fibrosarcoma, are the most common, although numerous other histologic subtypes of primary tumors as well as metastatic tumors have been reported. Most dogs with extradural vertebral body tumors will have cervical pain, and it can often be intense and unrelenting. Neurologic deficits, when present, can be acute onset and catastrophic when associated with pathologic fracture. Survey radiographs are valuable in that they will often demonstrate characteristic osteolytic lesions involving the vertebrae. All dogs with lytic lesions involving the vertebrae should be evaluated systemically for tumor staging purposes. The treatment of choice for most primary tumors is cytoreductive surgery with consideration given to adjunctive or primary radiotherapy. Although obtaining wide margins is not possible in most vertebral tumors, surgical debulking can often be done in a fashion that allows for temporary improvement or resolution of clinical signs.
Head trauma or traumatic brain injury (TBI) is a common emergent presentation in both humans and animals. In human medicine the recommendations are largely based on the guidelines from the Brain Trauma Foundation that provide meta-analysis of the large body of current literature for diagnosis and treatment of TBI. In veterinary medicine, the number of studies evaluating TBI is scant. Many assessments of human TBI patients involve cognitive testing and do not translate to the dog or cat. Most of the tests that evaluate basal neurologic function demonstrate the severity of the condition at a point beyond which intervention would prove successful. Rapid and aggressive therapy is therefore essential. Despite the lack of recent advance in TBI cases, most veterinary patients can have a reasonable prognosis with supportive systemic treatment.

**Intracranial physiology**

The Monro-Kellie hypothesis describes the intracranial space as a rigid volume with three main compartments: The brain, blood and CSF. As the total volume is fixed, enlargement of one compartment or addition of a new compartment (ie.hematoma or tumor) necessitates the decreasing volume of another.

The brain requires a fixed perfusion for the neuronal components to function adequately. The total cerebral perfusion pressure (CPP) is a function of the mean arterial blood pressure (the pressure of blood entering the intracranial space) and the intracranial pressure (ICP), which opposes this inflow of blood.

$$\text{CPP} = \text{MABP} - \text{ICP}$$

In the normal patient, this equation is regulated by a function known as auto regulation. Two types of autoregulation are mechanical and chemical. In mechanical autoregulation, baroreceptors of the intracranial vessels detect an increase pressure and consequently constrict. Chemical auto-regulation controls vessel size by detecting proton (CO2) levels. Vasoconstriction occurs when the patient becomes hypocapnic. This effect decreases intracranial blood volume and consequently increases perfusion, but may have negative consequences on tissue vascular exchange.

When intracranial pressure is low (<25mmHG), there is adequate compliance in the system where these autoregulatory changes can have volumes fluctuate without affecting pressure significantly. However, should ICP raise up 25mmHG (such as in the TBI patient), these autoregulatory changes are ineffectual, because the system has reached the limits of its compliance and small volume changes lead to major pressure changes.

The other consequence of an elevated intracranial pressure is the secondary effects that they exert on the brain compartment, eventually leading to brain shifting or herniation. These shifts lead to neurologic dysfunction and death soon thereafter.

**Assessment of the patient**

The Modified Glasgow Coma scale (MCGS) was created to emulate the validated human correlate that grades TBI as mild, moderate or severe. The test evaluates the animal’s mentation, motor function and cranial nerve reflexes and assigns a numeric value that correlates with prognosis. Clinical signs of elevating intracranial pressure include postural changes, pupillary size and the Cushing’s reflex. Miosis often represents forebrain dysfunction and mydriasis indicates CNIII dysfunction following brain herniation. The Cushing’s reflex also demonstrates a systemic effort to correct acute ICP changes. With elevated ICP, the body will increase MABP to maintain CPP. Peripheral baroreceptors detect this pressure change and accordingly decrease the heart rate. It is important to recognize that once these clinical signs emerge, the patients are considered severely affected.

**Imaging**

Cross sectional imaging is being used as a prognostic indicator with more frequency in human medicine. In veterinary medicine, its prognostic value is somewhat unknown, but it can lead to changes in therapeutic direction, specifically the need for surgery.

