Neurological deficits, neck pain, and neck stiffness are the most common clinical abnormalities related to the equine cervical region and, therefore, the most common reasons to pursue advanced imaging of the neck. It is well established that neurological signs associated with neck disease are almost always caused by compression of the cervical spinal cord subsequent to narrowing of the vertebral canal (cervical vertebral compressive myelopathy [CVC])1-3; however, it appears to be much more difficult to determine the cause and therefore a successful treatment for horses with neck stiffness and pain.4 Although many horses with neck stiffness or pain have osteoarthropathy of 1 or more cervical articular process joints5,6 and treatment of affected joints leads to improvement in clinical signs,7,8 studies have now shown that the presence of articular process joint osteoarthropathy is common and often not associated with clinical signs.9 Less common, but increasingly more recognized, is the occurrence of thoracic limb lameness, falling, and occasionally other gait abnormalities associated with neck disease.5,10,11

Our awareness of the significance of the horse’s neck as it contributes to overall function and comfort, paired with the challenge of diagnosing the

**OBJECTIVE**
To determine reasons for horses to have neck radiographs performed, the incidence of transposition of the ventral lamina of C6 onto C7 (TC67), and the final diagnoses for all horses. Our hypotheses were to find a similar incidence of TC67, as has been previously reported, and an increased incidence of neck pain and dysfunction in horses with TC67.

**ANIMALS**
135 horses.

**METHODS**
Retrospective observational study. Medical records of 135 horses with cervical vertebral column radiographs between 2020 and 2022 were assessed. Patient signalment, reasons for radiographs, radiographic findings, and diagnoses were analyzed. The Shapiro-Wilk test was used for normality determination. Nonparametric tests were used to analyze data.

**RESULTS**
20% of horses were diagnosed with TC67. Significantly more horses with TC67 were warmblood horses (63%); TC67 was found in 28% of warmblood horses. There was no significant difference in signalment or whether horses were in work between the groups, although significantly more horses with TC67 performed in English disciplines (71%). No differences in reasons for examination or final diagnoses of neurologic disease, cervical orthopedic disease, or lameness were present between groups. In horses with neck pain, TC67 was significantly more common (31%) than in horses without (18%).

**CLINICAL RELEVANCE**
Our results indicated that TC67 occurs more in warmblood horses. In the small group of horses with neck pain reported, TC67 was more commonly seen than in those without. Given the complexity of this region and the paucity of studies exploring neck pain and neck biomechanics, we suggest the need for standardized prospective studies.

**Keywords:** malformation, neurology, behavior, equine caudal cervical morphological variation, pain

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precise source of any dysfunction, has led to studies that seek to deepen our understanding of equine neck anatomy and function.

The past few years have seen a surge of reports on the presence of anatomical variations affecting the equine distal cervical vertebral column, providing mixed conclusions as to whether these variations are associated with clinical signs of neck dysfunction. Developmental variations of the vertebral column are described in terms of homeotic variation (variation in the relative number of types of vertebrae with preservation of the total number), meristic variation (variation in total number), homologous variation (variation in size and shape of vertebrae), and developmental variations in ribs, orientation of dorsal spinous processes, and the intertransverse joints. The most discussed morphological variation currently is the homologous variation where the ventral lamina of the transverse process of the sixth cervical vertebra is transposed to the ventral aspect of the transverse process of the seventh cervical vertebra, either uni- or bilaterally, in part because this variation has been found to affect certain breeds at a relatively high frequency. Additionally, the distal neck is an important structural region for neck and forelimb use.

