Dynamic computed tomographic myelography.

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Cervical myelography, the gold-standard antemortem test for diagnosing cervical vertebral compressive myelopathy in horses, has been in use for over 30 years.[1,2] The recognition of spinal cord compression as stenotic and dynamic requires myelograms to be performed in neutral, flexed, and extended positions. Measurements of the dorsal dye column and dural diameter remain the preferred diagnosis methods, although in radiographic myelograms, information is only obtained in two dimensions, dorsal to ventral.[3] Computed tomography (CT) has allowed a three-dimensional (3D) examination of the cervical spine. Historically, it has been limited to neutral and extended positions as horses are typically scanned in lateral or dorsal recumbency, requiring radiographic myelography to rule in or out dynamic spinal cord compression.[4–8] The author's practice has recently developed a method of dynamic CT myelogram allowing three-dimensional imaging in neutral, flexion, and extension. All horses undergo a neurologic exam and are graded on the modified Mayhew ataxia score. Horses are placed under general anesthesia, cerebrospinal fluid is aspirated from an atlanto-occipital approach, and non-ionic contrast media is placed within the subarachnoid space aseptically. The head is elevated on a pad for approximately 8 minutes, and the horse moved into position in the CT. The order of image acquisition is caudal flexed, cranial flexed, cranial neutral, caudal neutral, caudal extended, and dorsal.

After the procedure, the horse is placed in a padded recovery stall, and assisted rope recovery is performed. Since January 2023, the practice has performed over 135 studies. To date, there have been no fatal complications in recovery. Four horses did become more ataxic post-procedure, but those signs resolved within twenty-four hours.

Results of the dynamic CT myelograms can be grouped into spinal cord compression/impingement, abnormalities of the articular process joints (APJ)/intervertebral foramen (IVF), pathology of the intervertebral disc (IVD), and anomalous findings. Spinal cord compression/impingement is categorized as circumferential or focal with a notation of cervical position and if there is attenuation of the dye column and/or shape change of the spinal cord. Dural diameter and dorsal dye column measurements are also made.

Findings unique to dynamic CT myelogram include focal dorsolateral or lateral spinal cord compression and discrepancies with published dural diameter changes related to specific sites. A radiographic myelogram only demonstrates changes to the subarachnoid contrast and dural diameter dorsal to ventral. Also, particularly at C3-4 and C4-5, published sagittal dural diameter measurements tend to overestimate compression compared to transverse images on CT both in neutral and flexion.[2,3]

The APJ have an array of abnormalities ranging from osteoarthritic changes to osteochondritis dissecans (OCD) and size/shape changes. Enlargement of the APJ has been observed in our population to either occur in a dorsal abaxial direction, axially, ventroaxially, or a combination. If the enlargement occurs dorsal abaxially, the subarachnoid dye column is unaffected, as is the IVF. Axial enlargement can cause spinal cord impingement or compression, while ventral enlargement can reduce the cross-sectional area of the IVF. The cervical spinal nerve exits the IVF mid to caudally.[9–11] These findings become increasingly important dynamically as, typically, neck extension narrows the IVF, and flexion increases the IVF size.[9] Contrast arthrogram has also allowed investigation into the APJ capsule in abnormal joints. Previous reports have been modeled on normal horses.[12] In the author's experience, the joint capsule in an abnormal APJ can push axially toward the spinal cord with the cervical spine in extension. In flexion, it tends to push caudally out the IVF. In several cases, a soft tissue extradural mass effect in neutral, extended, and flexion has been confirmed to be the joint capsule through arthrography. In some cases, the joint capsule, not bone proliferation, of an abnormal APJ is causing spinal cord compression. This also has implications for soft tissue impingement on the cervical spinal nerve, playing a role in the pathogenesis of cervical radiculopathy.

Pathology of the IVD has been increasingly recognized as a cause of cervical pain/dysfunction or ataxia in horses.[13–16] In our population, some dorsal protrusion of the IVD at C3-4 and C4-5 is extremely common in flexion and rarely accompanied by other abnormalities. However, C5-6, C6-7, and C7-T1 should have minimal dorsal disc protrusion and mineralization, or endplate remodeling indicates pathology. CT also underestimates the degree of change in the IVD, as demonstrated by comparing post-mortem MRI, gross pathology, and histopathology.

As with any newer modality, several interesting findings have been observed in our caseload, including apparent osseous cyst-like lesions, subarachnoid meningeal cysts, and variability in the shape and thickness of normal anatomic structures.

Interestingly, the author has become increasingly aware of variability in clinical signs of ataxia/cervical pain and dynamic CT myelogram findings. Some horses have little ataxia with significant spinal cord compression, while others with minimal impingement are quite ataxic. This creates a problem in managing these horses, prognosticating their ability to perform, and creating safety issues with riding.

Dynamic CT myelograms have allowed 3D imaging of the cervical spine, improving the evaluation of horses with ataxia. With any new imaging modality, care must be taken to interpret findings carefully and attempt to correlate them with clinical signs and postmortem findings.

