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Descriptive Clinical Report

Anatomical variation of the spinous and transverse processes in the caudal cervical vertebrae and the first thoracic vertebra in horses

I. SANTINELLI, F. BECCATI*, R. ARCELLI and M. PEPE

Centro di Studi del Cavallo Sportivo, Dipartimento di Medicina Veterinaria, University of Perugia, Perugia, Italy.

*Correspondence email: francescabeccati@hotmail.it; Received: 13.08.14; Accepted: 26.11.14

Summary

Reasons for performing study: There are scant data on the incidence of different anatomical variants of the equine caudal cervical spine, despite interest in cervical pathology.
Objectives: To identify morphological radiographic variation in the 6th and 7th cervical vertebrae and the first thoracic vertebra in horses of different breeds and to determine whether there are breed- and sex-related differences.
Study design: Retrospective descriptive study.
Methods: Radiographs of the cervical spine of 270 horses were assessed retrospectively. The Chi-square test, or Fisher's exact test when appropriate, was used to test for associations between radiographic findings and sex or breed, and residual analysis was performed to localise differences. Chi-square tests and calculation of phi coefficient (φ) were used to test for associations between different types of radiological variation.
Results: Three variants were identified in the spinous process of the 7th cervical vertebra, and 2 variants were identified in the spinous process of the first thoracic vertebra. The presence of the spinous process of the 7th cervical vertebra was associated with breed, and transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra was associated with sex. The shape of the spinous process of first thoracic vertebra was associated with the shape of the spinous process of the 7th cervical vertebra and with the presence of transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th.
Conclusions: A large number of anatomical variants can be detected radiographically in the caudal cervical area; some of these have a higher frequency, depending on sex and breed. Knowledge of the different shapes is very important in avoiding misdiagnosis of periarticular new bone formation. The spinous process of the first thoracic vertebra has 2 morphological variants.

Keywords: horse; cervical radiography; cervical anatomy; cervical spine; cervical vertebra

Introduction

Cervical pathology can be associated with neurological deficits, lameness and/or abnormal behaviour [1]. Advanced diagnostic techniques for diagnosis of disorders of the cervical spine are available [2–9], but radiography remains the diagnostic imaging technique of choice to investigate the cervical vertebrae [10–14]. Radiological interpretation of the equine cervical spine is difficult because of the complex anatomy and numerous anatomical variants [12,14–17]. Spurs on the dorsocaudal aspect of the second cervical vertebra may project into the vertebral canal. The ventral process or lamina of the 6th cervical vertebra, and occasionally other vertebrae, has a small separate centre of ossification. The ventral process of the 6th cervical vertebra may be transposed onto the ventral aspect of the 7th cervical vertebra and, more rarely, onto the 5th cervical vertebra. This transposition can be present unilaterally or bilaterally. The 7th cervical vertebra can have a small spinous process, which may be superimposed on the synovial joint between the 7th and 6th cervical vertebrae and should not be interpreted as periarticular new bone formation [12,16,17]. Variants that may or may not be readily detectable on radiographs include a cervicothoracic transitional vertebra, articular process articulation asymmetries, variable vertebral body lengths and additional ribs, especially on the 7th cervical vertebra, with a rib articulating with the transverse process [14,18].

There have been few studies that describe the prevalence of the variants [14,19,20] and their relationship with breed and sex. The aim of this study was to describe the prevalence and to evaluate the morphology of the anatomical variants of the caudal cervical area using the radiographic technique. It was hypothesised that anatomical variation would be related to breed and/or sex.

Materials and methods

Study population

Radiographs of the cervical spine obtained from horses admitted between January 2006 and May 2014 to the Veterinary Teaching Hospital University of Perugia (n = 270) were reviewed. Of these 270 horses, 190 had a radiographic set suitable for the evaluation of the first thoracic vertebra, 247 radiographic sets were suitable for the evaluation of the spinous process of the 7th cervical vertebra, and in all 270 horses the bodies of the 6th and 7th cervical vertebrae could be evaluated. There were 138 Warmbloods, 41 Thoroughbreds, 29 Arabs, 27 Anglo-Arabs, 13 Quarter Horses, 6 Standardbreds, 6 sports ponies, 4 Paint horses, 2 of other breeds, and for 4 horses the breed was unknown. There were 106 females, 106 geldings and 58 intact males. Their age ranged from 6 months to 34 years (median 8 years; mean 9.25 years). The horses were used for a variety of disciplines: showjumping (125), general purpose (45), racing (42), endurance (18), showing (12), Western performance (11), dressage (9), eventing (6) and miscellaneous (2).