Finally, a subset of performance horses develop undesired behaviors for which sometimes no cause can be found despite thorough veterinary evaluation. Although studies have reported incidence and clinical signs associated with transposition of the ventral lamina of C6 onto C7 (TC67), the aim of this study included reporting the reason for cervical vertebral column radiography and determination of a final diagnosis for the cause of clinical signs, which has not yet been evaluated as far as the authors are aware. Therefore, the objectives of this study were to determine the reasons for horses to have neck radiographs performed, the incidence of TC67, and the final diagnoses for affected horses. Our hypotheses were (1) reasons for neck radiography were the presence of neurologic disease, neck stiffness and pain, and forelimb lameness; (2) we would find a similar incidence of TC67 as has been previously reported; (3) no association would be found between horses with TC67 and the presence of neurologic disease; and (4) we would find an increased incidence of TC67 in horses with neck pain or open/unclear diagnoses.

Methods

This was a retrospective observational study in which data were retrieved from medical records of all horses that had their cervical vertebral column radiographed through the Johnson Family Equine Hospital of Colorado State University between August 1, 2020, and August 31, 2022. All horses for which lateral-lateral cervical vertebral column radiographs were obtained during the study period were included in this study. Horses with an incomplete set of radiographs were excluded from this study. Records were examined for signalment, horse use, presenting complaint, examination findings, and diagnoses. Presenting complaints were condensed to the following: (1) neurologic examination, (2) neck pain, (3) performance or behavioral changes, (4) musculoskeletal lameness, and (5) other. Signs of neurologic disease included the presence of cranial nerve deficits, abnormal mentation, seizures, and ataxia. In-hospital imaging was performed using an overhead generator (Toshiba 1700; GE) with lateral-lateral projections from the caudal occiput to T1 and oblique projections when indicated. Cervical radiographs acquired in the field were obtained with a portable x-ray generator (TR8020 or TR90+; MinXRay). Horses were sedated with 0.2 mg/kg of xylazine, 0.01 mg/kg of detomidine, and 0.01 mg/kg of butorphanol or combinations of these as needed. Radiographic interpretation, including identification of TC67, was performed by American College of Veterinary Radiology board-certified equine radiologists. The presence of TC67 was determined when there was unilateral or bilateral absence of the ventral laminar part of the transverse process of C6 in combination with the presence of a ventral protuberance at the transverse process of C7 (Figure 1). Furthermore, presence or absence of degenerative joint disease of the articular facet joint of C6 and C7 was recorded. Final diagnoses were condensed to the following: (1) CVCM, (2) cervical orthopedic disease, (3) appendicular lameness, (4) neck pain, (5) other neurologic disease, and (6) other (Table 1).

Figure 1—Transposition of ventral lamina of C6 onto C7. Examples are shown of a normal distal cervical vertebral column with ventral lamina present on C6 (A) and a morphological variation whereby the ventral lamina are bilaterally and completely absent from C6 and instead found on C7 (B). Arrows are directed at the ventral lamina in panel A and at the absence thereof in panel B. Arrowheads in panel B are directed at the lamina on C7.

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Four groups of horses were identified for further analysis: those that showed signs of neurologic disease and were diagnosed with TC67 (N+T+), those that showed signs of neurologic disease without TC67 (N+T–), those that did not show signs of neurologic disease and were diagnosed with TC67 (N–T+), and those that did not show signs of neurologic disease without TC67 (N–T–). For most of the analysis, N+T+ and N–T+ groups were merged (TC67) and N+T– and N–T– groups were merged (no transposition).

Statistical analysis
Data analysis was performed in Prism, version 10.1.1 (GraphPad). The Shapiro-Wilk test was used for normality determination. Nonparametric tests were used for further data evaluation. Kruskal-Wallis and Mann-Whitney tests were used to analyze differences in age across the groups. Chi-squared tests were used to analyze breed, gender, use, presenting reasons, and diagnoses. The chi-squared test was also used to analyze the group of horses with neck pain. A value of \( P < .05 \) was considered significant.

