COMPARISON OF DIAGNOSTIC VALUES OF ADVANCED IMAGING TECHNIQUES AND ELECTRODIAGNOSTIC PROCEDURES IN THE ASSESSMENT OF CERVICAL SPINAL CORD DISORDERS IN DOGS. A PRELIMINARY STUDY

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Abstract

The retrospective study was designed to compare the diagnostic value of computed radiography, magnetic resonance imaging, computed tomography, and electrodiagnostic procedures like brainstem evoked potentials and somatosensory evoked potentials in cervical spinal cord diseases in dogs; including wobbler syndrome, intervertebral disc disease, trauma, neoplasma, and syringomyelia. Thirty-one dogs with cervical spine and spinal cord disorders were chosen during 2007-2009. All patients were clinically and neurologically examined, also laboratory tests like blood, and urine profile were done. Subsequently value of each diagnostic procedure was assessed individually and in comparison to others. MRI was found to be the most valuable diagnostic imaging technique in cervical spinal cord diseases, when compared with myelography, X-ray, and CT. It showed a 100 % accuracy in diagnosis of IVDD, neoplasm, syringomyelia, and wobbler syndrome. Among the electrodiagnostic procedures, SSEP is superior to BAER technique. It is extremely helpful in IVDD, wobbler syndrome, neoplasm, and syringomyelia diagnosis. BAER showed usefulness in wobbler syndrome and syringomyelia diagnosis.

Key words: dogs, cervical spinal cord diseases, electrodiagnosis, neuroimaging.

Cervical spine and spinal cord disorders are a common problem in clinical veterinary practice. Due to the specificity of the region, they usually cause diagnostic problems which often prevent a doctor from accurate diagnosis. In this region, diseases like cervical spodylomyelopathy (Wobbler syndrome), intervertebral disc disease, traumas, neoplasms, and syringomyelia are observed in dogs. The wobbler syndrome refers to a set of disorders (3) concerning cervical vertebrae malformation, intervertebral disc disorders, and hypertrophy of flaval ligament resulting in spinal cord compression. Disc associated wobbler syndrome (DAWS) is characteristic for middle-aged large breed dogs, particularly for Dobermans. The syndrome is also characteristic for young large breed dogs of 6-12 months of age like Leonbereggers, st. Bernard’s dogs, etc, when spinal canal is too narrow for the spinal cord, subsequently causing compression. Syringomyelia (SM, syrinx, hydromyelia) can be genetic and posttraumatic. This is a condition when fluid filled cavities in the middle of spinal cord are formed. Posttraumatic cavities observed in syringomyelia are caused by demyelination of the nervous tissue, oedema, and inflammation. Disc calcification and degeneration predispose individuals to clinical intervertebral disc disease (IVDD), which is classically differentiated into two main types: I and II (4). IVDD type I is the most common for chondrodystrophic breeds and results from a complete extrusion of nucleus pulposus through the annulus fibrosus into the epidural space. IVDD type II is more prevalent in non-chondrodystrophic breeds and is caused by the dorsal haemiation of nucleus pulposus leading to annulus fibrosus protrusion into the epidural space. In the differential diagnosis of the cervical spinal cord diseases tumours like primary central nervous system lymphoma need to be considered.

The oldest diagnostic imaging procedure is X-ray. When it comes to spine, it mainly allows seeing hard tissues like bones, therefore it is useful in diagnosis of trauma or calcified intervertebral discs. Myelography may be a very useful technique, where contrast is administered into a subarachnoid space. Magnetic resonance imaging (MRI) is a technique of choice when it comes to nervous system imaging. MRI scanners are valuable at looking at the non-bony parts or "soft tissues" of the body. In particular, the brain, spinal cord, nerves; also muscles, ligaments, tendons are seen much more clearly with MRI than with regular X-rays and...
computed tomography (CT) scans. A disadvantage of MRI is its higher cost compared to a regular X-ray or CT scan. CT combines special X-ray equipment with sophisticated computers to produce multiple images or pictures of the inside of the body. CT scans of internal organs, bones, soft tissue, and blood vessels provide greater clarity and reveal more details than regular X-ray exams, therefore it is useful in soft tissue and bone imaging. Electrodiagnostic procedures like somatosensory evoked potentials (SSEP) and brain auditory evoked potentials (BAER) are techniques commonly used in human medicine and are being introduced into veterinary medicine. Electrodiagnosis checks the integrity of neural pathways and nervous conduction (12).

