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Atlanto-axial approach for cervical myelography in a Thoroughbred horse with complete fusion of the atlanto-occipital bones

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Abstract — A 2-year-old Thoroughbred gelding with clinical signs localized to the first 6 spinal cord segments (C1 to C6) had complete fusion of the atlanto-occipital bones which precluded performing a routine myelogram. An ultrasound-assisted myelogram at the intervertebral space between the atlas and axis was successfully done and identified a marked extradural compressive myelopathy at the level of the atlas and axis, and axis and third cervical vertebrae.

Résumé — Approche atlanto-axiale pour une myélographie cervicale chez un cheval Thoroughbred avec la fusion complète des os occipito-atloïdiens. Un hongre Thoroughbred âgé de 2 ans avec des signes cliniques localisés aux 6 premiers segments de la colonne vertébrale (C1 à C6) avait une fusion complète des os occipito-atloïdiens qui empêchait la réalisation d'un myélogramme de routine. Un myélogramme par échographie à l'espace intervertébral entre l'atlas et l'axis a été réalisé avec succès et a identifié une myélopathie extradurale compressive prononcée au niveau de l'atlas et de l'axis ainsi que de l'axis et de la troisième vertèbre cervicale.

(Traduit par Isabelle Vallières)

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Myelography is a commonly used diagnostic procedure in horses with clinical signs of spinal cord disease (1–4). The technique has been thoroughly described in the literature and is routinely done through the atlanto-occipital subarachnoid space on dorsal midline under general anesthesia (2,3). Positive contrast myelography through this space has been used for the evaluation of cervical vertebral canal stenosis and identification of sites of compression if present (2). The first report of standing myelography in the horse was done by Foley in 1986 (5). However, due to major complications such as seizures and loss of consciousness in 4 of 6 horses, standing myelography was not established as a routine diagnostic procedure in the clinical setting (5). Type of contrast medium (metrizamide, a nonionic contrast medium no longer used) and volume (85 to 100 mL per adult horse) were thought to be associated with the observed complications (5). A more recent report of standing myelography done under sedation using a different contrast medium (iohexol) at the lumbosacral space was considered diagnostic in 5 of 8 horses (6). Ultrasound-guided myelography at the atlanto-occipital space has also been described (7). More recently, successful collection of spinal fluid from the subarachnoid space between the atlas and axis was reported through an ultrasound-guided technique in 11 standing horses under sedation (8). An atlanto-axial approach for cervical myelography has not been previously reported. This report describes a horse with complete fusion of the atlanto-occipital bones which precluded performing a routine myelogram for the evaluation of spinal cord disease localized to the first through sixth cervical spinal cord segments. Therefore, a different diagnostic approach was needed for a full imaging evaluation.

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Case description

A 468-kg 2-year-old Thoroughbred gelding was presented for a chronic non-progressive 4-limb gait abnormality. The gelding was reported to have had a normal birth and growth. A traumatic event at few months of age was suspected based on the observation of generalized stiffness, reluctance to move, and swelling of the cranial cervical region at that time. These reported observations lasted several days and the colt appeared to recover. The horse was castrated under intravenous anesthesia as a yearling and was reported to have had an uneventful recovery. According to the attending veterinarian at the time, the gelding's physical examination was normal with no apparent gait deficits.