Results
During the study period, cervical vertebral column radiographs were obtained in a total of 135 equids; all were included in this study. Transposition of the ventral lamina of C6 onto C7 was identified in 27 horses (20%; Figure 2). Signs of neurologic disease were seen in equal numbers of horses with and without TC67 (12 of the 27 [44%] horses with TC67) and 47 of the 108 (44%) horses without TC67, respectively. Demographic data are shown in Table 2. Age was not significantly different between the 4 groups (median N+T+ age, 11 years [range, 3.5 months to 25 years]; median N+T– age, 7 years [range, 5 weeks to 22 years]; median N–T+ age, 6 years [range, 3 to 19 years]; median N–T– age, 10 years [range, 3.5 months to 18 years]) or between horses with and without TC67. Warmblood

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**Table 1**—Examples of clinical signs reported in the groups of horses. Note that for some cases, multiple reasons for veterinary evaluation were provided.

<table>
<thead>
<tr>
<th>CVCM</th>
<th>Symmetric ataxia affecting 4 limbs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vertebral narrowing shown radiographically</td>
</tr>
<tr>
<td></td>
<td>Spinal cord compression shown by myelography</td>
</tr>
</tbody>
</table>

**Cervical orthopedic disease**

Radiographic diagnoses
- Osteophytosis, osteochondrosis, osteoarthropathy, or degenerative joint disease affecting articular process joints or other areas of cervical vertebral bodies
- Cervical vertebral body fracture

**Lameness**

Regular gait irregularity not caused by neurologic disease
Confirmed musculoskeletal disease

**Pain**

Restricted movement of neck
Undesired behaviors with neck manipulation
Restriction or pain elicited by musculoskeletal palpation, myofascial examination, or acupressure examination

**Other neurologic disease (CVCM excluded)**

Ataxia, paresis, dysmetria not caused by musculoskeletal or muscle disease
Examples: equine degenerative myelonecephalopathy, equine protozoal myelonecephalitis, intracranial abscess, polynuropathy, botulism, brachial plexus disease

**Other**

Examples: vitamin E–responsive myopathy, lumbar spine osteoarthropathy, sacroiliac disease, impingement of thoracic or lumbar vertebral dorsal spinous processes
Open diagnoses

CVCM = Cervical vertebral compressive myelopathy.

Figure 2—Final diagnoses shown for horses with and without TC67. No significant difference was found between groups. Cervical ortho = Cervical orthopedic disease. CVCM = Cervical vertebral compressive myelopathy. Other neuro = Other neurologic diseases. TC67 = Transposition of the ventral lamina of C6 onto C7.
horses were overrepresented among horses with TC67 (P < .01). More specifically, warmblood horses were overrepresented in the N–T+ group, of which 11 (73%) were warmblood horses, 3 (20%) were a Quarter Horse and American Paint Horses, and 1 (7%) was another breed. There was no significant difference between gender in any of the groups. As expected with seeing more warmblood horses with TC67, significantly more horses with TC67 participated in English disciplines (P < .005). Specifically, the number of horses participating in English disciplines was significantly higher in the N+T+ (n = 6 [67%]) and N–T+ (11 [74%]) groups (P < .005). For both the N+T+ and N–T+ groups, significantly more horses were reported to not be in work (P < .05).

Table 3 shows that most horses that underwent cervical radiography were presented for a neurologi- cal or lameness examination. One horse that was presented for prepurchase examination (included in oth- er) had TC67. More horses in which TC67 was found were presented for neurologic and poor performance evaluations when compared to the group in which no TC67 was found, but this was not statistically significant. Although fewer horses were presented for evaluation of neck pain in the TC67 group, in this group

Table 2—Demographic data, the presence of neurologic signs, and intended use for 135 horses with and without TC67 (transposition of the ventral lamina of C6 onto C7) that had cervical vertebral column radiographs acquired.