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<tr>
<th>PRO</th>
<th>CT</th>
<th>MR</th>
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<tr>
<td></td>
<td>Speed</td>
<td><em>Soft tissue resolution</em></td>
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<tr>
<td></td>
<td>Availability/affordability</td>
<td>Identify herniation</td>
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<tr>
<td></td>
<td>Less susceptible to motion artifact</td>
<td>Identifies hemorrhage</td>
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<td></td>
<td>Less susceptible to metal artifacts</td>
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</tr>
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<td></td>
<td>Resolution of bone and blood</td>
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<td></td>
<td>3D reconstructive ability</td>
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<tr>
<th>CON</th>
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<th>Time consuming</th>
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<tr>
<td></td>
<td>Ionizing radiation</td>
<td>Expensive</td>
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<td></td>
<td>Poor Soft tissue resolution</td>
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Treatment
Therapy is geared at maintaining CPP by decreasing ICP and maintaining CPP. More advanced therapy targets secondary brain injury, the downstream effects following the initial insult that can cause further injury (ie. Free radical formation, excitatory neurotransmitters, and inflammatory metabolites).

To this point, two therapies have been definitively proven to improve patient outcome in the human field: fluid therapy and osmotic diuretics.

**Intravenous fluids**
Hypertonic saline administration (4–5 ml/kg over 3–5 minutes) draws fluid from the interstitial and intracellular spaces into the intravascular space which improves blood pressure and cerebral blood pressure and flow, with a subsequent decrease in ICP. Often colloid therapy is used in conjunction to maintain intravascular volume once the hypertonic solution has extravasated. Balanced isotonic solution administration to maintain normovolemia follows this treatment to maintains MABP and CPP.

**Osmotic diuretics**
Osmotic diuretics such as mannitol are very useful in the treatment of intracranial hypertension. Mannitol has an immediate plasma-expanding effect that reduces blood viscosity, and increases cerebral blood flow and oxygen delivery. This results in vasoconstriction within a few minutes causing an almost immediate decrease in ICP. The better known osmotic effect of mannitol reverses the blood-brain osmotic gradient, thereby reducing extracellular fluid volume in both normal and damaged brain. Mannitol should be administered as a bolus over a 15-minute period, rather than as an infusion, in order to obtain the plasma-expanding effect; its effect on decreasing brain oedema takes approximately 15–30 minutes to establish and lasts between 2 and 5 hours. Repeated administration of mannitol can cause an accompanying diuresis, which may result in volume contraction, intracellular dehydration and the concomitant risk of hypotension and ischaemia. There has been no clinical evidence to prove the theory that mannitol is contraindicated in the presence of intracranial haemorrhage. There is contradictory evidence that the combination of mannitol with furosemide (0.7 mg/kg) may lower ICP in a synergistic fashion, especially if furosemide is given first.

**Oxygenation and ventilation**
Hyperoxygenation is recommended for most acutely brain-injured animals. Partial pressure of oxygen in the arterial blood (PaO₂) should be maintained as close to normal as possible (at or above 80 mm Hg). Supplemental oxygen should be administered initially via face-mask, as oxygen cages are usually ineffective since constant monitoring of the patient does not allow for a closed system. As soon as possible, nasal oxygen catheters or transtracheal oxygen catheters should be used to supply a 40% inspired oxygen concentration with flow rates of 100 ml/ kg/min and 50 ml/kg/min respectively. If the patient is in a coma, immediate intubation and ventilation may be needed if indicated by blood gas evaluations. A tracheostomy tube may be warranted in some patients for assisted ventilation. Hyperventilation has traditionally been known as a means of lowering abnormally high ICP through a hypocapnic cerebral vasoconstrictive effect. However, hyperventilation is a double-edged sword. Besides reducing the ICP, it induces potentially detrimental reductions in the cerebral circulations if the pCO₂ level is less than 30–35 mm Hg. The major difficulty with hyperventilation is our present inability to monitor the presence and effects of ischaemia on the brain. It is important that animals do not hypoventilate, and such animals should be ventilated to maintain a PaCO₂ of 30–40 mm Hg. Aggressive hyperventilation can be used for short periods in deteriorating or critical animals.

