The Where, What and Why’s of MRI’s
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J.A. Hass DVM, MS

Introduction:

I would like to thank you all for inviting me to visit the Fort Wayne Veterinary Medical Assn this evening I feel that regional veterinary medical associations are a very important part of our profession. Unfortunately, they are beginning to wither and die in the face of internet associations and our very busy lives. I appreciate the opportunity to meet you all.

There are many challenges when presented with a neurological patient, but the two major challenges are the localization of the area of the nervous system affected and the application of the most appropriate and informative diagnostic tests. Tonight I would like to discuss these issues with a particular emphasis on the use of MRI’s to aide in the diagnosis and treatment of the neurological patient.

First, I would like to introduce myself. I am co-owner of Veterinary Care Specialists and VCS Pets First in Milford, MI. We are a 24 hour veterinary emergency and referral center as well as a general or family practitioner to the area pets.

I am a 1986 graduate of MSU and performed my internship at Virginia Tech then began a residency in medical neurology and received my Masters of Science at the Ohio State University. I completed my residency training with Dr. Steven Steinberg at Veterinary Referral associates in 1990 and moved back to Michigan in 1992. In 1997 my husband and I built our current hospital. I work with a board certified surgeon and 3 very capable emergency doctors. Along with the typical professional associations we are supporters of a variety of community organizations and I am a member of the Optimists and Rotary. We believe that it is very important to support our local community and the people that make our cities and towns great places to live.

The Question:
From my perspective the central and peripheral nervous systems are the most important systems in the body. They are the center of the functional unit, the body. They are also one of the most mysterious. Their inner workings are still poorly understood, in part because of our limited access to them.

You can appreciate the importance of the central nervous system by looking at how well protected it is. Not only are the brain and spine protected by bone, like the heart, but also they are protected by an incredibly strong barrier the Blood Brain Barrier (BBB). These barriers provide such substantial protection that the brain succumbs only once all the supporting systems perish or once the barriers are breached. These defenses are what keep our patient’s brains and spines safe, but they are also very effective in keeping us from evaluating them when they are diseased.

Our challenge is to gain access to the nervous system, effectively diagnose our patient’s problem and then treat the problem, mean while avoiding doing our patient further harm.

### Typical Diagnostics Available to the Neurologic Patient

- History and Physical examination
- Blood Biochemistries, Hematology, Urinalysis, Serology, and Immune testing.
- Radiography
- Contrast Radiography
- Histopathology, Cytology, Fluid analysis
- Electro diagnostics
- CAT Scan
- MRI

The diagnostic options that we have available to us are, however, many. Our diagnostic choices are more varied and informative that when I began practicing 20+ years ago. We are also more familiar with electrodiagnostics (EMG, nerve conduction, ERG and BAER), MRI’s and CT’s and have a larger data base to refer to when analyzing these tests.

In many cases we utilize most of the tests mentioned above for a neurological patient. Each category of testing builds on the previous set of information – narrowing in on our diagnosis ___ and making sure that our patient is in the best condition to with stand the challenges of the next test.

**The Where:**

So the first challenge we have as clinicians that have been presented with a neurological patient is, ‘where is the lesion?’ or ‘what part of the nervous system is affected?’ One of my mentors would challenge the students to begin with whether the problem is above or below the foreamen magnum,
from there, narrowing down to the more specific location of the defect. Another approach is to identify whether the problem lies within the central or the peripheral nervous system and then further localize the lesion.

Regardless how you choose to begin, your primary tools that allow you to achieve accurate localization of the affected area are 1. history, then 2. your observations and then 3. your neurological examination.

I find that whenever one of these three items is not performed thoroughly, critical mistakes in sue. Take your time with these patients and be thorough. Make sure that you take a orderly and chronological history. While you take the history, be sure that you allow your patient TO MOVE ABOUT THE ROOM, TAKE YOUR TIME AND OBSERVE THEIR NATURAL MOVEMENTS AND RESPONSES. This is particularly important with cats. Also, have the owner walk the dog outside, again in their more comfortable surroundings. The observations and continued dialogue that you have with the owner are invaluable.