Radiography

Lateral projections of the cervical spine were acquired for all 270 horses at a focus-film distance of 100 cm using a suspended vertical stand; all images were acquired using a computed radiography system. Exposure factors varied, depending on the size of the horse. All radiographs were evaluated retrospectively by one trained analyst (I.S.). Before image analysis, 70 sets of radiographs were selected randomly and evaluated by an experienced analyst (F.B.) and I.S. to determine acceptable agreement in interpretation. Any queries concerning image interpretation were considered by the analysts (I.S., F.B.) and an experienced equine surgeon (M.P.), and a consensus was reached.

For interpretation, all images were orientated with cranial to the left and caudal to the right. The presence of the following findings was recorded: a small centre of ossification at the caudal limit of the ventral process of the 6th cervical vertebra; transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra; spinous process on the 7th cervical vertebra; and abnormal shape of the spinous process of the first thoracic vertebra.

Following analysis of all images, a classification system was devised to describe the shape of the spinous process of the 7th cervical vertebra and the first thoracic vertebra. The radiographs were reassessed to categorise

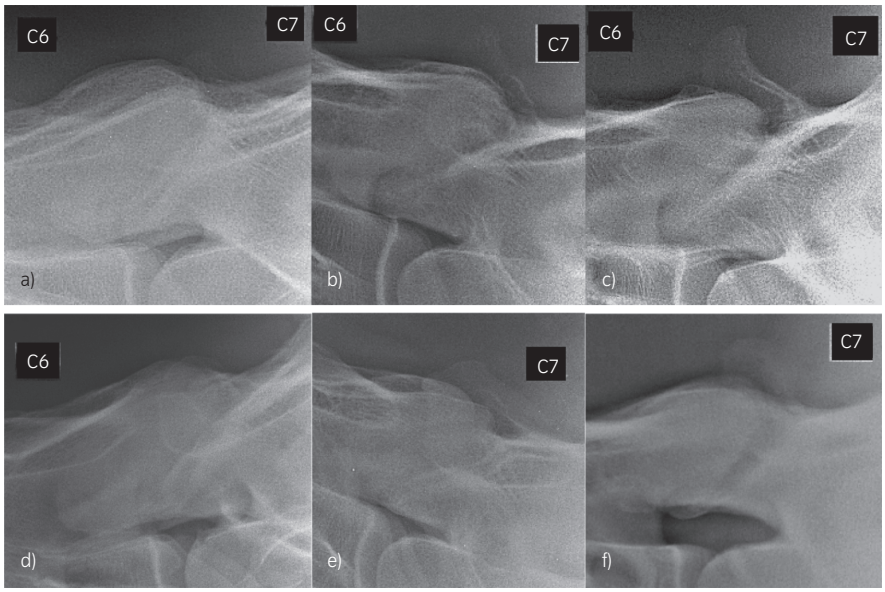

Fig 1: Detail of lateral radiographs of the caudal cervical area. Note the variable shape of the spinous process of the 7th cervical vertebra: '*type 1a*' (a), '*type 1b*' (b), '*type 1c*' (c), '*type 2a*' (d), '*type 2b*' (e) and '*type 3*' (f).

the shape of the spinous process of the 7th cervical vertebra (sharp triangular, rounded triangular or spur-like) and the spinous process of the first thoracic vertebra (high and pronounced or short and squat).

Data analysis

For statistical analysis, the geldings and intact males were pooled. The Chi-square test, or Fisher's exact test when appropriate, was used to test for associations between the radiographic findings and sex or breed; categories with fewer than 6 horses were not included in the statistical analysis. Residual analysis was performed to localise the differences. Chi-square tests and calculation of the phi coefficient (φ) were used to test for associations between different radiological variants. All analyses were selected by one of the authors (F.B.) and performed using R statistics (R Development Core Team)[a] with significance set at P≤0.05.

Results

Morphological variants

The spinous process of the 7th cervical vertebra was identified in 188/247 (76.1%) of horses. Three variants were identified in the spinous process of the 7th cervical vertebra, as follows: it had a sharp triangular shape (*type 1*) in 105/188 (55.8%) horses, a rounded triangular shape (*type 2*) in 67/188 (35.6%) and a spur-like shape (*type 3*) in 16/188 (8.5%) horses (Fig 1).