**Hyperventilation, head elevation and hypothermia**
Though its efficacy is unknown, head elevation between 15-30 degrees is recommended to promote venous drainage, as it is a benign treatment. Hyperventilation to reduce CO₂ levels and promote intracranial vasoconstriction has little evidence support. However, preventing hypoventilation is important and emphasizes the importance of providing the patients with a patent airway. Intubating the patient allows for a capnography and airway protection in the mentally debilitated patient. The BTF suggests maintaining normocapnea. Similarly, hypothermia was suggested but not adequately substantiated as a treatment with the goal of decreasing neuronal activity and subsequent excitatory neurotoxicity. While hypothermia is preferable to hyperthermia, maintaining normothermia is ideal. Other techniques to decrease neuronal activity, such as barbiturate coma are fraught with possible complications including decreasing MABP. This technique is not recommended unless advanced monitoring with electroencephalography and continuous mean arterial blood pressure are available.

**Glucocorticoids**
1. Do not lower ICP
2. Do not improve outcome in head-injured patients (human studies)
3. Not recommended in animals with brain trauma
4. Often associated with adverse effects
Surgery
Decompressive surgery for the sake of improving ICP elevations has poor evidence based support and should only be pursued in cases of progressive neurologic deterioration despite medical intervention. However, ongoing compressive lesions, such as fractures or hematomas, can be removed to restore normal anatomy.

Despite the limited effective therapies available to the practitioners many dogs severely debilitated with neurologic dysfunction following TBI have a good prognosis with supportive care. If animals
Function of the vestibular system
The vestibular apparatus is a sensory system essential for the maintaining posture and balance relative to gravity and movement. The system has its sensory receptors in the inner ear, its processing center in the brainstem and its output caudally through the spinal cord and rostrally towards the eyes. It receives regulatory input/feedback from the cerebellum. It is clinically divided into peripheral and central components, both because of the ability to separate neurolocalization based on clinical signs and because of the implications these localizations have on differential diagnosis.

Peripheral vestibular anatomy
The membranous labyrinth deep within the inner ear and the vestibular portion of the vestibulocochlear nerve make up the peripheral vestibular system. Within these labyrinths are cavities that contain endolymph fluid. The receptors (crista ampularis) detect the movement of this fluid and in turn detect angular acceleration. Angular acceleration is essentially rotational movement of the head from its resting state. Other receptors (the utricle and saccule; The maculae) have small rocks (otoliths) which give the receptors mass and make them capable of detecting the exerted force of gravity. This is known as linear acceleration. These mechanoreceptors give afferent information along with auditory inputs to the vestibular ganglion and then to the brainstem. The proximity of CN VIII to CN VII is highest within the middle ear and can have clinical consequences. The sympathetic innervation to the face also runs adjacent to these nerves.

Central vestibular anatomy
The four vestibular nuclei are in the most dorsal portion of the medulla, directly under the cerebellum. This proximity manifests clinically in that diseases causing herniation of the cerebellum though the foramen magnum can compress these cell bodies. There is a direct connection between these nuclei and the “vestibulocerebellum” made up of the floccular-nodular lobe. The primary outputs of the vestibular system are to the extraocular muscles of the eyes and caudally through the spinal cord. The medial longitudinal fasciculus sends outputs to CN III, IV and VI, maintaining the globe’s position in the orbit and the ability to maintain gaze in the face of head rotation. The outputs to the spinal cord are through the vestibulospinal system, essential an anti-gravity tract facilitating mostly extensor muscles to the neck, trunk and limbs.