Finally, perform an examination. Not only a physical examination, but a complete neurological examination is necessary. These examinations will take 5 minutes, maximum and will allow you to focus more accurately on the location of your patient’s lesion. I prefer to begin at the head and work back. Dogs are usually examined on the floor, where they are most comfortable, and cats and small dogs on the examination table. Be careful to try to minimize stress and if a patient is not tolerant of reflex evaluation, don’t pursue that aspect of the exam since reflexes will be inaccurate under those circumstances.

The Where

- General categories for Neuroanatomical localization
  - Intracranial
  - Spinal
    - Cervical C1-C4
    - Cervical-Thoracic C5-T2
    - Thoracic – Lumbar T3-L4
    - Lumbar-sacral L5-S3
  - Neuromuscular
  - Multifocal

As we evaluate a patient, we are gradually able to place their condition within certain categories or neuro-anatomical locations. Certainly the groups can be structured in a variety of ways, but generally, I find the categories listed above to be the most useful.

First, we start with intracranial disease or abnormalities that exist above the foreamen magnum. There are a few diseases that may locate themselves within the head, like otitis media/otitis interna or nasal neoplasia that are not necessarily within the central nervous system, but may create neurological signs. When we consider imaging for those diseases we would consider a brain or head MRI since they are located in such close proximity to the brain.
Next, I think it is very useful to consider the spinal cord in segments. The segments are chosen based on the particular signs that refer to defects within these spinal segments.

Next, we would move outside the central nervous system and consider neuromuscular disease which has its own distinctive signs, history and diagnostic tools.

Finally, we have the challenging patient with multifocal disease. I always seem to reach for this diagnosis hesitantly, feeling like it is a cop-out. But realistically, there are many patients that fall within this category. If nothing else, multifocal disease means that we have a wider variety of diagnostic options available.

Like each category that we will consider, each patient with a lesion within that location has very distinctive signs.

- **Intracranial**: Cranial nerve deficits- When considering intracranial disease, remember that it is extremely uncommon, nigh on to impossible, to have a single cranial nerve deficit with no other signs of intracranial disease. That means that patients that are blind, have a facial nerve paralysis, trigeminal nerve dysfunction, stridor, trismus, or vestibular signs with no other signs of intracranial disease most likely have a focal neuropathy or peripheral disease.

- **Cervical**: These patients are often noticeably painful (if the lesion is extradural). They may demonstrate a quadraparesis or paralysis. The signs may lateralize to one side or another. Remember that the sympathetic innervations to the pupil and some of the extraocular muscles of the eye runs through the cervical cord and exits along the ventral roots at T1-T2 and then runs along the cervical soft tissues in the vago-sympatetic trunk bilaterally to innervate the pupil, extraocular musculature and the upper lid on the ipsilateral side. Injuries to the cervical cord on the same side as the Horner’s Syndrome can be the cause of that clinical sign.

- **Cervical-Thoracic**: This is where things get interesting and easier…. Typically this patient will have very divergent signs when it comes to the thoracic and pelvic limbs. As with all the other scenarios they may also be very asymmetrical with lower motor neuron signs to one thoracic limb and UMN signs to all other limbs. The presence of the cervical intumescence and the peripheral nerves that run to each of the thoracic limbs in this area is the reason for the distinctive clinical signs that we see in these patients.

  Muscle atrophy results from the peripheral nerve damage that can occur with injuries in this area. Atrophy from peripheral nerve injury occurs within 7 days of the injury. As opposed to atrophy that occurs from disuse (as with a patient with a paresis or paralysis) which can develop over weeks to months. Also, with PNS related atrophy, it may be focal, reflecting the particular nerve that was injured.

  Root signature is something that you may have heard mention of and I suspect you have often seen this clinical sign. These patients are lame on a thoracic limb and may or may not indicate cervical pain. The lameness may be subtle, periodic or leg carrying. This is not from orthopedic pain, but neurogenic pain. The patients with a root signature will often be weak (a weakened
withdrawal) on that limb during your examination. You may often be able to appreciate muscle fasciculation on this limb and there may be focal muscle atrophy.

The sympathetic nerves making up the sympathetic trunk exit at T1-2. Commonly patient with brachial plexus avulsions will have an ipsilateral Horner’s as a result of their injuries.