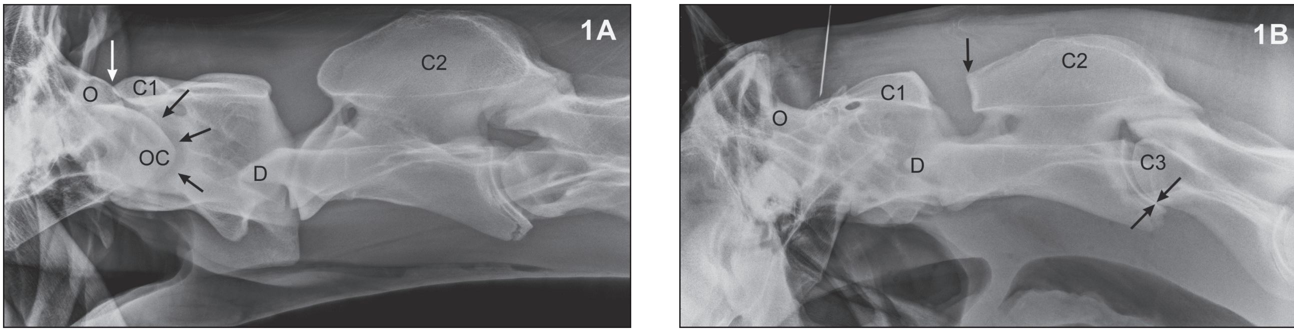


Figure 1. Survey radiographs of occipital condyles and atlas. Normal horse, lateral view; note the normal atlanto-occipital articulation delineated by black arrows, occipital bone (O), occipital condyle (OC), arch of atlas (C1), spinous process of axis (C2), and dens (D) (1A). Current case; note no obvious atlanto-occipital articulation, unidentifiable occipital condyles, blunted cranial aspect of the spinous process of the axis (single black arrow), and dorsal deviation of the third cervical vertebra (C3) with collapse of the intervertebral disc ventrally (double black arrows) (1B). The spinal needle is pointing to the area of the attempted atlanto-occipital cisternal centesis.

The horse started training a few months later and the owner noted an abnormal unsteady gait that consisted of a wide stance, tripping, and knuckling of all limbs. The horse was rested in a stall and taken for walks. Attempts to re-initiate training failed due to the persistence of the abnormal gait. The owner reported no progression over the next few months prior to presentation, and improvement was noted when rested.

On presentation, the gelding was bright, alert, and responsive. There was mild generalized diffuse muscle atrophy, with marked bilateral, but asymmetrical muscle atrophy of his cranial cervical region, more pronounced on the left side than the right. Palpation of the cranial cervical vertebrae and musculature caused resentment with the horse evading the examiner. The horse appeared reluctant or unable to flex and extend his neck, and was observed to advance the right thoracic limb in abduction to eat and drink on the ground. An abnormally prominent external occipital protuberance and reduced distance between the occipital bone and atlas were also palpated. There was normal mentation and behavior and normal cranial nerve function. Limited evaluation of segmental reflexes (cervicofacial, cutanous trunci, perianal/anal, flexor) was normal, but proprioception was markedly reduced in all limbs. The horse's gait consisted of proprioceptive ataxia of all limbs and tetraparesis, more pronounced on the left side and slightly worse in the pelvic limbs compared to the thoracic limbs.

From a published grading scale for ataxia and paresis (9), this horse was graded 2+ of 5 deficits. The neuroanatomical localization was first to sixth cervical spinal cord segments, worse on the left side. Possible causes included cervical vertebral trauma with resultant myelopathy; congenital osseous (occipital, cervical vertebrae), or spinal cord malformation with resultant myelopathy; cervical vertebral compressive myelopathy with any of its variants; and intervertebral disc disease. Other degenerative diseases such as neuroaxonal dystrophy/equine degenerative myelopathy were less likely due to the presence of apparent cervical pain, asymmetric signs and muscle atrophy (10). Equine protozoal myelitis was also considered and immunofluorescent antibody test was negative for antibodies against *Sarcocystis neurona* and *Neospora hughesi.*

Due to the apparent abnormal anatomy of the occiput and cranial cervical vertebrae identified on physical examination, and the anticipation of difficulties for full imaging evaluation and collection of cerebrospinal fluid; the decision was made to anesthetize the colt. Survey radiographs under general anesthesia showed an abnormal atlanto-occipital articulation (Figure 1). The occipital condyles appeared to be fused with the cranial aspect of the atlas which was moderately irregular immediately cranial to the dens. The dens had a blunted shape. The caudodorsal margin of the atlas and craniodorsal margin of the spinous process of the axis were blunted and misshapen. The intervertebral disc space between the axis and third cervical vertebrae was wedge shaped with mild dorsal deviation of the cranial aspect of the third vertebral body into the vertebral canal. The intravertebral minimum sagittal ratio was reduced (0.44) at the cranial aspect of the third cervical vertebra, increasing the likelihood of spinal cord compression at that level. The remaining intravertebral minimum sagittal ratios were within reported values for Thoroughbreds (11).