Material and Methods

Thirty-one dogs with cervical spine and spinal cord disorders were identified during 2007-2009. For inclusion in the study, all dogs were required to be clinically examined. The retrieved information included signalment, occurrence, type and result of former treatment (before diagnosis), duration of clinical signs, physical and neurological examination findings, medical imaging, and electrodiagnostic findings. A dog was excluded if a suspicion of diagnosis had not been confirmed by radiography, myelography, MRI, CT, SSEP, and BAER, or when concurrent diseases influencing the images results were detected. Radiography was performed in lateral and dorso-ventral recumbency. Myelography was performed under general anaesthesia using conventional techniques, primarily via lumbar puncture. The contrast medium was iohexol (Omnipaque 300, Nycomed, Poland) in the dose of 0.3-0.5 mg/kg b.w. MRI examination was performed with 0.25 T ESAOTE low-filed MR, under general anaesthesia with the dog positioned in dorsal recumbency. Anaesthesia was induced with medetomidine (Cepetor, Scanvet, Poland) in a dose of 40-80 µg/kg of metabolic bodyweight. Anaesthesia was prolonged with a single intravenous dose of propofol (Fresenius Kabi, Poland) in a dose 1-2 mg/kg b.w. A dog was intubated and anaesthesia was maintained with 4 mg of propofol kg/h. The minimal imaging protocol had to include fast-spin echo (FSE) T2-weighted images in a sagittal and transverse plane and a high resolution gradient echo T1 sequence, FLAIR (fluid attenuated inversion recovery), SSEP examination with electrodiagnostic unit (Viasys Nicolete, USA) was performed (2). The tibial nerve was stimulated. SSEP recordings were performed under anaesthesia using the same protocol as for MRI examination. Disposable stainless steel EEG needles were used. The first channel was consistent of two electrodes; negative Cz electrode placed in the frontal lobe region and the second positive tFpz, which was placed between eyes. The second channel was positive needle electrode placed again between eyes, whereas negative was in the C5 region; another pair (the third channel) was placed in the TH13-L1. The fourth channel electrodes were placed in L7-S1 region. A ground electrode was placed subcutaneously in the fossa subpoplitea. Stimuli for SSEP recording were square-wave pulses of 0.2 ms duration, applied at an intensity of 8 V, generated by a stimulator and started by computer signal. The stimulus intensity was set at causing a clear, visually detectable digital extension, and tarsal flexion. After SSEP of left tibial nerve the dog was turned on the other side and recordings were repeated after stimulation of the right tibial nerve. In BAER protocols dogs were sedated with medetomidine. Earphones were applied in dog’s ears, whereas needle electrodes were positioned subcutaneously in the scalp at the vertex and rostral to the base of each ear. Electrodiagnostic unit (Viasys Nicolete, USA) was used for the exam registration.

All dogs underwent the neurological examination. Upper motor neuron signs in four limbs, neck pain, and ataxia were noted.

The dogs were categorised into five groups. The first group consisted of six dogs with wobbler syndrome, the second group were three dogs with cervical spine trauma, the third group were 15 dogs with diagnosed IVDD (intervertebral disc disease), five were diagnosed with spinal tumours (fourth group), the fifth group consisted of two dogs with posttraumatic syringomyelia. All dogs underwent diagnostic procedures like radiography; myelography, CT, MRI when necessary, and electrodiagnostic procedures like SSEP and BAER.