The panniculus reflex is a response that has its efferent innervation provided by the C8-T2 nerve roots, the lateral thoracic nerve. The patients with lesions in this area will have an absence of the panniculus on the ipsilateral side.

- **Thoraco-lumbar:** The patients with lesions in the T/L region are probably the most commonly seen veterinary neurology case. The classic down dachshund is a great example. These patients have upper motor neuron signs – spastic paralysis or paresis of the pelvic limbs, incontinence, pain along the thoracic or lumbar spine, and a Schiff-Sherrington posture a just afew of the more common deficit noted on the patients examination.

- **Lumbosacral:** A T1 weighted MRI image of the lumbosacral region in the dog.

  In contrast to our down Dachshund that I mentioned previously, this patient has a flaccid paralysis of the pelvic limbs and often the combination of fecal and urinary incontinence. Also the urinary incontinence if characterized by the inability to stop urinating, as opposed to the retention of urine that is seen with an upper motor neuron bladder.

  A root signature with these patients may be a lameness or a stomping or chewing of the foot. We see this as well with cervicothoracic patients that have more chronic disease. Like the Doberman with the lick granulomas along the carpi, the L/S dog is more commonly the GSD that chews or licks his hocks and feet.

- **Neuromuscular:** Patients have lower motor neuron signs, decreased reflexes, weakness and intolerance to exercise. They may have sensory deficits will have muscle atrophy, particularly if motor nerves are affected. Sensory deficits may also cause self mutilation.

  Autonomic dysfunction and cranial nerve deficits may be present- like megaesophagus and laryngeal paralysis

- **Multifocal:** These are the GME patients, the patients with infectious or viral disease or the ketoacidotic patient that also has diabetic neuropathy. Also, the cat with cardiomyopathy that has had a saddle thrombus or a cerebral infarct is an example on a patient with metabolic disease causing multifocal signs. Another example is the hypothyroid (usually severely) patient, who may present with seizures, weakness, altered mentation.
Over the past century, really over the past 10 years, we veterinarians have created many other ways to identify and characterize disease within our patients. We also have the benefit of far more clinical data that allows us to further characterize disease based on our exam and our professions experience. The day of a completely mobile hospital like this one is gone.

Every patient that is presented with neurologic disease, in my practice, deserves a basic minimum database. A full biochemistry, CBC, thyroid testing, thoracic radiographs, and in most cases, blood pressure testing.

Myelography remains a valuable diagnostic tool particularly for those of us without an MRI! It still remains a very appropriate and helpful test to identify extradural and some intradural lesions—like discs or intradural/extradural tumors. Also, we collect CSF, in most cases, and this too makes the procedure more informative.

This is an example where a myelogram fails the diagnostician and the patient. Swelling or distention of the silhouette of the cord is a very non-specific change and warrants further characterization. Surgical exploration, once an option, seems inappropriate when we have more powerful, non-invasive tools that may influence our therapeutic choices. Later we will look at a case that had we chosen to perform a myelogram we would have been left with a result such as this and not had the ability to characterize the patient’s disease more accurately.

Electro diagnostics are vastly underused and underappreciated. EMG’s allow us to characterize the changes within the muscles from nerve damage, changes within the neuromuscular junction, the effects of metabolic diseases or primary muscle disease. Nerve conductions find evidence of injuries to the nerves themselves or the neuromuscular junction. These tests allow us to localize lesions and these for narrow our differential list. Other electrodiagnostic procedures such as repetitive nerve stimulations can diagnose diseases like myaesthenia.
CAT scan is best used when we expect a defect in the bone surrounding the CNS like a neoplastic process of the skull, spine or nasal sinuses.

MRI remains one of our most powerful diagnostic tools. MRI’s use magnetic fields to

1. Align hydrogen protons
2. Radiofrequency energy is then applied to the protons
3. Then the energy is withdrawn and as the hydrogen protons ‘relax’ they release energy and this is the signal recorded by the scanner.
4. Different relaxation times produce different signals. Major groups T1 and T2. The relaxation times for different tissues vary from T1 to T2 therefore their images will look different. Fluid and edema on the T2 is white while it is dark on the T1. Fat is white on T1 and dark on T2 images.
5. T1 and T2 images can be further manipulated by the timing of the field application.
6. The larger the magnets, the more powerful the machine and the greater detail provided.