The anatomical landmarks for the collection of cerebrospinal fluid at the atlanto-occipital space were abnormal as previously described. Attempts to collect cerebrospinal fluid failed because the atlanto-occipital space could not be adequately identified. Ultrasound-assisted cerebrospinal fluid centesis was performed at the intervertebral subarachnoid space between the atlas and axis using a parasagittal oblique approach as follows. With the patient in right lateral recumbency, an ultrasound transducer (7.5 MHz microconvex probe) was placed on the left side of the patient at approximately 3 cm lateral from dorsal midline. The caudal aspect of the transverse process of the atlas and cranial aspect of the spinous process of the axis were identified using ultrasound assistance (MegaES FD570A; Biosound ESAOTE, Indianapolis, Indiana, USA). An angle of 60° from a horizontal plane allowed visualization of the intervertebral subarachnoid space between the atlas and axis (Figure 2). The depth and width of the subarachnoid space; and depth of the spinal cord were determined using electronic calipers. A 10 cm^2 area was aseptically prepared and an 18G (8.9 cm) needle (Monoject; Tyco Healthcare Group, LP Mansfield, Massachusetts, USA) was inserted following the direction, angle, and depth (7.5 cm) determined by ultrasound. Clear spinal fluid (15 mL) was collected and a test of 5 mL of contrast medium (Iohexol 300 mgI/mL, Omnipaque; Novaplus, Princeton, New Jersey,

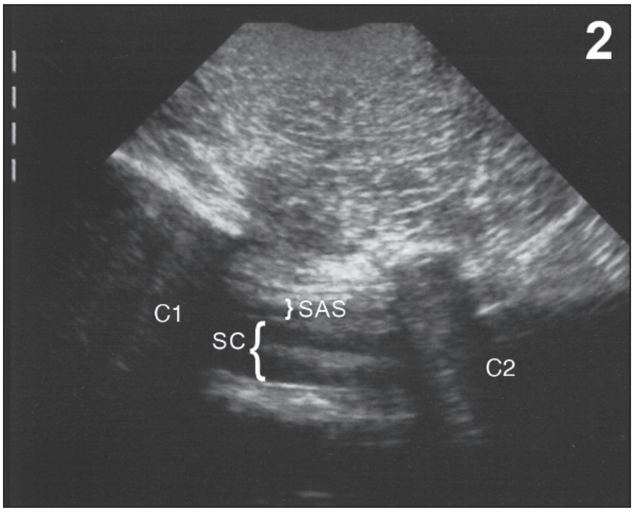


Figure 2. Sonographic anatomy for cerebrospinal fluid centesis between the atlas and axis. Longitudinal ultrasound view of the atlas (C1) and axis (C2) cervical vertebrae. Note subarachnoid space (SAS) depicted by white small key symbol, spinal cord (SC) indicated by white large key symbol; needle placement not shown.