Results

Group 1. Six dogs were diagnosed with Wobbler syndrome. All dogs underwent radiographic examination, but only in two cases (28.6%) abnormalities like altered shape of vertebral body, loss of its ventrocranial border, or calcified discs were seen. Subsequently, myelography revealed protrusion of two discs in C3-C4 and C4-C5 with a concomitant dorsal compression of the ligamentum flavum. The rest of the dogs (71%) with no abnormalities found on X-ray images underwent MRI (57%) and CT (14%). CT was a modality of choice only in one case of 9-year-old Doberman with a concurrent cardiac disease, due to shorter time of procedure and anaesthesia. The examination revealed calcified disc protrusion in C3-C4 intervertebral space, and changes of the third and fourth cervical vertebra signal suggesting its lipid degeneration. MRI (T1 weighed, T2 weighed, FLAIR) with a human torso coil was performed in the remaining four dogs. The abnormalities visible on MRI images included total loss of normal hyper intense signal of nucleus pulposus in C3-C4 (23%), C4-C5 (33%), C5-C6 (21%), and C6-C7 (13%) indicating dehydration of the discs. Severe ventral disc protrusion was observed in all cases, in those spaces compression of the spinal cord caused its elevation so it was touching the vertebral arch. Occlusion of subarachnoid space and hypertrophy of the ligamentum flavum was seen only on two MRI images.
Spinal cord in the compressed part was hyperintense, which was associated with oedema, malacia, and gliosis of neural tissue. SSEP was performed in all patients. Waves from a cervical region (second) were of prolonged latency and the amplitude was lessened. BAER examination revealed in one case (33%) a prolonged latency and diminished amplitude, prolonged III-V interpeak latency.

**Group 2.** Three dogs (one poodle, two mixed breed dogs) were diagnosed with cervical vertebra fracture (C4, C3). In all cases radiography was performed, but bone fracture was seen only in one case (33%). CT images in all three cases (100%) revealed fractured vertebrae. MRI was also performed to get a closer image of neural tissue. Apart from bone fracture (33%), it showed signs of oedema and gliosis of neural tissue in all cases. Additionally, features of bone marrow lipidosis were diagnosed in vertebral body (60%). SEP turned out to be helpful when spinal cord compression was present (66%), it was more sensitive to sensory impairment than neurological examination, thus correlation with CR, CT was poor. No BAER changes were noticed. SSEP examination was altered only in one case (33%), which correlated with severity of lesions visible on CT, MRI images. Cervical wave latency was prolonged, peak amplitude was diminished.

**Group 3** consisted of 15 dogs with intervertebral disc disease (IVDD), among which six were dachshunds, two Pekinese, three French bulldogs, two American Staffordshire terriers, and two mixed breed dogs. All dogs underwent a routine radiography procedure in sagittal and lateral projection. Only in three cases (21%) X-ray image of chondrodystrophic pedigree dogs (dachshunds) revealed calcified discs in C3-C4, C4-C5, protruding into the spinal canal compressing the spinal cord. All dogs underwent MRI and CT procedure. The locations of disc haemiation were intervertebral spaces C2-C3 (three dogs), C3-C4 (five dogs), C4-C5 (seven dogs), C5-C6 (three dogs), and C6-C7 (two dogs). Haemiation was right sided in five dogs, left sided in six dogs, and median in four dogs. The compressive material was hypo intense in T1 and T2 sequences in 13 dogs, and had high signal intensity in T2 images and was slightly hypo in T1 in two dogs. Protruded discs compressed the thecal sac and the nerve roots on adjacent side. In three dogs with severe neurological deficit, high signal intensity of spinal cord in T2 sequence was observed, subsequently these dogs had a longer recovery time, and the prognosis was worse. Degeneration (dehydration) of discs was identified by a loss of signal intensity of nucleus pulposus in T2W spin echo image. The differential diagnosis for it was gliosis, oedema, and myelomalacia. The spinal cord was deviated dorsally and severely flattened in eight dogs. The compression grade ranged from 30% to 50%. No BAER changes were noticed.

