

PREVALENCE OF ANATOMICAL VARIATION OF THE SIXTH CERVICAL VERTEBRA AND ASSOCIATION WITH VERTEBRAL CANAL STENOSIS AND ARTICULAR PROCESS OSTEOARTHRITIS IN THE HORSE

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The sixth cervical vertebra (C6) has unique morphology due to a ventral extension from the transverse process known as the ventral lamina. Little information was found regarding the prevalence and clinical relevance of morphologic variations. Aims of this observational, retrospective study were to characterize C6 morphologic variations in a large sample of horses. Cervical radiographic studies of 100 horses were retrieved. Data recorded were signalment, clinical history, morphology of the C6 ventral lamina, presence of articular process osteoarthritis, and presence of static vertebral canal stenosis. Morphologic variations were found in C6 vertebrae for 24/100 horses, with symmetric absence of the ventral lamina in nine horses and asymmetric absence in 15. Anomalous C6 vertebrae were more common in Warmbloods, with 19/55 Warmbloods in the population being affected ($P = 0.006$). No association was found with sex. There was no significant difference in the mean of the intravertebral sagittal ratios between horses with normal or anomalous C6 vertebrae; however there was a significantly greater proportion of horses with anomalous C6 vertebrae that had an intravertebral sagittal ratio of less than 0.5 at C6 ($P = 0.047$). There was no association between the morphology of C6 and articular process osteoarthritis. Anomalous C6 vertebrae in our population were associated with a higher likelihood of cervical pain ($P = 0.013$). Authors propose that morphologic variations in the C6 ventral laminae could be linked to other developmental abnormalities such as vertebral canal stenosis, might affect regional biomechanics and should therefore be considered clinically relevant in horses. Future, controlled prospective studies are needed to test this theory.

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Key words: Anatomical variation, cervical osteoarthritis, cervical spine, radiography, vertebral canal stenosis.

Introduction

THE EQUINE CERVICAL VERTEBRAL COLUMN consists of seven vertebrae. The third through fifth cervical vertebrae have similar shape and dimensions, while vertebrae 1, 2, 6, and 7 have unique anatomical features.¹ The sixth cervical vertebra (C6) presents a large ventral expansion of the caudal part of the transverse process, officially named lamina ventralis (ventral lamina),² but also sometimes referred as ventral tubercle or ventral process.^{3,4} Abnormal development or transposition of this structure from the sixth to the seventh vertebra (C7) had been reported.³⁻⁷ Recently, prevalences for anomalies of the C6 ventral lamina of 13.3 and 18.7% were published from Italian and

Australian horse populations, respectively.^{3,4} A predisposition of Thoroughbreds was identified in the Australian population,⁴ whereas the Italian study could not identify a breed predilection but found a higher prevalence in females.³ Functional consequences due to changes in the biomechanics were considered possible⁴ but the clinical significance of anomalous C6 ventral lamina had not been evaluated.

The objectives of this study were to (1) determine the prevalence of anomalies of the ventral lamina of C6 in an American population of equine patients presenting for cervical radiography, (2) determine the association of anomalous C6 ventral lamina with other vertebral morphometric parameters and presence of osteoarthritis, and (3) assess the association of anomalous C6 ventral lamina with clinical signs of cervical myelopathy. Our hypothesis was that anomalous C6 ventral lamina would be associated with abnormalities in morphometric parameters such as vertebral canal stenosis and an increased presence and severity of osteoarthritis with corresponding clinical signs of neurologic dysfunction and/or cervical pain.

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Materials and Methods

The study design was observational and retrospective, including a prevalence study (objective 1) and an analytical cross-sectional study (objectives 2 and 3). The hospital database at the Veterinary Medical Teaching Hospital, University of California Davis, was searched for equine patients subjected to cervical radiography to identify a total of 100 studies from skeletally mature horses (4-year-old and older). Studies that did not permit adequate evaluation of C7 due to technical limitations were excluded. Studies were performed with digital radiography (Eklin EDR-6 detector, Eklin Medical Systems, Inc., Santa Clara, CA, USA), and were archived on a PACS system (Sound-Eklin, Carlsbad, CA, USA). The technique used ranged from 90 to 125 kVp and 10–32 mAs, depending on patient size.