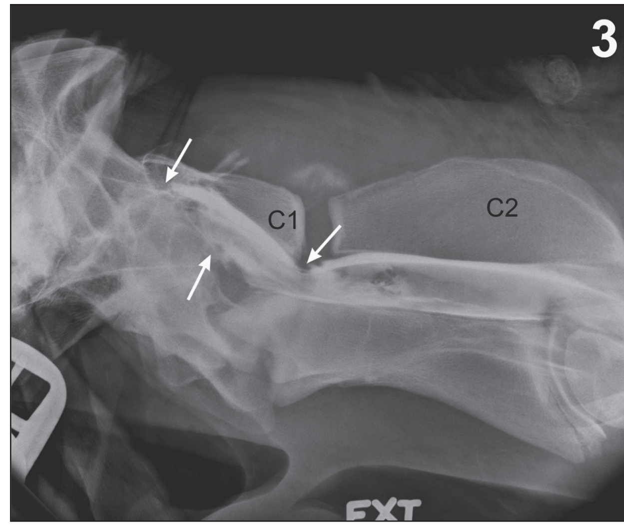


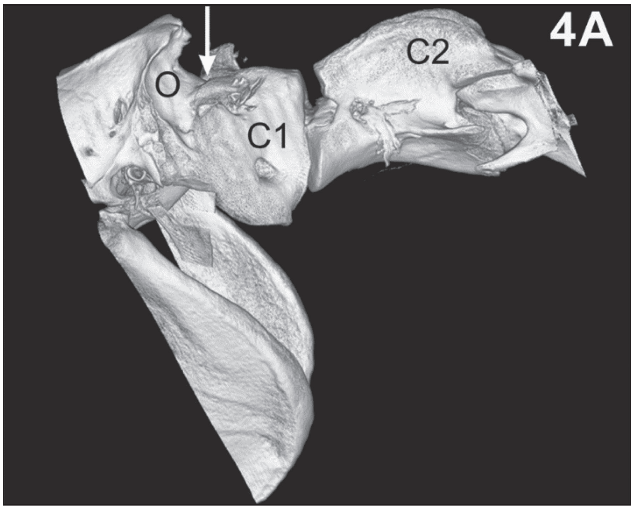
Figure 3. Myelogram showing subarachnoid contrast distribution. Myelogram in lateral position with limited extension of the neck. Note abrupt interruption of contrast columns at the level of the atlas vertebral body (dorsal and ventral shown by first 2 white arrows on the left), and marked attenuation of the dorsal contrast column at the level of the atlas and axis [third white arrow (right of image)].

USA) was infused. There was initial filling of the epidural space as seen radiographically, and the needle was repositioned in the subarachnoid space after which a total dose of 0.1 mL/kg body weight (BW) of contrast medium was infused over 5 min. The head was immediately elevated and lowered in attempts to improve flow of the contrast medium. Multiple lateral-lateral radiographs of the cervical vertebral column in the neutral, flexed, and extended positions were obtained. Cerebrospinal fluid analysis showed hemodilution with no cytological abnormalities.

On post-contrast radiographs, the dorsal contrast column appeared to terminate abruptly at the level of the atlanto-occipital articulation (Figure 3). There was attenuation of the dorsal contrast column at the level of the cranial aspect of the spinous process of the axis with compression of the spinal cord on the extended view. The radiographic features included fusion of the atlanto-occipital articulation, abnormal shape of spinous process of the axis, malalignment of the third cervical vertebral body, and dorsal extradural compression of the spinal cord at the first and second cervical intervertebral space. Extradural spinal cord compression in this myelogram was defined as 50% reduction of the dorsal myelographic column at the level of intervertebral disc space compared to that of the midbody of the cranial vertebra, 20% reduction in the total dural diameter at the same level, and height reduction of the dorsal myelographic column to < 2 mm (12,13).