Clinical signs of vestibular disease
Certain clinical signs are inherent to any form of vestibular disease and are in some cases pathognomonic for the neurolocalization. They include
1. Head tilt
2. Nystagmus (resting or positional)
3. Vestibular Ataxia
4. Ventrolateral strabismus

These clinical signs emerge because of imbalance of vestibular input. In the normal patient, the vestibular system is bilateral providing input that when processed together yields the precision system of balance. When one side is diseased and fails to provide normal input, the non-diseased side produces unilateral information and thus clinical signs often reflect the non-diseased side rather than the diseased side. Many of the clinical signs of vestibular disease would be absent in the animal affected bilaterally. The precedent for this is seen mostly in cats with bilateral otitis media/interna. They have no nystagmus, head tilt or ataxia. Clinical signs in these patients include snake like movements of the head and a lack of normal vestibular-ocular function best assessed by evaluating the physiologic nystagmus (vestibulo-ocular reflex).

Differentiating central vs. vestibular disease
As previously stated, differentiating these diseases are essential for differential diagnosis creation and prognostication. The differences are inherent to the adjacent structures that would be affected. The peripheral component is in close proximity to CN VII and the sympathetic nerve to the face. Thus facial paresis and Horner’s syndrome are commonly seen with this neurolocalization. Central disease is in proximity to the sensory proprioceptive systems, the arousal centers and other cranial nerves. Therefore, proprioceptive deficits, mental dullness and cranial nerve dysfunction (other than CN VII) are common with this localization. Although simple in theory, distinction of central vs. peripheral disease can be difficult in practice as the clinical signs are rarely clear and completely present. Should the vestibular cerebellum become diseased, these signs would point to a central vestibular
localization, but often with conflicting sign sidedness. This is known as paradoxical vestibular disease. Postural reaction deficits are used to determine sidedness, as they are consistently ipsilateral to the lesion.

<table>
<thead>
<tr>
<th>Clinical Sign</th>
<th>Peripheral</th>
<th>Central</th>
<th>Paradoxical</th>
</tr>
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<tbody>
<tr>
<td>Head tilt or circling</td>
<td>Toward lesion</td>
<td>Toward lesion</td>
<td>Away from lesion</td>
</tr>
<tr>
<td>Nystagmus</td>
<td>Horizontal or Rotary, Non-positional</td>
<td>Horizontal, rotary or vertical, +/- positional</td>
<td>Horizontal, rotary or vertical, +/- positional</td>
</tr>
<tr>
<td>Mentation</td>
<td>Alert</td>
<td>+/- Mentally inappropriate.</td>
<td>+/- Mentally inappropriate.</td>
</tr>
<tr>
<td>CP Deficits</td>
<td>No</td>
<td>Ipsilateral</td>
<td>Ipsilateral</td>
</tr>
<tr>
<td>CN deficits</td>
<td>+/- CN VII</td>
<td>+/- CNs V-XII</td>
<td>+/- CNs V-XII</td>
</tr>
<tr>
<td>Horner’s syndrome</td>
<td>+/- Ipsilateral</td>
<td>No</td>
<td>No</td>
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**Differential diagnosis of vestibular disease**

Creation of a differential diagnosis list is best approached by using the VITAMIN D scheme. Common differentials for peripheral disease include infectious (otitis media/interna) and idiopathic, commonly seen in the geriatric patient. More common central vestibular differentials include neoplasia, infectious/inflammatory (meningoencephalitis), vascular, and toxic (metronidazole toxicosis).

Cross sectional imaging is a mainstay of diagnosing the cause of vestibular disease. MRI has supplanted CT as the diagnostic modality of choice. CT can adequately identify disease of the peripheral system and most specifically tympanic bulla changes. However, beam hardening artifact limits the modality in evaluating the caudal fossa (central vestibular system). MRI can image the entire system with superior contrast resolving ability. Other ancillary diagnostics may include myringotomy/culture and brain auditory evoked potentials to evaluated the auditory component of CN VIII. Treatment and prognosis are largely contingent on the etiology itself.
Neurolocalization is the ultimate goal of the neurologic examination, piecing the puzzle of reflexes and responses together to an anatomic segment. Once accomplished, the practitioner is able to assign a rank list of differential diagnosis for this neuroanatomic site based on the patient’s age, breed, clinical onset/progression and the presence of spinal hyperesthesia. Whereas this list can easily be found in any neurology text, the ability to interpret findings and combine them to fit a single lesion site requires practice.