**Group 4** consisted of five dogs with cervical spinal cord neoplasms. In all dogs lesions were best visible on MRI images (100%), whereas CR images showed no changes. CT examination revealed lesions in three dogs, but after a contrast application (60%). All dogs revealed changes in SSEP examination (100%). Only one dog (20%) showed changes in BAER examination: prolonged III-V interpeak latencies and reduced latency.

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**Fig. 1.** A: BAER –due to compression of brain stem wave latencies, III-V inter-peak latencies are prolonged. B: MRI image of Great Dane is present in C5-C6, C6-C7 articular arthritis. Blue arrow shows erupted disc compressing the spinal cord. An increase in T2 signal intensity is present in center of the spinal cord in C3-C5 region, what likely is syringomyelia/ hydromyelia and cordoedema.
Fig. 2. A: CR image, a fracture of C5 vertebra, B: SSEP obtained from the same dog, blue arrow indicates a prolonged latency and diminished amplitude. C: CT image, a blue arrow indicates a fracture of cervical vertebra.

Fig. 3. A: SSEP obtained from a dog with IVDD in C3-C4, C4-C5, C5-C6, there is no conduction of nervous impulse (blue arrow) on the right side and the amplitude is severely diminished and latency is prolonged (yellow arrow) on the left B: myelography of cervical region, a black arrow indicates a mild disc herniation.

Fig. 4. A: MRI image showing nephroblastoma in cervical region in a dog. B: T2 sagittal, well demarcated hyperintensive neoplastic lesion in a Pekinese dog (lesions were confirmed to be of neoplastic character).
Table 1
Usefulness of diagnostic methods in diagnosis of cervical spinal cord diseases

<table>
<thead>
<tr>
<th>Group</th>
<th>CR</th>
<th>MRI</th>
<th>CT</th>
<th>SSEP</th>
<th>BAER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>36% (n=2)</td>
<td>100% (n=6)</td>
<td>18% (n=1)</td>
<td>83% (n=5)</td>
<td>36% (n=2)</td>
</tr>
<tr>
<td>2</td>
<td>33% (n=1)</td>
<td>33% (n=1)</td>
<td>100% (n=3)</td>
<td>33% (n=1)</td>
<td>0% (n=0)</td>
</tr>
<tr>
<td>3</td>
<td>21% (n=3) + contrast</td>
<td>100% (n=15)</td>
<td>33% (n=5)</td>
<td>93% (n=14)</td>
<td>0% (n=0)</td>
</tr>
<tr>
<td>4</td>
<td>0% (n=0)</td>
<td>100% (n=5)</td>
<td>60% (n=3) + contrast</td>
<td>100% (n=5)</td>
<td>20% (n=1)</td>
</tr>
<tr>
<td>5</td>
<td>0% (n=0)</td>
<td>100% (n=2)</td>
<td>100% (n=2)</td>
<td>100% (n=2)</td>
<td>50% (n=1)</td>
</tr>
</tbody>
</table>

**Group 5** consisted of two dogs with posttraumatic syringomyelia. Dogs when referred to the hospital were taken to have X-ray done, but no abnormalities were observed. Due to clinical status of the patients and shorter time of procedure, CT was a modality of choice; unfortunately it only suggested widening of vertebral canal especially in C2-C3 region and scoliosis was observed. Subsequently MRI was performed. It revealed intramedullary cavities and dilatation of central canal communicating with ventricular system. In T1 image, low signal intensity was observed in the cervical spinal cord, which correlated with widening of the affected region. In T2 increased signal intensity of tissue surrounding the syrinx was seen. In the post-contrast T1W spin echo transverse plane images, there was a dilation of central canal and a thin circumferential rim of central canal. To check integrity of somatosensory pathways and neurotransmission SSEP examination was done. In both cases (100%) the third wave from cervical region was altered; amplitude was lowered and latency prolonged, which implicates on neurotransmission disturbances in traumatised region. BAER examination revealed in one case (20%) a prolonged latency, and diminished amplitude, prolonged III-V interpeak latency.