Horses were classified in 2 groups (“normal” or “anomalous”) based on the radiographic morphology of the C6 vertebra. Radiographic assessment was performed independently by all three authors (including a radiology resident, a board-certified veterinary radiologist, and a board-certified veterinary neurologist). A consensus was reached if needed. C6 were considered “normal” if two characteristic ventral laminae were seen arising from the transverse processes (Fig. 1). C6 were classified as “anomalous,” either if they presented asymmetric appearance to the transverse processes, with unilateral absence of a ventral lamina (asymmetric anomaly), or if both ventral laminae were absent (symmetric anomaly) (Fig. 1).

A series of measurements was performed on the radiographic studies at C6 and C7. Vertebral body length and height, height of the vertebral canal, intervertebral disc space width, and dorsoventral height of the articular process joints was performed on both C6 and C7. All measurements were performed either parallel or perpendicular to the ventral aspect of the vertebral canal for repeatability. Measurements were performed by one author (AD) using commercially available DICOM viewing software (Osirix, Geneva, Switzerland). Intravertebral sagittal ratio was calculated by dividing vertebral canal height by vertebral body height.⁸ Normal intravertebral ratio was considered greater than 0.5 at C6 and greater than 0.52 at C7.⁸

Assessment of the presence of osteoarthritis of the articular process joints at C5-C6 and C6-C7 was performed via consensus among the three authors, based on enlargement of the articular process joint by new bone production.⁹

The medical records were reviewed and patient age, gender, breed, and clinical findings were recorded. Based on clinical examination findings, four different clinical presentations were defined: neurologic disease, cervical pain (discomfort upon palpation of the cervical area and/or reduced range of motion or reluctance of cervical flexion), thoracic limb lameness and no clinical signs related to the cervical area.

