Identification of Cervical Vertebral Column Variations and Pathology in The Adult Ataxic Horse. A Computed Tomography and Radiographic Evaluation.

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Summary

Objective: Anatomy and disorders like osteoarthritis, cervical vertebral stenosis and intervertebral disc degeneration of the equine cervical vertebral column analyzed with Computed Tomography (CT) has received little attention in literature. The aim of this study is to get a better understanding of the equine cervical vertebral column, comparing radiography and CT as different imaging techniques.

Methods: Nineteen radiographic studies and twenty-six CT scans were analyzed for the presence of osteoarthritis. In CT, osteoarthritis was defined by sclerosis, subchondral osteolysis and osteophyte formation. Moreover, intravertebral sagittal ratio and intervertebral disc space was measured in both imaging modalities, of which the results were compared. In sub analysis of intervertebral disc space, the impact of neck position, measuring side and age were compared.

Results: The quantity of osteoarthritis was higher in CT (94,8%) than in radiographic images (29,5%). The intravertebral sagittal ratios (ISR) in radiographic images (0.54-0.57 ± 0.059-0.082) and CT (0.52-0.56 ± 0.046-0.089) did not significantly differ from each other ($t(38) = 0.4518$, $p = 0.654$), 95% CI [-0.0348, 0.0548]. The intervertebral disc spaces width (IDS) in radiographic images were dorsally smaller (4,75-6,57 ± 0,75-1,16) than in CT images (5,41-7,24 ± 0,79-1,90), but the ventral results of radiography (4,28-5,33 ± 0,60-0,77) and CT (3,64-5,45 ± 0,57–1,57) were comparable. The IDS in neutral positions are larger (4,14mm – 8,1mm) than the IDS width in flexed positions (3,52mm – 6,68mm). The widest IDS in both positions and both sides of measuring was analyzed at C6-C7 articulations. There was a difference in IDS results of location of measuring (dorsal side 5,72mm – 8,1mm; ventral side 3,52mm – 6,56mm), but not with age (e.g. cervical column in flexed position: 16 years old horse with the smallest IDS width (4,25mm) and another 16 years old horse with the largest IDS width (6,82 mm)).

Conclusion: CT showed more osteoarthritic changes compared to radiography, therefore CT could be more superior to get detailed information about the equine cervical vertebral column and its pathology. Moreover, the ISR could also be used in detecting cervical vertebral stenosis in CT images. The IDS results were the highest in CT images, at neutral cervical column positions, at dorsal measuring sides, but there was no difference with age.

Introduction

The standard clinical work-up of a horse presented with ataxia consists of a neurological examination followed by diagnostic tests such as EMG and diagnostic imaging of the cervical vertebral column. After the work-up, a differential diagnosis and a localization and severity of the lesion can be estimated [7].

Radiography and ultrasonography are the diagnostic imaging modalities that are widely available and used in the work-up of the ataxic horse. In humans and companion animals, a computed tomography (CT) or magnetic resonance imaging (MRI) examination of the cervical spine can be made in case of neurological deficits. The sensitivity for detection of spinal canal lesions is much higher in these modalities and would form a welcome additive to the already used modalities. This retrospective study is an onset to evaluate the usefulness and clinical relevancy of CT images of the equine cervical vertebral column compared to radiography. Unfortunately, it is impossible to fit the caudal cervical region into the CT scanners of nowadays [6]. For this study, the horses were euthanized and the muscles were removed to scan the cervical spine. Hopefully in the future, bigger CT scanners become available for examination of the cervical spine of the horse.

The advantages of CT, which are no superposition of different tissues and the fact that the image can be reconstructed in three dimensional planes (x-, y-, z-axis), are sophisticated [18]. Osteoarthritis, intervertebral disc space width and symmetry, and the intravertebral sagittal ratio's are several aspects that can be evaluated with radiography and CT [2,5,10]. The aim of this retrospective study is to identify and evaluate cervical vertebral column variations, as mentioned above, with CT and radiographic images to get a better understanding of what relevant pathology is missed in radiographs by interpreting CT images.

Summarized, little is found in literature concerning morphology of the equine cervical vertebral column and almost none is present for CT; taking into account the clinically important subjects and referring to literature concerning CT of human and canine findings. Because of the great clinical interest and the many unanswered questions related to the equine vertebral column, a CT evaluation of equine cervical vertebral column was deemed an important step.

Material en Methods

Computed Tomography

For this study, the post-mortem CT imaging data available in the PACS [14] from cervical vertebral columns of horses were used. These images were made at the Division of Diagnostic Imaging, Faculty of Veterinary Medicine, Utrecht University. CT was performed using a single slice helical CT scanner (Philips Secura), using 120 kV, 220 mA, 1s scanning time and 2-3 mm thick contiguous slices [16].