All results are displayed in the Table 1 and Figs 1-4.

**Discussion**

Magnetic resonance imaging turned out to be the most useful in evaluating spinal cord lesions in cervical region. MRI is a modality of choice when soft tissues like nerves, are to be examined. MRI accurately localises lesions like syringomyelia (100%) (7), protruded discs (100%), and Wobbler syndrome (100%). It is merely helpful with cervical vertebra fracture (33%) being not a modality of choice in bones evaluation. MRI should be undoubtedly a modality of choice in IVDD diagnosis (9). Degeneration (dehydration) of discs can be identified by a loss of signal intensity of nucleus pulposus in T2W spin echo image, whereas narrowing of intervertebral space is best evaluated in T1W echo spin image. Degenerated disc losses its ovoid shape (4) which is the best visible in transverse plane and is highly predictive of its degeneration and subsequent protrusion. With a disc protrusion, a change of spinal cord shape is always associated, because it is pushed to the dorsal wall of spinal canal, which lessens the cerebrospinal fluid reserves around it. Highly indicative of disc protrusion is a disappearance of epidural fat. MRI is non invasive examination, which needs to be performed under general anaesthesia, which may be taken as its limitation especially with cardiac patients, or those after communication accidents requiring quick surgical intervention. Other limiting factors are costs of examination (1) and longer time comparing to CT procedure. MRI advantages include evaluation of spinal cord, spinal canal, discs, delineation between intradural and extradural lesions (which is especially useful in spinal tumours diagnosis), and evaluation of intervertebral and extradural spaces (11). In human medicine, MRI is considered to be superior to CT when neurological diseases are considered, so it is in veterinary medicine. The quality of images is dependent on patient positioning, size of dog, slice thickness, magnet size, and experience of technician performing examination.

Our study revealed that CT should be a modality of choice when vertebra fracture is suspected.
(100%). It was also helpful with Wobbler syndrome dogs (18%), or IVDD (33%). CT enables evaluation of changes in bony tissue and evaluation of intervertebral space and foramen. Unfortunately, CT is not a good examination to evaluate disc degeneration rate, syringomyelia. CT is superior to MRI when a traumatized patient needs to be quickly examined before surgery, it is a shorter time procedure than MRI, slightly longer than CR, but definitely more accurate than CR. It could be also a modality of choice in a routine check-up examination after hemi/laminectomy surgery. It is important to remember that CT and MRI cannot be directly compared, due to different slice thickness and spatial resolution.

CR-computed radiography in this study was mostly helpful in IVDD diagnosis (45%). 90% of dogs with a disc protrusion visible on CR were chondrodystrophic pedigree dogs. 77% discs were degenerated and calcified. When images were compared to CT and MRI it turned out that 10 protruded but not calcified yet discs were not seen in CR images. Narrowed intervertebral space on CR images was considered to be of a great diagnostic value of protruded material, because of optimal combination of sensitivity, and high positive predictive value. To assess the width of an intervertebral space, it is necessary to compare the adjacent spaces. In some cases, only a subtle decrease in width of the mentioned space was noticed after a disc protrusion. Sometimes, a disc material may be difficult to visualise on sequentional radiographs because it is dispersed, or may be gradually removed by phagocytes. It needs to be considered that radiographic interpretation may be further complicated by imprecise positioning for radiography, parallax, which makes intervertebral spaces away from the centre of primary X-ray beam. This may lead to diagnostic problems, therefore CR may have a high but only predictive value of disc protrusion. Performing CR turned out to be not accurate enough to diagnose side of disc prolapse, which is a helpful information for surgery procedure (8). CR turned out not to be diagnostic in dogs prone to disc disease type II, in which only annulus fibrosus bulges as a result of hypertrophy or stretching and it is less likely to extrude. Radiographically, Hansen type I disease may be more likely diagnosed than Hansen type II disease. CR was useful in Wobbler syndrome diagnosis only when stenosis and cervical vertebra abnormalities, osteophytes, or ligamentum flavum hypertrophy were present (33%), but also in cervical vertebra fracture (33%). A conclusion, that it is a little specific examination only indicating the problem, was made (6, 13). CR turned out to be useless when syringomyelia is suspected. CR is a cheaper examination than CT and MRI, and is widely achievable. Myelography is a mainstay of diagnostic procedure to evaluate the spine (8). For many years, myelography has been the main diagnostic imaging technique in dogs with spinal cord diseases, particularly when they were considered for surgery. It is convenient, cost effective, and allows examining the whole spine. Myelography can localise the lesion but it does not give any information about its aetiology (11). Accuracy of myelography, according to McCartney (10), can vary between 72% and 90%. Evaluation of intramedullary lesion, nerve roots, or discs is not possible either. Risks are associated with myelography only when dog is suspected of infectious disease, or when it is performed by person with no experience. It is superior to MRI and CT when it comes to costs of procedure, it may also be commonly used by practitioners (8). Myelography and MRI in dogs with cervical spinal cord disorders were compared with eachother. It resulted in conclusion that MRI is more accurate in predicting the site, severity, and cause of spinal cord compression, which was also confirmed by our researches.