<table>
<thead>
<tr>
<th>TC67</th>
<th>No transposition</th>
<th>All cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>N (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td>Neurologic signs</td>
<td>12 (44)</td>
<td>47 (44)</td>
</tr>
<tr>
<td>Breed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warmblood</td>
<td>17 (63*)</td>
<td>43 (40)</td>
</tr>
<tr>
<td>Quarter Horse/Paint</td>
<td>6 (22)</td>
<td>32 (30)</td>
</tr>
<tr>
<td>Thoroughbred</td>
<td>1 (4)</td>
<td>12 (11)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (11)</td>
<td>21 (19)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mare</td>
<td>9 (33)</td>
<td>37 (34)</td>
</tr>
<tr>
<td>Gelding</td>
<td>18 (67)</td>
<td>66 (61)</td>
</tr>
<tr>
<td>Stallion/colt</td>
<td>0 (0)</td>
<td>5 (5)</td>
</tr>
<tr>
<td>Occupation/intended use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In work/performance</td>
<td>24 (89)</td>
<td>89 (82)</td>
</tr>
<tr>
<td>English discipline</td>
<td>17 (71*)</td>
<td>42 (47)</td>
</tr>
<tr>
<td>Western discipline</td>
<td>3 (12)</td>
<td>18 (20)</td>
</tr>
<tr>
<td>Discipline not listed</td>
<td>4 (17)</td>
<td>29 (33)</td>
</tr>
<tr>
<td>Not in work</td>
<td>2 (7)</td>
<td>11 (10)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1 (4)</td>
<td>8 (8)</td>
</tr>
<tr>
<td>Total</td>
<td>27 (20)</td>
<td>108 (80)</td>
</tr>
</tbody>
</table>

Median age of horses with TC67 was 11 years (range, 4 months to 25 years); median age of horses without TC67 was 7 years (range, 5 weeks to 22 years); median age of all horses was 9 years (range, 5 weeks to 25 years).

*P < .01.

Table 3—Reasons for veterinary evaluation and cervical radiography. Note that for some cases, multiple reasons for veterinary evaluation were provided.

<table>
<thead>
<tr>
<th>TC67 (n = 27)</th>
<th>No transposition (n = 108)</th>
<th>All cases (n = 135)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>N (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td>Neurological examination</td>
<td>15 (56)</td>
<td>44 (41)</td>
</tr>
<tr>
<td>Neck pain</td>
<td>2 (7)</td>
<td>12 (11)</td>
</tr>
<tr>
<td>Performance/behavior change</td>
<td>6 (22)</td>
<td>19 (18)</td>
</tr>
<tr>
<td>Musculoskeletal lameness</td>
<td>9 (33)</td>
<td>40 (37)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (4)</td>
<td>11 (10)</td>
</tr>
</tbody>
</table>

![Figure 3](image-url) — Incidence of TC67 in horses with and without neck pain. TC67 was found in significantly more horses with neck pain than in those without. *P < .01.
close to twice as many horses (19%) were ultimately diagnosed with neck pain when compared to the group without TC67 (10%); however, this did not reach statistical significance ($P = .68$). When only looking at the group of horses that were diagnosed with neck pain, 5 (31%) were found to have TC67 and 11 (69%) did not (Figure 3). Although the number of horses is small in these groups, this finding was significantly different from the horses for which neck pain was not reported, in which TC67 occurred in 22 (18%) and did not occur in 97 (82%; $P < .001$). Most horses were ultimately diagnosed with cervical orthopedic disease (36%) and lameness (36%; Table 4; Figure 2).

Table 4—Final diagnoses shown for horses with and without TC67.