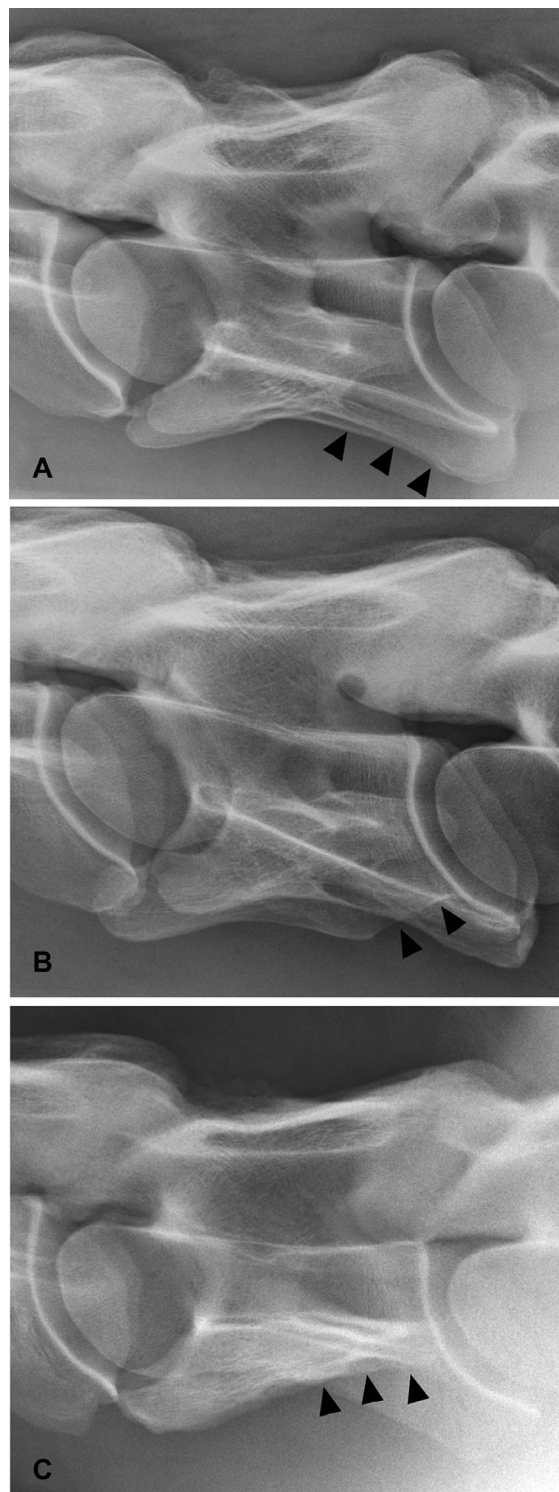


FIG. 1. Left-right lateral standing digital radiographs of the caudal cervical spine illustrating the different conformation of the sixth cervical vertebra (C6). (A) Normal ventral laminae, indicated with arrowheads. (B) Asymmetric absence of the ventral lamina; the arrowheads indicate the truncation of the caudoventral aspect of one of the transverse processes. (C) Symmetric absence of the ventral laminae; the arrowheads show the abnormal caudoventral aspect of both transverse processes.

The mean and standard deviation were calculated for all quantitative data. The Shapiro–Wilk test was used to assess the normal distribution of the quantitative data. The association between breed, sex or clinical signs and the C6 morphology was evaluated using the Chi Square test. Multivariate linear regression analysis was used for assessment of the association between articular process osteoarthritis and C6 morphology, with correction for patient age. The Student's *t* test was used to compare the morphometric measurements between normal and anomalous C6. Association between C6 morphology and a stenotic vertebral canal was assessed using the Chi Square test. All significance was set at $P < 0.05$.

Results

Study Population

All the 100 selected studies were acquired between August 2012 and October 2013. There were 55 Warmbloods, 16 Quarter horses, 12 Thoroughbred, 9 Arabians, and eight other (two Tennessee Walking horses, one Irish draft, one Missouri Fox trotter, one Appaloosa, one Standardbred, and two mixed breed horses). There were 70 geldings, four intact male, and 26 females. The mean age was 10.2-year-old and the standard deviation was 5.3 years. Fifty-one horses presented due to neurological signs, 10 were diagnosed with cervical pain or reduced cervical flexion, 32 had lameness and seven had no underlying clinical signs.

Prevalence of Anomalous C6 (Objective 1)

Twenty-four of 100 (24%) horses were found to have anomalous appearance of the C6 ventral lamina, including 15 with asymmetric anomaly and nine with symmetric anomaly. Nine of the 15 horses with asymmetric anomaly and five of the nine with symmetric anomaly had projections on the transverse processes of C7 resembling C6 ventral lamina.

Association of Anomalous C6 with Signalment and Morphometric Parameters (Objective 2)

The breed distribution and morphometric parameters, in both the 24 horses with an anomalous C6 and the 76 horses with a normal C6, are depicted in Figs. 2 and 3, respectively. In horses with an anomalous C6, the mean age was 9.3 years old (SD, 1.1 years) and there were 15 geldings, eight mares, and one stallion; vertebral canal stenosis was identified in seven (29.4%) and four (16.7%) horses at C6 and C7, respectively. In horses without an anomalous C6, the mean age was 10.5 years old (SD, 0.6 years) and there were 55 geldings, 18 mares, and three stallions. In this group, vertebral canal stenosis was identified in eight (10.6%) and six (7.9%) horses at C6 and C7, respectively. When comparing the two groups, there was a statistically significant associations with breed ($P = 0.006$), C7 vertebral body length ($P = 0.037$), C6-7 intervertebral disk space width ($P = 0.027$), and C6 vertebral canal stenosis ($P = 0.046$), but not for sex ($P = 0.348$), age ($P = 0.361$), C6 length ($P = 0.103$), C6 height ($P = 0.156$), C6 canal ($P = 0.943$), C5-6 intervertebral disk space width ($P = 0.939$), C5-6 joint ($P = 0.414$), C7 height ($P = 0.912$), C7 canal ($P = 0.134$), C6-7 joint ($P = 0.993$), and C7 vertebral canal stenosis ($P = 0.246$).