A computed tomography (CT) myelogram scan was performed immediately following the conventional myelogram. Computed tomographic images were acquired with a high-speed helical CT scanner (GE 9800 CT scanner; General Electric Medical Systems, Milwaukee, Wisconsin, USA). The findings included atlanto-occipital articulation collapse with fusion of the occipital condyles to the atlas. The caudal most aspect of the basioccipital bone was sclerotic, and appeared completely fused with the atlas (see three-dimensional reformatted CT image, Figure 4A). The right ventrolateral aspect of the atlas was irregular with ill-defined cortical bone and sclerosis of the trabecular bone adjacent to the vertebral canal. Contrast medium highlighted the pronounced dorsal extradural compression of the spinal cord by the dorsal arch of the atlas. At this location, the dorsal subarachnoid contrast column was markedly attenuated and the spinal cord was deviated ventrally. At the level of the atlas and axis, the dorsal contrast column was reduced by $\geq 75\%$, and the total dural diameter was reduced by 38%. The dorsal contrast column was reduced by 3 mm total at that level. There was $> 50\%$ attenuation of the dorsal contrast column at the level of the axis and third cervical vertebra. This marked attenuation was not evident on the conventional myelogram. Additionally, there was attenuation of the contrast column laterally on a transverse view at that level on CT (Figure 4B). There was mild dorsal angulation of the third cervical vertebra and narrowing and wedging of the axis and third cervical intervertebral disc space. The findings were consistent with complete fusion of the atlanto-occipital bones and malalignment of the occipitoatlantoaxial bones with resultant dorsal extradural compressive myelopathy at the level of the atlas and axis and axis and third intervertebral spaces.

Due to poor prognosis for athletic performance, apparent cervical pain, severity of spinal cord compression, and safety concerns, the horse was euthanized. A postmortem evaluation confirmed the imaging findings of the absence of space at the atlanto-occipital area due to fusion of these bones and severe extradural compressive myelopathy resulting in degeneration of the white matter tracts within ascending, descending, superficial, and deep funiculi of the first to fourth cervical spinal cord segments bilaterally but more severe on the left side.



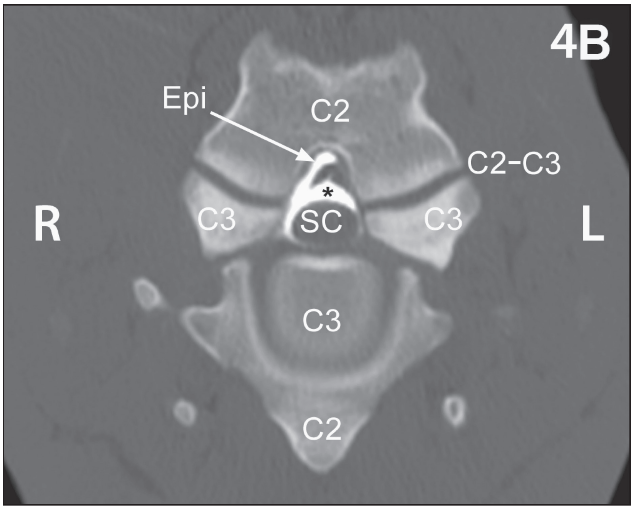


Figure 4. Computed tomographic (CT) myelogram. Three-dimensional reformatted CT image of the axial-atlanto-occipital region. Note the absence of atlanto-occipital space (white arrow). O = occipital bone, C1 = atlas, C2 = axis (4A). Transverse CT myelogram at the level of the axis and third cervical vertebra showing lateral impingement of the spinal cord (note attenuation of contrast column on left side) (4B). Note the maintenance of the contrast column dorsally at this level. Dorsal is top, ventral is bottom, right (R) and left (L) sides are shown. C2 = axis, C3 = third cervical vertebra, C2-C3 = C2-C3 articulation, Epi = epidural space, SC = spinal cord, * = subarachnoid space highlighted by contrast material.