BAER examination is helpful only when lesion is placed in high cervical region and it influences the pons causing oedema, inflammation, and nervous impulse conduction disruption. Therefore, abnormalities were diagnosed in syringomyelia patients, neoplasm infiltrating C1- C2 region in the medulla oblongata, and IVDD in C1-C2, C2-C3 region. Inter-peak latencies were prolonged.

All dogs underwent SSEP examination. Evoked potentials are time locked responses of the central nervous system to the external stimuli. SSEP were generated by stimulation of afferent peripheral and central nervous system, and turned out to be helpful in syringomyelia (100%), Wobbler syndrome (100%), and IVDD (100%). In this study, SSEP were merely helpful in cervical vertebra fracture (30%). It was concluded that segmental SSEP testing in syringomyelia and spinal cord tumours could be helpful to delineate the neurophysiologic boundaries of the lesions. It is important to remember that SSEP are not disease specific but can indicate afferent conduction impairments associated with certain disorders. This examination is a tool that can confirm or reject when suspicion of diagnosis is uncertain, by indicating whether a disease concerns somatosensory pathways (12). SSEP are often helpful in localising the anatomic site of the lesion, which is extremely helpful before performing surgery in IVDD patients. SSEP are helpful in identifying indistinct abnormalities and lesions causing only vague or equivocal signs or symptoms (2); this was confirmed by SSEP changes in examination performed in dogs with IVDD of grade 1 or 2. In syringomyelia and IVDD patients SSEP are helpful in evaluating the effect of compression on dorsal spinal column (14). When procedure is performed segmentally, it is useful in assessing the width of lesion. SSEP have been shown to have a great prognostic value in functional outcome of acute spinal cord injury and should be widely used in clinical medicine to diagnose abnormal sensory function and monitor neurologic status of animals treated conservatively or surgically.

Our study proved its diagnostic value in cervical spinal cord disorders, therefore, we think it should be performed as a supplementation of all imaging techniques. Borderline cases with intermittent, slight neurologic deficits or those that reached a stage of presence/absence of deep pain perception should undergo a SSEP examination, which may be helpful in determining with prognosis. It is a useful tool in
examining the ascending somatosensory function in a non-invasive manner (5).

Both diagnostic imaging and electrodia

gnostic procedures should be performed to qualify a dog for pharmacological or surgical treatment. MRI and myelography are the best diagnostic imaging techniques for IVDD diagnosis. Bone fractures and lesions are best visible in CT. Nervous system function and impulse conduction can be assessed only by electrodiagnostic examination.

References


7. Lamb C.R., Pfeiffer DU., Targett M.P.: Neurological signs and results of magnetic resonance imaging in 40 cavalier King Charles spaniels with Chiari type 1-like malformations. Vet Rec 2003, 153, 260-263.