Association of Anomalous C6 with Osteoarthritis

Osteoarthritis was present at the articular process joints of C5-6 in 6/24 (25%) of horses with anomalous C6 and in 32/76 (42.1%) horses with normal C6. At C6-7, osteoarthritis was observed in 11/24 (45.8%) horses with anomalous C6 and 39/76 (51.3%) horses with normal C6. There was no significant association between the morphology of C6 and the presence of radiographic signs of osteoarthritis of the C5-6 or C6-7 articular process joints using multivariate regression analysis with correction for age ($P = 0.164$ and 0.588 for C5-6 and C6-7, respectively).

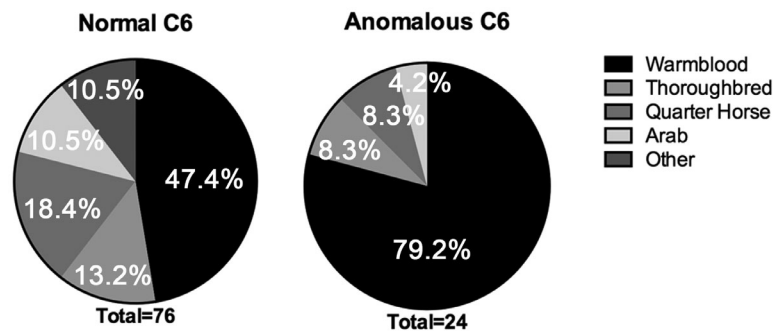


FIG. 2. Pie charts illustrating the breed distribution between horses with normal sixth cervical vertebra and anomalous sixth cervical vertebra. The Warmbloods are overrepresented in the anomalous group ($P = 0.006$).

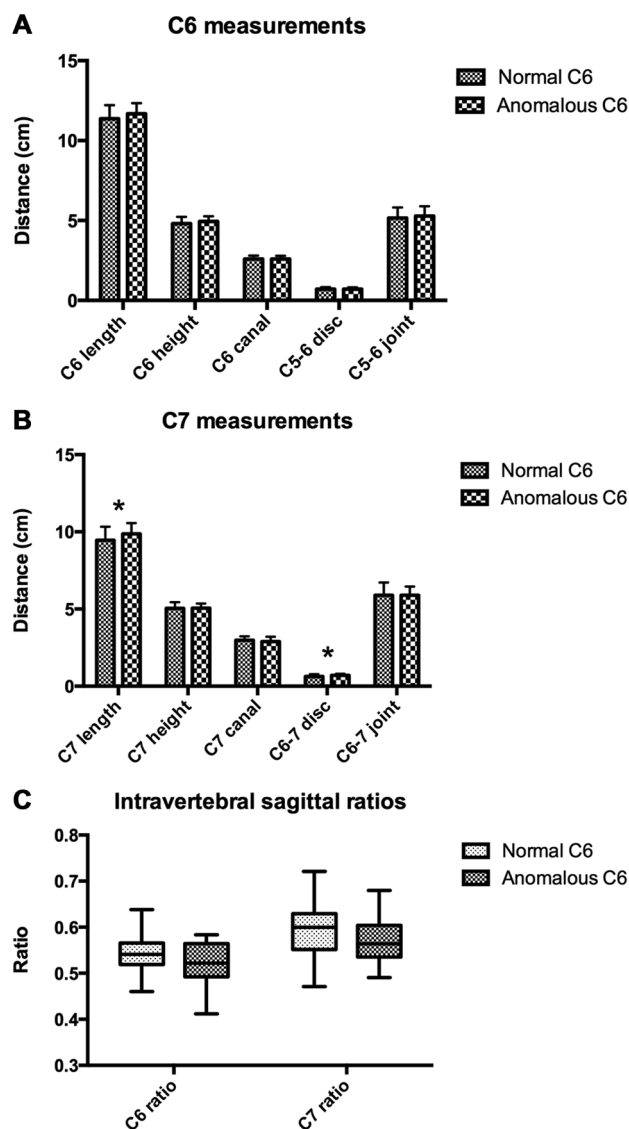


FIG. 3. Morphometric parameters measured on the sixth (C6) and seventh (C7) cervical vertebrae (A and B, respectively). The different parameters include measurement of vertebral body length (length), the widest portion of the vertebral body (height), the narrowest portion of the vertebral canal (canal), intervertebral disc space width (disc), and dorsoventral height of the articular process joints (joint). The parameters with statistically significant difference between normal and anomalous C6 are denoted with an asterisk. Graph C demonstrates the intravertebral sagittal ratios at C6 and C7 in normal and anomalous horses. A nonsignificant trend toward a decreased intravertebral ratio exists in anomalous horses.