A concept integral in localization is that of the Upper Motor Neuron (UMN) and Lower Motor Neuron (LMN). The Upper Motor Neurons are essentially the long tracts from the brain that instruct the lower motor neurons what to do. The LMN consists of the motor neuron cell body within the spinal cord, the nerve itself, the neuromuscular junction and the muscle itself. In cases of UMN disease, the lower motor neuron works without instruction, known as a loss of inhibition. It is classically hypertonic, with normal to increased reflexes and minimal atrophy. In cases of LMN disease, the upper motor neuron is irrelevant, because the LMN cannot respond to its instruction. Thus hypotonicity, decreased reflexes and severe neurogenic atrophy are noted.

The spinal cord can be divided into four areas. The LMN of the limbs are located in swellings of the spinal cord known as intumescences. When these intumescences are the site of disease, LMN signs are notable. When the lesion blocks the long tracts between the limb the brain and the LMN, UMN signs emerge. Thus the spinal cord can be divided into the following segments.

<table>
<thead>
<tr>
<th>Lesion location</th>
<th>Thoracic limbs</th>
<th>Pelvic limbs</th>
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<tbody>
<tr>
<td>C1-C5</td>
<td>UMN</td>
<td>UMN</td>
</tr>
<tr>
<td>C6-T2</td>
<td>LMN</td>
<td>UMN</td>
</tr>
<tr>
<td>T3-L3</td>
<td>Normal</td>
<td>UMN</td>
</tr>
<tr>
<td>L4-S3</td>
<td>Normal</td>
<td>LMN</td>
</tr>
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The neurologic examination is comprised of multiple parts for accurate localization.

Gait
Ataxia is defined as an uncoordinated gait and is frequently classified as “the drunken sailor walk”. It is often classified as
1. Proprioceptive/spinal-a.k.a The true drunken sailor walk, often coupled with a spastic/long strided gait suggesting UMN dysfunction. Patients are often thought of as overstepping or “floating”
2. Vestibular-Characterized by imbalance often manifest as “wall walking, coupled with a head tilt and nystagmus
3. Cerebellar lesions –Characterized by hyper/dysmetria (Goose stepping), truncal swaying, and intention tremors.

Paresis is weakness of the gait, reduced voluntary movement, whereas paralysis is complete loss of voluntary movement. Both paresis and paralysis (-plegia) can be used to describe the deficits in only one limb (monoparesis/plegia), in the pelvic limbs (paraparesis/plegia), in all four limbs (tetraparesis/plegia) or on one side of the body (hemiparesis/plegia).

Proproprioception
The ability of a patient to identify the location of its limbs in space. A subjective but integral component to the examination, these tests confirm the presence of a neurological disorder and can detect subtle dysfunction, helping identify which limbs are affected. This includes paw position, hopping and placing responses.

Spinal reflexes
Reflexes are quite different than responses, such as proprioception, in that they do not require forebrain input. This is an important distinction
The easiest and most reliable are the patellar reflex in the pelvic limbs and the withdrawals in both the pelvic and the thoracic limbs. Don’t forget to examine the tail and anus (perineal reflex). Reduced reflexes in a limb identify a LMN lesion in that limb, whilst normal or increased reflexes localize the lesion to the UMN

- Cutaneous trunci reflex (panniculus)--helps narrow down lesion localization in the thoracolumbar region. After pinching the skin, the sensory information enters the spinal cord approximately two vertebral spaces cranially, ascends the spinal cord to the level of C8-T1 where bilateral synapse occurs with the motor neurons of the lateral thoracic nerve, which then course through the brachial plexus and innervate the cutaneous trunci muscle, resulting in bilateral contraction of these muscles. Normally, this reflex is present from T2 to about L4-L5 and a cut-off in this region suggests a spinal cord lesion just cranial to the cut-off level. Loss of the cutaneous
trunci reflex can also be due to a brachial plexus lesion, in which case it will be completely absent on the side of the lesion and normal on the contralateral side.