Discussion

Myelography performed at the atlanto-axial intervertebral space region is a diagnostic alternative for the evaluation of abnormalities in horses in which a routine cerebellomedullary cistern puncture is not possible, as demonstrated in this patient. The technique should be safe provided there is identification of anatomical landmarks to avoid puncture of the spinal cord, nerve roots, and arterial supply. Myelography at the level of the atlanto-axial intervertebral space can be done ultrasound-assisted (ultrasound used to identify landmarks) or ultrasound-guided (needle placement directly visualized with ultrasound). Ultrasound-assisted myelography can determine landmarks and depth of needle placement as in this horse, in which collection of cerebrospinal fluid was successful. More precise needle placement can be visualized if the procedure is performed ultrasound-guided rather than assisted, and would have avoided infiltration of the epidural space at the start of the myelogram in this horse. It is possible that the needle was slightly displaced during the initial infusion of the contrast material. Upon repositioning of the spinal needle, contrast material was successfully infused and a diagnostic myelogram was obtained. Based on this, the authors recommend an ultrasound-guided approach.

This case highlights the advantages of CT myelography since all the sites and severity of extradural compression in this horse were not fully visualized initially on conventional myelogram. This could explain, at least in part, the discrepancy between conventional myelographic and histological findings in some cases. However, this additional information did not alter the outcome in this horse, since marked radiographic alterations were seen on a conventional myelogram. A conventional lateral myelogram has some limitations of not being able to evaluate lateral spinal cord compression due to articulation malformation, osteoarthritis, synovial cysts, or lateral to lateral canal stenosis (14–16). Furthermore, three-dimensional reconstruction of images on CT provides complete visualization of all structures under study from different angles. Also, the amount of contrast material required for CT myelography is less than that required for conventional myelography. The main limitation of CT myelography is the evaluation of the entire cervical vertebral column, which might not be possible due to the size and anatomy of the horse and size of the CT gantry, only allowing the evaluation of the most cranial cervical vertebrae as it was in this case.

This case highlights the importance of considering other causes of cervical myelopathy in young horses, in addition to cervical vertebral compressive or stenotic myelopathy (11). Common farm practices of placing mares and foals in large pastures until the weaning period, followed by placement of weanlings in pastures until the onset of training, could have precluded detailed observation of gait deficits in this horse, either prior to or as the result of the suspected traumatic event. A congenital anomaly was also considered in this horse since malformations of the atlanto-occipital bones have been described in horses (17). Reports of congenital malformations of the cervical vertebral column in horses include occipitoatlantoaxial malformation(17–21), occipitoatlantoaxial malformation with duplication of the atlas and axis (22), atlantoaxial malformation with fusion (23,24), and spina bifida at the fifth and sixth cervical vertebrae (25).

Musculoskeletal injuries are the leading cause of death in racing Thoroughbreds (79%) and Quarter Horses (71%) with the majority consisting of limb injuries (26,27). Vertebral column injuries in racing horses vary from 2% to 10% of all musculoskeletal injuries but reports in pleasure horses or in training or with other physical activities are scarce, and the prevalence is unknown (26–31). Fractures have been reported to occur in all 7 cervical vertebrae (32,33). Based on sporadic case reports of cervical vertebral fractures and studies on a large number of racing Thoroughbreds and Quarter Horses, it appeared that the axis and third cervical vertebrae were the most commonly injured vertebrae in the cervical region (26–29,34–37). Causes of fractures vary from over flexion or extension to trauma of the cervical region; and the signs might vary from pain, to minimal neurological deficits, to recumbency and death (30,32–35,38). This horse was suspected to have sustained trauma as a colt, but a pre-existing congenital anomaly resulting in neurological deficits and trauma could not be ruled out. The imaging and pathological findings included complete fusion of the atlanto-occipital bones with resultant malalignment of the occipitoatlantoaxial bones. There was marked dorsal extradural compressive myelopathy at the first and second and less severe at the second and third cervical spinal cord segments; both of which were accentuated on dynamic views. Complete fusion of the atlanto-occipital space precluded performing a myelogram at this routine site. This case presented a diagnostic challenge due to its abnormal anatomy. However, an ultrasound-assisted atlanto-axial approach for myelography proved successful and should be considered as an alternative diagnostic technique in horses with abnormal or fused atlanto-occipital bones. The technique should be safe provided there is proper identification of anatomical landmarks.

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