Three subtypes of a sharp triangular spinous process of the 7th cervical vertebra were detected, as follows: a small faint spinous process with straight cranial margin and straight or slightly concave caudal margin (*type 1a*; 41 horses), a well-defined spinous process with straight cranial and caudal margins (*type 1b*; 46 horses) and a well-defined spinous process with straight cranial margin and concave caudal margin (*type 1c*; 18 horses; Fig 1). Two subtypes of rounded triangular spinous process of the 7th cervical vertebra were detected, as follows: a small and faint spinous process (*type 2a*; 41 horses) and a well-defined spinous process (*type 2b*; 26 horses; Fig 1).

Two shapes were identified in the spinous process of the first thoracic vertebra, as follows: high and pronounced (*type 1*; 139/190; 73.2%) or short and squat (*type 2*; 51/190; 26.8%; Fig 2).

The ventral process of the 6th cervical vertebra was transposed onto the ventral aspect of the 7th cervical vertebra in 36/270 (13.3%) horses; this was partial in 21/36 (58.3%) and complete in 15/36 (41.7%; Fig 3).

A small centre of ossification at the caudal limit of the ventral process of the 6th cervical vertebra was identified in 13/270 (4.8%) of the horses (Fig 4), but it was not evaluated statistically because of the low frequency in this study group. However, 11/13 horses that had this variant were <3 years old, and the other 2 horses were 4 and 8 years old, respectively.

Association with sex, breed and between variants

Details of the prevalence of anatomical variants according to breed and sex are presented in Tables 1 and 2. The presence of a spinous process of the 7th cervical vertebra was not associated with sex. However, a statistically significant difference among breeds was identified in the shape of the spinous process of the 7th cervical vertebra (P = 0.05); the Quarter Horse had the highest frequency of *type 3* spinous processes, whereas the Thoroughbred had the highest frequency of absence of a visible spinous process (Table 1). Females (P = 0.003; Table 2) had the highest frequency of transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra, but this was not associated with breed.

The shape of the spinous process of the first thoracic vertebra was not associated with breed or sex. The short and squat type (*type 2*) of the first thoracic vertebra was associated with absence of the spinous process of the 7th thoracic vertebra (φ = 0.35; P<0.01) and with transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra (φ = 0.33; P<0.01). Transposition of the ventral

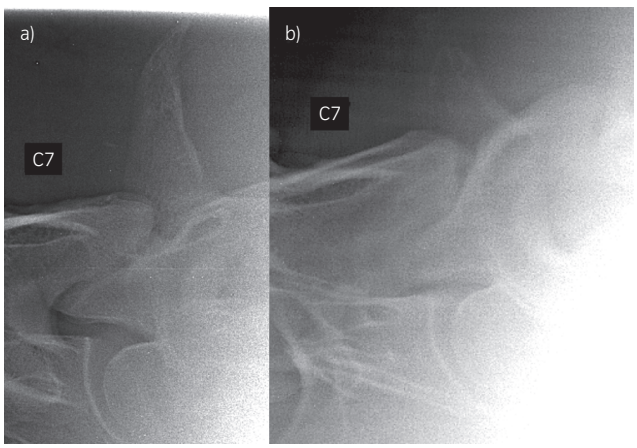

Fig 2: Detail of lateral radiographs of the caudal cervical area. Note the variable shape of the spinous process of the first thoracic vertebra: '*type 1*' (a) and '*type 2*' (b).

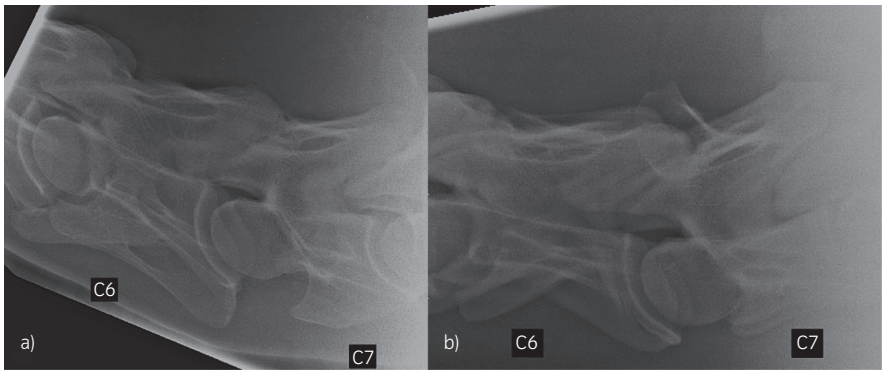

Fig 3: Detail of lateral radiographs of the caudal cervical area. Note the transposition of the ventral lamina of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra. a) Partial transposition. b) Complete transposition.