**Pain sensation**
The spinal pathways that carry pain sensation are located deep in the spinal cord so only a severe lesion will impair pain perception (making this an important prognostic factor). For conscious perception of pain, manifested by vocalization and/or turning the head and trying to bite, the information needs to be recognized by the sensory nerve, travel up the entire spinal cord cranial to that area and be interpreted by the brain. It is important to differentiate a pain response from a local withdrawal reflex (which should be present if both the peripheral nerve and spinal cord segment of the stimulated peripheral nerve are intact), in which case the limb will be retracted but no signs of conscious awareness of the pain will be evident. Pain sensation is tested by applying heavy pressure with haemostats to the bones of the digits (don't forget to test different digits) or to the long bones of the limbs.

**Spinal palpation**
Looking for areas of hyperesthesia or deformities. Pressure is applied to the spinous and transverse processes of the vertebrae in all spinal segments. Manipulation of the cervical spine in all directions is performed.
Seizure Disorders are extremely common in dogs with an incidence estimated as high as one percent of the pet population. The cause of these seizures is generally classified as structural, metabolic or idiopathic/heritable. Idiopathic epilepsy is by far and away the most common cause, representing 30% of all epileptics. Despite large advances in anatomic imaging, genetic characterization and surgical care, the understanding of the cause of idiopathic epilepsy is still in its infancy. However, many novel anti-seizure medications are entering the clinical arena with potential use in patients unresponsive to traditional medications such as phenobarbital and bromide.

Managing seizure disorders presents a major challenge to the veterinarian, especially when a dog does not respond to standard (i.e., phenobarbital, bromide) therapy. Such refractory cases account for between 25–30% of all epileptics. It is very important for the clinician to inform the pet owner that most epileptic dogs do not reach seizure-free status; success is typically considered a reduction in the frequency and duration of seizures. Nonetheless, the goal of anticonvulsant therapy should be to eliminate seizure activity in the patient, or come as close to this goal as possible, without subjecting the patient to unacceptable side effects of drug therapy or the client to unreasonable financial burden.

**Phenobarbital**

**MOA**
- Primary mechanism of action is by decreasing seizure onset via enhanced GABA activated chloride conductance
- Secondary mechanism of action is by decreasing seizure spread via reduced current through calcium channels and reduce glutamate-mediated excitation

**T ½**
- 24-40 hours

**Metabolism/excretion**
- Majority metabolized by the liver, with 1/3 excreted unchanged in the
- Phenobarbital will induce hepatic microsomal enzymes (p450 enzymes) and it can be expected that elimination half-lives will decrease with time with concomitant reductions in serum levels

**Side effects**
- Behavioral: hyperexcitability, restlessness, sedation. Normally this is seen for the first few weeks of treatment
- Immune mediated neutropenia or thrombocytopenia or anemia (these reversible blood dyscrasia occurs within the first 6 months of dosing)
- Idiosyncratic hepatic reactions: RARE. Evidenced by a rapid elevation in ALT and abnormal bile acids – phenobarbital should be stopped immediately and another AED should be loaded and started
- With chronic dosing, PU/PD is common and psychogenic polydipsia may develop. The most common serum biochemical changes include elevated alkaline phosphatase

**Dose**
- 2.5mg/kg PO BID as a starting dose, with all future adjustments based on serum drug concentrations in conjunction with clinical assessment

**Blood levels**
- Serial serum phenobarbital concentrations should be evaluated at 14, 45, 90, 180 and 360 days, and 60 days thereafter
- Therapeutic range: 20-40mg/dl

**Bromide**

**MOA**
- Primary mechanism of action is by decreasing seizure onset via enhanced GABA activated chloride conductance

**T ½**
- 20-46 days

**Metabolism/excretion**
- Bromides are principally excreted by the kidneys

**Side effects**
- PU/PD, lethargy and mild ataxia
- Pancreatitis and gastrointestinal intolerance have been reported but are infrequent

**Dose**
- 40-60mg/kg PO SID
**Blood levels**
- Measured 8-12 weeks after initiating treatment
- Monotherapy: 1000-3000mg/l
- With Phenobarbital: 1500-2500mg/l