Association of Anomalous C6 with Clinical Presentation (Objective 3)

The clinical presentation for both groups of horses is depicted in Fig. 4. There was a significant association between the morphology of C6 and the clinical presentation ($P = 0.013$, Fig. 4). The frequency of pain associated with the anomalous C6 was 2.5 higher than expected (six observed for 2.4 expected, $P < 0.05$) and was the main con-

tributor to the association between the morphology and the clinical signs (Chi-Square contribution of 5.4, total Chi Square 10.4). Cervical pain was present in 4/76 horses with normal C6 versus 6/24 horses with anomalous C6. The frequency of neurologic cases in the anomalous C6 group was lower than expected (seven observed, 12.2 expected) but this was not significant (Chi-Square contribution of 2.2).

Discussion

Anomalous C6, with either asymmetric or symmetric absence of the ventral lamina of the transverse process, were common in our population, present in 24% of horses. This is higher than the 13.3 and 18.7% previously reported.^{3,4} Interestingly, we identified a strong predilection for the Warmblood breeds, as these accounted for almost 80% of horses with anomalous C6. Also 35% of the Warmblood horses included in the study had anomalous C6. Previously, no breed predilections were identified in an Italian population but a strong association with Thoroughbred breed was found in Australia. The Australian study found anomalous C6 in 38% of Thoroughbreds.⁴ Thoroughbreds and Thoroughbred crosses accounted for 95.7% (22 of 23) of the horses with anomalous C6.⁴ This is in contrast to our study, where 2 of 10 Thoroughbreds were classified as having anomalous C6. This probably reflects difference in the composition of the population but the breed association in two different populations might suggest a genetic basis for the anomalous C6.

Another difference between the two studies was the association with sex, as there was no association in the current study compared to increased prevalence in females in the Italian study.³

Our hypothesis that anomalies of the C6 ventral lamina would be associated with morphometric abnormalities of the regional vertebrae was supported by the results of the intravertebral ratios measurements. At C6, there were a greater proportion of horses with anomalous C6 that had an intravertebral sagittal ratio less than 0.5. This suggests that anomalous C6 might be associated with other regional developmental abnormalities including the formation of the vertebral canal. There was no difference between the intravertebral sagittal ratio of Warmblood breeds versus the other breeds making this result unlikely to be secondary to breed bias of the anomaly.

The measured morphometric parameters were similar between horses with normal and those with anomalous C6 except for C7 vertebral body length and C6-7 intervertebral disc space width. Due to the large number of Warmbloods in the horses with anomalous C6, it was speculated that a breed bias might have contributed to this result. In this study, Warmbloods, compared to all other patients, had larger C7 vertebral body length and C6-7 intervertebral disc space width.

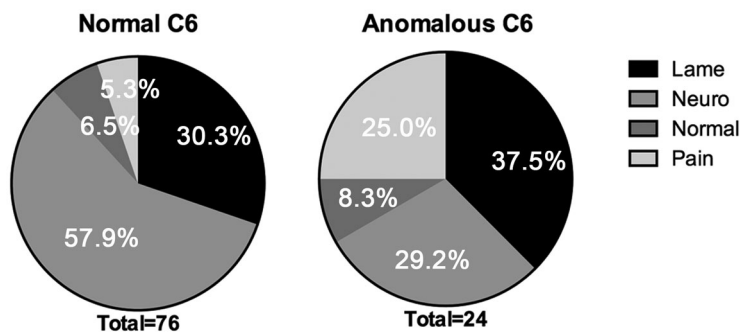


FIG. 4. Pie charts illustrating the clinical signs distribution between horses with normal sixth cervical vertebra and anomalous sixth cervical vertebra. There is a significantly higher proportion of horses presenting for pain in the anomalous group, whereas neurologic horses tend to be more common in the normal group.