The picture compares CT on the left to T1 and T2 MRI studies. You can appreciate that the CT does not provide the detailed evaluation of the soft tissues that we see in the MRI. However, when looking at the bone of the skull and nasal passages the MRI may not be as informative as the CT.
Air and bone are dark on both T1 and T2

- T1 - fluid dark, fat is white
- T2 - fluid is light, fat is dark

FLAIR

Gaddolinium

FLAIR – Fluid Attenuated Inversion Recovery - a sequence that removes the influence of CSF on the images and is helpful in identifying more subtle lesions that sit close to areas containing CSF. This is often utilized to identify the demyelination lesions in MS or the lesions associated with other infectious diseases like toxoplasmosis.

Gaddolinium is a contrast agent that is administered IV. The contrast of edema (dark) against the Gaddolinium (white) that leaks through the blood brain barrier where abnormalities are present on T1 images, produces a dramatic effect.

Unfortunately, or maybe fortunately, not many of our patients are like this fish. They cannot be placed in a MRI and a whole body scan performed. This is why the neuroanatomic localization is so important. Also, by localizing the lesion we can have more detailed and more diagnostically powerful scans performed because they are tailored both for a specific location and possibly even for the differentials we may be considering.

Some of the benefits of utilizing a MRI include: no radiation exposure, you can identify space occupying lesions as well as inflammatory disease due to its high resolution, the anesthesia can be a challenge since we are limited to either using specially manufactured anesthesia equipment (remember the MRI is a big magnet, nothing metal) or utilizing injectable anesthesia. MRI’s also provide the versatility of many different views of the same anatomic structure as well as the ability to create reconstructions that are three dimensional. The views above are sagittal, coronal and axial.
Some examples of lesions identified on MRI:

This is a patient with a brain stem mass evident.

Here is a sagittal view, T1 of a syrinx in the cervical spine over C3.
C5-6, and C6-7 herniated discs. I did not see this patient’s full study, but I suspect this dog is a Wobbler or has some cervical instability as well.

This was a patient of mine a few years ago, Fritz, who had focal low lumbar pain and pelvic limb weakness. He had a compressive lesion at L6-7.

Syringomyelia is a condition commonly identified in King Charles Cavalier Spaniels (KCCS), but has been seen in other breeds as well. In the KCCS the animals have a malformation of the occipital bone as well as a small cranial vault. This leads to blockage of the flow of CSF out of the cranial vault, called a Chiari malformation. The animals are also
predisposed to the formation of syrinx, or fluid pockets within the cervical spinal cord. MRI is the gold standard for the diagnosis of this position. CT scans are inferior in their ability to distinguish soft tissue changes and structural anomalies that are so significant in these patients.

Case Study: Ziggy B. A 5 year old, MN, Labrador

- Scuffed thoracic limb paws R>L
- Resting anisocoria OD<OS
- Right parascapular muscle atrophy
- No withdrawal or pain response to the right thoracic paw

T1 with contrast
His clinical signs localized to the cervico-thoracic region, right lateralizing. The MRI found a focal lesion at C6. It contrast enhanced. CSF was normal. All infectious disease titers were normal. Ziggy has done well as long as he is on steroids. He regained sensation to the right pelvic limb paw, but now has paraesthesias and will self mutilate if allowed. He is 2 years post MRI. We have not had the benefit of another MRI. At this time this lesion appears to not be progressing clinically, the patient’s condition has been static for some time. I suspect that the etiologic agent is gone and was inflammatory.

Although, often with inflammatory diseases in the CNS, CSF is a more informative diagnostic tool than a MRI. Performing a MRI first may be helpful in allowing us to appreciate whether a cisternal tap is a safe procedure. As with the KCCS’s we spoke of earlier or a small dog with occipital dysplasia, a CSF tap could prove fatal.

GME and other diseases cannot be distinguished between on a MRI, but by observing these changes we can modify our list of differentials and better modify our diagnostic plan.

Thank you.