**Zonisamide**

**MOA**
- Primary mechanism of action is by decreasing seizure spread via reduced current through calcium channels
- Secondary mechanism of action is by decreasing the seizure onset via enhanced sodium channel inactivation

**T1/2**
- 15-20 hours

**Metabolism/excretion**
- Most of the drug is excreted via the kidneys into the urine, but about 20% is metabolized, primarily in the liver

**Side effects**
- Sedation, dry eye, ataxia, inappetence and vomiting – patients with a history of sulfa drug hypersensitivity should NOT be prescribed this medication
- Metabolic acidosis and liver dysfunction has been reported in dogs

**Dose**
- 5-10mg/kg PO BID

**Blood levels**
- Currently, zonisamide levels are able to be evaluated at Auburn University. This is a new medication and at this time we aim to obtain a blood level close to 20ug/ml (10-40ug/ml). It has been reported that stable plasma concentrations are achieved within 3-4 days with oral administration of zonisamide

**Levetiracetam (Keppra)**

**MOA**
- Binding with a specific synaptic vesicle protein (SV2A) in the brain.
- No directly affect common neurotransmitter pathways (e.g., GABA, NMDA) or ion channels (e.g., sodium, T-type calcium).

**T ½**
- 3–4 hours

**Metabolism/excretion**
- 70% excreted in urine
- no hepatic metabolism

**Side effects**
- Lethal dose is 100 times the recommended dose. Dosing can be increased several fold in attempts to increase efficacy.
- No side effects of note

**Dose**
- 20 mg/kg PO TID

**Blood levels**
- Not typically performed because dose-efficacy ratio not direct.

**Other notes**
- neuroprotective properties, and may ameliorate seizure-induced brain damage.
- Prevents further seizures (anti-kindling)
- Injectable-Possible emergency drug for SE
- Honeymoon effect
- More effective in cats- with limited side effects and no noted honeymoon effect

**Felbamate**

**MOA**
- Positive modulator of GABA\textsubscript{A} receptors
- Possible NMDA antagonist of the MR2B subunit

**T ½**
- 5-6 hours

**Metabolism/excretion**
- 70% excreted in urine
- Remainder hepatic metabolism
Side effects
- No sedation
- Possible hepatotoxicity
- Blood dyscrasia and KCS

Dose
- 15-20 mg/kg PO TID with dose escalation permissible

Blood levels
- The author has not performed drug levels of Felbamate

Other notes
- Expensive

Gabapentin
MOA
- binding to the α2δ subunit of voltage-gated neuronal calcium channels. This binding decreases intracellular calcium influx, leading to decreased synaptic release of excitatory neurotransmitters.

T ½-
- 3-4 hours

Metabolism/excretion
- Urine excretion
- Hepatic metabolism-30–40% of the orally administered dose of gabapentin undergoes hepatic metabolism to N-methyl-gabapentin

Dose
- 15–60 mg/kg PO TID or QID

Blood levels
- Suspected blood levels are 4–16 mg/L. As this drug has questionable AED efficacy, I rarely have blood levels checked.
- In recent years, the efficacy of gabapentin as an anti-convulsant has come into question, particularly with the other previously mentioned tertiary agents.

Pregabalin (Lyrica)
MOA: Same as gabapentin
T 1/2
- 7 hours (11 hours in cats)
- The half-life of elimination of pregabalin in dogs is about

Dose
- 2-4mg/kg PO BID

Topiramate
MOA
- Mechanisms of action include
  - decreasing seizure onset via both enhanced sodium channel inactivation and enhanced GABA activated chloride conductance
  - decreasing seizure spread via reduced glutamate-mediated excitation

T 1/2
- 2-4 hours

Metabolism/excretion
- Low rate of hepatic metabolism
- Both unchanged topiramate and its metabolites are excreted mainly by the kidneys

Side effects
- Sedation and weight loss
- In recent studies elevations in liver enzymes were appreciated, however, these patients were also receiving phenobarbital (in conjunction with the topiramate) so it is unknown if the liver elevations were secondary to the phenobarbital or the topiramate

Dose
- 5-10mg/kg PO BID

Blood levels
- Not established at this time