Fig 4: Detail of lateral radiographs of the caudal cervical area. Note the small centre of ossification at the caudal limit of the ventral process of the 6th cervical vertebra.

process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra was not associated with the shape of the spinous process of the 7th cervical vertebra.

Discussion

This study describes the prevalence of anatomical variants of the spinous and transverse processes of the caudal cervical vertebrae and the first thoracic vertebra in horses. Although the several anatomical variants in this area have been reported, this study evaluated the different morphological types of the spinous process of the 7th cervical vertebra and the first thoracic vertebra.

There is great variation in the spinous process of the 7th cervical vertebra, from absence to several different shapes [14]. The presence of a spinous process of the 7th cervical vertebra was the most common variant we identified, in partial accordance with a previous study on 12 neck specimens in which a spinous process of the 7th cervical vertebra was invariably identified [14]. Among the subtypes, *type 1b*, *type 1a* and *type 2a* were most commonly identified. Knowledge of the different radiographic shapes is very important in avoiding misdiagnosis of periarticular new bone formation on the articular process of the synovial joints between the 6th and 7th cervical vertebrae. This is particularly true for faint spinous processes, of both triangular and rounded shapes, and especially for those of the spur-like shape. However, other factors can affect the ability to differentiate periarticular new bone formation, including anatomical variants and artefacts, such as image quality, oblique projections or the summation effect.

The identification of 2 morphological variants of the spinous process of the first thoracic vertebra is of particular interest. Variation and abnormalities are common at the level of the transitional vertebra and are described in horses [19,21,22], dogs [23,24], goats [25] and man [26];

TABLE 1: The prevalence of anatomical variants of the cervical spine in various breeds

	Anglo-Arab		Arab		Thoroughbred		Quarter Horse		Warmblood	
Anatomical variant	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Spinous process of C7	(n = 26)*		(n = 28)*		(n = 36)*		(n = 12)*		(n = 127)*	
Absent	5	19.2	3	10.7	**13**	**36.1**	2	16.6	31	24.4
Type 1a	5	19.2	4	14.3	6	16.6	1	8.3	21	16.5
Type 1b	7	27	8	28.5	2	7.7	1	8.3	24	18.9
Type 1c	1	3.8	4	14.3	2	7.7	1	8.3	8	6.3
Type 2a	2	7.7	4	14.3	3	8.3	3	25.1	25	19.7
Type 2b	4	15.4	4	14.3	4	11.1	1	8.3	13	10.2
Type 3	2	7.7	1	3.6	4	11.1	**3**	**25.1**	5	4
Spinous process of T1	(n = 23)*		(n = 25)*		(n = 15)*		(n = 12)*		(n = 100)*	
Type 1	17	74	20	80	11	73	10	83	69	69
Type 2	6	26	5	20	4	27	2	17	31	31
Transposition of the ventral process of C6 on C7	3/27*	11	3/29*	10	4/41*	10	3/13*	23	21/138*	15

*Number of horses with a suitable set of radiographs for the evaluation of each anatomical variant according to breed. C6 = 6th cervical vertebra; C7 = 7th cervical vertebra; T1 = first thoracic vertebra. Bold text indicates that the prevalence of this variant is significantly different in this breed compared with the others.