The hypothesis that abnormality of the C6 transverse process ventral lamina would lead to articular process osteoarthritis due to altered biomechanics was not supported by these results. The ventral lamina serves as a muscular attachment site for perivertebral musculature including the longus colli that is important in its function as a cervical vertebral column stabilizer.¹⁰ However, radiography was recently shown to differ from necropsy evidence of articular process joint pathology with a sensitivity of 63% and specificity of 67%.¹¹ The decreased sensitivity of radiography might have resulted in false negative diagnoses in horses with anomalous C6 lamina. Also the high prevalence of osteoarthritis in this clinical population might have biased this outcome. A prospective study on horses without clinical signs may be indicated to better assess the association between anomalous C6 and osteoarthritis.

Interestingly, although horses with anomalous C6 were more likely to have an intravertebral sagittal ratio less than 0.5, they were less likely than horses with normal C6 to have neurologic deficits attributable to the cervical region. This highlights the lack of accuracy of the intravertebral sagittal ratio for diagnosis of cervical vertebral stenotic myelopathy.^{12,13} Initially the intravertebral sagittal ratio was reported to have sensitivity and specificity as high as 89% for identification of cervical stenotic myelopathy.⁸ Previous studies have shown decreased utility of survey radiography for diagnosis of spinal cord compression compared to myelography with an accuracy of 50%, a false-positive rate of ~50%, and false-negative rate of ~20% depending on anatomic site.¹⁴ In addition, most of compressive lesions are dynamic, which cannot be evaluated without dynamic radiography and/or myelography. More recently, a sensitivity of 50% and specificity of 70% were reported for intravertebral ratios compared to necropsy findings of compression.¹¹

A positive association between the presence of anomalous C6 lamina and perceived cervical pain or decreased range of motion was identified. These horses may be ex-

periencing dynamic pain or pain from conditions not elucidated by static and plain radiography. We speculate that alteration of the attachment site for regional musculature due to anomalous C6 may lead to altered biomechanical forces resulting in perceived pain or reduced range of motion.

The retrospective nature of the study resulted in several limitations. The most notable limitation occurred with review of the clinical data. A proportion of the patients that underwent cervical radiographic studies did not have complete neurologic examination performed. Cervical radiography is a common diagnostic test at our institution performed by multiple services and for numerous reasons, not all of which are prompted by a clinical complaint of neurologic dysfunction. Examples include a component of the prepurchase exam or for increased uptake of the articular process joints on a scintigraphic exam. Additionally, the neurologic consultations were performed by multiple clinicians, which might have resulted in inconsistent classifications of the patients. Other consideration includes the subjectivity of the neurologic examination especially when evaluating horses with mild neurologic deficits. Both neurologic dysfunction and perceived cervical pain are subjective assessments that vary between individuals.¹⁵ A limitation of the radiographic assessment was the use of the intravertebral ratio, as this measurement has been reported to be unreliable with variation of 5–10%.^{12,13} The main reason for including this parameter in the study was as part of the morphometric study, to refer to parameters commonly used, and not as a diagnostic test. Another limitation of the study was the subjective radiographic identification of articular process osteoarthritis. This was mitigated by using consensus opinion of the three authors.

In conclusion, anomalous C6 vertebrae, with symmetric or asymmetric absence of the ventral lamina, were a relatively common radiographic variation, especially in Warmbloods in our population. The greater proportion of patients with anomalous C6 presenting an intravertebral

sagittal ratio of less than 0.5 at C6 suggested that the lamina anomaly might be associated with other developmental anomaly of C6. The association with increased rates of perceived cervical pain suggested that anomalous C6 should be interpreted as clinically relevant. Authors recommend that

morphologic assessment of C6 be performed when assessing cervical radiographic studies in the horse. A larger scale prospective study including control horses without clinical signs would be needed for more definitive testing of these theories.

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