<table>
<thead>
<tr>
<th></th>
<th>TC67 (n = 27)</th>
<th>No transposition (n = 108)</th>
<th>All cases (n = 135)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>N (%)</td>
<td>N (%)</td>
</tr>
<tr>
<td>CVCM</td>
<td>5 (19)</td>
<td>18 (17)</td>
<td>23 (17)</td>
</tr>
<tr>
<td>Cervical orthopedic</td>
<td>12 (44)</td>
<td>37 (34)</td>
<td>49 (36)</td>
</tr>
<tr>
<td>Lameness</td>
<td>11 (41)</td>
<td>37 (34)</td>
<td>48 (36)</td>
</tr>
<tr>
<td>Neck pain</td>
<td>5 (19)</td>
<td>11 (10)</td>
<td>16 (12)</td>
</tr>
<tr>
<td>Other neurologic</td>
<td>4 (15)</td>
<td>20 (19)</td>
<td>24 (18)</td>
</tr>
<tr>
<td>Other</td>
<td>9 (33)</td>
<td>32 (30)</td>
<td>41 (30)</td>
</tr>
</tbody>
</table>

Table 4—Final diagnoses shown for horses with and without TC67.

Note that some horses were diagnosed with multiple conditions. Table 1 shows criteria and examples of clinical signs and diagnoses for each category.

Discussion

We found no significant difference in the occurrence of neurologic disease, lameness, or cervical orthopedic issues when comparing horses with and without the morphological variation TC67. However, when we looked at the group of horses with recorded neck pain, we observed that almost twice as many horses had TC67 compared to those without neck pain. Further, we identified TC67 in 20% of the horses that had their neck radiographed, and most horses with TC67 were warmblood horses (63%). Of the warmblood horses radiographed in this study, TC67 was found in 28%. Our results on incidence of TC67 are similar to what has been shown in other studies from the US and Italy, with TC67 being found in 13% to 24% of horses.18–20 Also similar are the findings that most horses with TC67 in these populations are from the warmblood breed (62%,19 63%,20 78%18) and that TC67 is found in 15% to 35%18–20 of warmblood horses. Two Dutch studies14,21 showed TC67 to occur in 29% to 35% of warmblood horses, and 1 other Dutch study13 showed TC67 in 43% of warmbloods, which was notably more than in 2 other breeds (Shetlanders [6%] and Konik horses [0%]). That study13 used CT for evaluation of vertebral columns, which was also the case for one of the studies by Veraa et al13 that found TC67 in 35% of mature warmblood horses. It is likely that CT allowed for fewer false negative diagnoses of TC67 when compared to the other studies that were based on radiography.

Our study shows that in the group of horses with TC67, neck pain was more common, but not significantly so, than in the group of horses without TC67 (19% vs 10%). Moreover, neck pain as a reason to seek veterinary evaluation was reported by clients for only 2 of 27 horses with TC67. When evaluating only the subset of horses that were diagnosed with neck pain (n = 16), a significantly higher number of horses had TC67. One previous study18 did show that pain was more frequently present in horses with TC67. We do not find an association between the presence of neurologic disease, CVCM, lameness, cervical orthopedic disease, or behavior or performance concerns and the presence of TC67, which is consistent with the study by Veraa et al13 that found no association between clinical signs of disease and the presence of TC67 after evaluation of 377 horses, of which 108 had TC67. Moreover, that study showed TC67 occurred more frequently in the group of horses that were undergoing a prepurchase examination. Our study did not use a group of horses that were “normal,” as all the horses in our study were presented for veterinary evaluation, and only 1 was presented for prepurchase examination. Importantly, however, limitations of our study include the small number of horses for which neck pain was listed as a diagnosis and the retrospective nature of the study whereby neck pain may have been missed as a specific (secondary) diagnosis. Comparing individual studies that assess for neck pain is difficult in part because identification of neck pain remains a subjective assessment for which standardization in equine veterinary medicine is lacking.