TABLE 2: The prevalence of the anatomical variants of the cervical spine in males and females

	Female		Male	
Anatomical variant	Number	Percentage	Number	Percentage
Spinous process of C7	(n = 106)*		(n = 150)*	
Absent	18	16.9	41	27.3
Type 1a	20	18.8	21	14
Type 1b	14	13.2	32	21.3
Type 1c	7	6.6	11	7.3
Type 2a	19	17.9	22	14.6
Type 2b	14	13.2	12	8
Type 3	5	4.7	11	7.3
Spinous process of T1	(n = 79)*		(n = 112)*	
Type 1	60	76	79	70
Type 2	19	24	32	30
Transposition of the ventral process of C6 onto C7	**22/106***	**21**	14/164*	8

*Number of horses with a suitable set of radiographs for the evaluation of each anatomical variant according to sex. C6 = 6th cervical vertebra; C7 = 7th cervical vertebra; T1 = first thoracic vertebra. Bold text indicates that the prevalence of this variant is significantly different in this sex compared with the other.

many of these apparent abnormalities are normal variants. The short and squat (*type 2*) spinous process of the first thoracic vertebra looks more like the spinous process of the 7th cervical vertebra than the expected shape of the first thoracic vertebra. Interestingly, the short and squat (*type 2*) spinous process of the first thoracic vertebra was associated with absence of the spinous process on the 7th cervical vertebra and with transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra. However, all variants of the spinous process of the 7th cervical vertebra and the first thoracic vertebra may be present independently, as may the other anatomical variants considered in this study.

Transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra, including both partial and complete transposition, had a low frequency in this study (13.3%). A slightly higher incidence was identified in an *ex vivo* study using computed tomography [20] and in another radiographic study [14], where specimens were evaluated *post mortem*; it is possible that both computed tomography and gross specimens allow a better 3-dimensional evaluation of the vertebrae than 2-dimensional radiography.

In partial accordance with our hypotheses, some anatomical variants of the caudal cervical vertebrae were associated with breed or sex; however, this association did not involve all the anatomical variants considered in this study. Absence of the spinous process of the 7th cervical vertebrae was associated with the Thoroughbred breed, and *type 3* spinous process of the 7th cervical vertebra was associated with Quarter Horses; however, the result obtained in Quarter Horses needs to be interpreted with caution, because the number of Quarter Horses was low in this study. Transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra was more common in females than in males. It has been demonstrated that the prevalence of particular variants can be breed related in dogs [23,24], and some breeds and sexes are predisposed to congenital cervical abnormalities (e.g. cervical vertebral compressive myelopathy) [10,27]. It remains to be investigated whether there is an association between transposition of the ventral process of the 6th cervical vertebra onto the ventral aspect of the 7th cervical vertebra and the development of cervical vertebral compressive myelopathy. Transposition of the ventral process modifies muscle attachments in the caudal cervical area, potentially leading to instability in the cervicothoracic junction [21]. A small centre of ossification at the caudal limit of the ventral process of the 6th cervical vertebra had a low frequency in this study group, and the majority of affected horses were <3 years old. The small centre of ossification at the caudal limit of the ventral process of the 6th cervical vertebra should not be confused with a fracture line [16]; the caudal physis of the cervical vertebrae remain open until 4–5 years after birth, with fusion starting dorsally [16]. Considering that this centre of ossification was detected in only 2 adult horses among the 13 in which was identified, it is possible that in the majority of cases it fuses with the physis during growth.

Limitations of the study

This study has limitations because of the retrospective nature of the data collection. Some horses were excluded from the evaluation of the spinous processes of the 7th cervical and first thoracic vertebrae because the quality of the images was insufficient to allow adequate visualisation of the spinous processes. In addition, the prevalence of absence of the spinous process of the 7th cervical vertebra may be overestimated because of the inclusion of horses with enlargement of the articulation between the 6th and 7th cervical vertebra and with periarticular new bone formation, which potentially might have obscured small and faint spinous processes. Radiographs are 2-dimensional presentations of a 3-dimensional structure, and some findings may be inadequately visualised.

Conclusion

A large number of anatomical variants of the caudal cervical area can be detected radiographically. Additional studies are required to investigate whether there is a correlation between the presence of anatomical variation and the development of caudal cervical vertebral pathology.

Authors' declaration of interests

No competing interests have been declared.

Ethical animal research

Research ethics committee oversight not currently required by this journal: retrospective study of clinical records. Explicit owner informed consent for participation in this study was not stated, although owner consent for clinical investigations and treatment was given.

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None.

Authorship

Data collection and study execution: I. Santinelli and F. Beccati. Data analysis and interpretation: I. Santinelli, F. Beccati and M. Pepe. Study design, manuscript preparation and final approval: I. Santinelli, F. Beccati, R. Arcelli and M. Pepe.

Manufacturer's address

[a]R Development Core Team, Vienna, Austria, URL http://www.R-project.org.

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