Cervical radiculopathy is defined as cervical spinal nerve injury at the intervertebral foramen.[17] The condition has been recognized in horses and is a contributor to forelimb lameness and cervical pain/dysfunction.[10,18–22] In humans, it is most commonly associated with disc disease, spondylosis, cysts, tumors, or vascular anomalies.[17] In the horse it appears to be primarily caused by articular process joint osteoarthropathy and enlargement.[10,23,24] Previous treatments have been medical through injection, rehabilitation, or complementary medicine.[11,18,25–28] Recently, a novel minimally invasive surgical approach was published, allowing enlargement of the intervertebral foramen through a single incision.[10] The author adopted the technique after training with Dr. Swagemakers in Germany and performed the first foraminotomy in the United States. Subsequently, the author has performed thirty-one procedures on twenty-three horses to date.

Case selection for endoscopic foraminotomy (EF) is complex. Currently, the author identifies horses with cervical pain by ruling out other possible causes of the clinical signs and performs computed tomography (CT) or CT dynamic myelogram. If there is evidence of mild to moderate intervertebral foraminal stenosis (IFS) then either medical treatment or surgery is recommended. Cervical spinal nerve injection can be utilized to gauge response to therapy. A positive response reinforces the diagnosis, although a negative response does not mean surgery will not help. Horses with severe IFS generally have surgery recommended. Unfortunately, many horses with IFS will have multiple areas of cervical spinal pathology. The best candidate has two or fewer sites of IFS, no evidence of spinal cord impingement/compression, and minimal ataxia on clinical examination. Further complicating treatment options are horses with minimal clinical signs or signs that don’t correspond to the worst CT lesions. The author is currently exploring the use of electromyography to help determine if there is a dysfunction of the specific cervical spinal nerve in question.[29–33]

Once a diagnosis is made and surgical intervention is recommended, horses are placed in lateral recumbency under general anesthesia. At the author's practice, anesthesia is induced with ketamine and valium and maintained with isoflurane, lidocaine, ketamine, and xylazine continuous rate infusions. Pain management is provided via nonsteroidal anti-inflammatory drugs, morphine, and a perioperative dose of corticosteroids. A single perioperative dose of antibiotics is also administered. The surgery site is identified and approached with radiography and ultrasound. Richard Wolf Spine's instruments, specifically the Vertebris lumbar set, is utilized. The site is identified, and the ultrasound guides the placement of a Steinman pin just dorsal to the intervertebral foramen (IVF). A small 2-3 cm skin incision is made, and graduated dilators advanced to the cranial articular process, which is more superficial dorsal to the IVF. A cannula is then advanced over the dilators, which are then removed. The endoscope is placed in the cannula, and dissection commences through the musculature using radiofrequency and hand instrumentation. Once the edge of the articular process is identified varying size rotary burrs are used to enlarge the foramen. A post operative CT is performed immediately after the procedure and the horse rope recovered.

Intra-operative complications include those that accompany any anesthesia, hemorrhage that obscures the surgical field, and disorientation due to inadequate landmarks/patient positioning. Immediate post operative complications are prolonged recumbency, neuropathy, ataxia, pain. Short to long term complications are increased ataxia that usually resolves in 4-8 weeks, local muscle atrophy, localized sweating, and failure of resolution of clinical signs.

Postoperative care includes three days of stall rest and then a rehabilitation/controlled exercise schedule that progresses to ridden work six weeks after surgery (Figure 1). The author believes rehabilitation is as important as the surgical procedure.

To date the author has performed 32 surgeries on 23 horses. Clinical signs include refusal to go forward, behavioral changes (bucking, rearing, bolting), intermittent forelimb lameness, multiple limb lameness, and inability to raise the head. Complications have included 2 horses that intra-operative bleeding required early cessation of surgery (they were successfully operated one week later), one fatality that was found to have histopathologic evidence of cerebral hypoperfusion injury, one horse that had hindlimb ataxia that resolved in 2 hours, and one horse with minor forelimb neuropathy (resolved in 2 weeks) and hindlimb ataxia (resolved in 4 weeks) and subsequently developed supraspinatus and infraspinatus atrophy, and one horse that had worsened ataxia in the hindlimbs that resolved in 6 weeks post-operatively. Currently 17/23 horses are back in ridden work. Surgical sites included twenty-two C6-7, seven C5-6, and two C2-3. Dr. Swagemakers has performed 256 procedures on 170 patients, with 72.2% back in ridden work and over 80% having significant improvement, with half of those back to pre-performance levels or better. (personal communication Jan-Hein Swagemakers). The author is in the process of gathering information via anonymous surveys on owners' opinions of outcomes. Based on initial feedback from referring veterinarians and trainers, the outcomes have been similar to those in Germany.

There are still many questions about the procedure and information to be learned. It is currently unknown if the IFS will return and, if it does, how long post-procedure. Identifying clinically affected horses remains a challenge. Many patients have multiple areas of pathology and varying clinical signs, which often don't correlate with the imaging findings. Preliminary results have been very encouraging, and the author strongly believes these horses have reduced signs of clinical pain often several days postoperatively. Seven institutions across the country offer the procedure, with several more in the process of acquiring equipment. More information should be available for case selection, prognosis, and long-term outcomes as more surgeries are performed.

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