Neck pain is often a component of cervical region dysfunction, signs of which include regional or generalized muscle asymmetry, stiffness or inability to move the neck through a normal range of motion, altered head or neck carriage, and thoracic limb gait abnormalities.4,22 Most clinicians assess for neck pain through a combination of palpation and asking a horse to bend their neck laterally, dorsally, and ventrally by either using baits (carrots, treats) or not, and while these assessments are a good place to start, it is important to complement this evaluation with other techniques to be more complete.4 A thorough assessment should include careful observation of the horse's stance, neck posture, facial expressions, muscle symmetry, and sweat patterns and how the horse interacts with its surroundings and humans. Systematic and detailed palpation of the soft tissues (skin, muscle, fascia) and bony landmarks within the cervical region is a critical step in
identifying and localizing potential sources of neck pain and dysfunction. Finally, a dynamic spinal examination should take place that consists of both passive and active spinal movements. Passive spinal movements are applied to assess joint and soft tissue movement without muscle activation, whereas active spinal movements consist of the patient initiating the motion, which requires muscle activation. Treatments may be used to encourage neck movement for active mobilization; however, consideration needs to be taken for food-motivated horses that will work through pain to obtain what they want. Standardization and scoring of these examinations are needed to allow for evaluations of horses over time and comparison of data in these types of studies.

In humans, a thoracic outlet syndrome (TOS) is described whereby compression of the neurovascular bundle that exits the thoracic outlet results in clinical signs of neck, shoulder, or upper limb pain associated with distal paresthesia or weakness (neurogenic form), upper extremity swelling, venous engorgement, cyanosis, feelings of arm heaviness, and pain (venous form) or pain and weakening of the radial pulse, pallor, weakness, and fatigue (arterial form). Nearly 70% of TOS cases are related to soft tissue etiologies, including muscle variations and hypertrophy, and 30% are related to bone abnormalities such as cervical ribs or joint injury with resulting malunion. The most common cause of TOS is neck trauma; other populations with increased risk of TOS include athletes who frequently perform overhead movements, patients with tumors or cysts surrounding the thoracic outlet, and those born with anatomic variations such as cervical or anomalous first ribs. It should be noted, however, that while cervical ribs are commonly found in the arterial form of TOS cases, they are rare and typically asymptomatic in the general population. A low shoulder girdle positioning and hypermobility of the shoulder joint have also been found to increase the risk of TOS in people. Human anatomy and function of this region are very different from the equine system, given the presence of a clavicle bone and lack of weight support of the thoracic limbs in people; however, the TOS does underscore the complexity of the anatomy and biomechanical properties of the cervicothoracic junction. In TC67, the caudal ventral tubercle of C6 is unilaterally or bilaterally altered, absent, or transposed onto the ventral surface of C7. Both the cranial and caudal ventral tubercles of C6 provide attachments for the deep perivertebral longus colli muscle, and the caudal ventral tubercle is the insertion point for the thoracic tendon of the longus colli muscle that extends caudally to either T5 or T6. This muscle aids in fixation, stabilization, rotation, and flexion of the cervical vertebrae. Conceivably, in horses with TC67, the insertion of the longus colli muscle occurs on C7; however, specific data on this are lacking. Regardless, it is possible that morphological variations that occur in the caudal neck of horses may lead to changes in biomechanical and functional processes.

Limitations in this study include consequences of its retrospective nature, such as the reliance on information provided in the digitized medical record and inconsistencies of data the case summaries provided. Furthermore, most horses presented to our hospital are of the Quarter Horse and warmblood breeds, which could affect our data on breed predilection. Finally, the number of horses included in this study may have been too low to identify associations of certain diagnoses with TC67. In conclusion, we have identified TC67 in 20% of horses, with most cases affecting warmblood breeds. Our data suggested that TC67 is more common in horses with neck pain; however, these results should be interpreted with caution. Our findings added to the literature on clinical signs of neck dysfunction and did not show an association between TC67 and neurologic disease, but did highlight the need for further study of horses with signs of neck pain. Given the complexity of this anatomical region, the number of horses that are diagnosed with nonspecific disorders in this region, and the paucity of studies exploring this area, we suggest the need for standardized prospective studies to identify the causes of and methods to prevent or alleviate neck pain and dysfunction.

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