Radiography

Horses included in this study

Twenty-six horses were euthanized and dissected and there after a complete cervical vertebral column CT scan was performed, including at least Th1. Nineteen of these horses also had also X-rays of the cervical spine before euthanasia. The other seven horses did not have radiographic images. Six horses were previously used in the study of Sleutjens *et al.* 2010. They were euthanized for reasons not related to pathology of the neck region and were fixated in a wooden frame to manipulate and scan the cervical vertebral column in five different positions. For this retrospective study, three positions have been used. Neutral position: a horizontal line from the atlas to the top of spinous process Th6 is defined as neutral position and 0° flexion. Moderate flexed position: a flexed cervical spine of 20° and flexed position: flexed cervical spine of 40° [16]. The other twenty horses that were included in this study had clinical complaints, ranging from lameness to ataxia. Among the horse breeds there were eighteen Royal Dutch Warm Blood Horses (RDWH), two Friesian horses, a Westfalen horse, a Standardbred racehorse, an Oldenburger and two pony's, ranging in age from three to twenty-two years. There were fifteen geldings, nine mares and two stallions.

Data analysis

CT data has been analysed by one observer (FJ) by reporting the frequency and severity of pathologic changes. The radiographic images are analysed by FJ and a radiologist (SV). It can be noticed that the measurements start at cervical vertebra 2, because cervical vertebra 1 (the atlas) has no articular process (AP) and cervical vertebra 2 (the axis) only a caudal AP.

The most important abnormalities of osteoarthritis seen at CT images are (subchondral?) sclerosis, subchondral osteolysis and osteophyte formation [5,9,18]. These alterations are separately scored by determining the severity along the margins of the facet joints. Scoring the severity of sclerosis; score 0: no hyper attenuation, score 1: some hyper attenuation, score 2: the whole margin is hyper attenuated and more than 2 mm thick. Scoring the severity of subchondral lysis; score 0: absence of surface irregularities, score 1: focal porosity or pits in subchondral bone, score 2: deep pits and/or multifocal porosity in subchondral bone. Scoring osteophyte formation by: score 0: no osteophyte formation, score 1: osteophyte formation along the margins, a little bony hook is present, score 2: osteophyte forming along the margins, the bony hook reaches over the edge of the opposite AP.

Every vertebrae has four AP's; cranial left (CrL), cranial right (CrR), caudal left (CdL) and caudal right (CdR). The numbers at the end of the abbreviations represents the cervical vertebrae (Figure 1). Each articular facet joint (AFJ) alteration is scored at the side of the joint space and documented in Appendix I. Note that table 5a are the cranial APs and 5b the caudal APs.

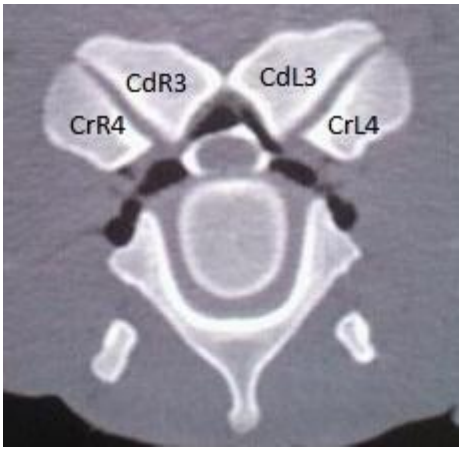

Figure 1: CT image of a transverse section of C3-C4 with abbreviations of the APs.

The results of Appendix I are transformed in SPSS 20.00 [11] to mean and standard deviation and documented in Appendix II. Table 2a shows the results of subchondral lysis, table 2b osteophyte formation and table 2c sclerosis. The cervical spine of one horse was not fully scanned. Imaging stopped after the cranial APs of thoracic vertebra 1. Therefore, the caudal thoracic APs of this horse are not scored and therefore N = 25.
Osteoarthritis at radiographic images are scored of the cranial and caudal AFJs by a radiologist (SV). Due to superposition there is no difference between the left and right AP and these images can only be examined in longitudinal plane. It was not possible to examine the cranial thoracic AFJ(Th1?) for three horses. For two horses it was not possible to examine the caudal thoracic articular facet joint, due to lack of images of that part of the cervical spine. The results of osteoarthritis at radiographic images are documented in Appendix III. To get a better survey of table 2a, 2b, 2c and 3, the mean and standard deviation results are plotted in charts (Figure 5a, 5b, 5c and 6). To be able to compare osteoarthritis at cervical articulations between CT and radiographic images, the results of Appendix II are transformed and summarized in figure 5. For example see Figure 1: C3-C4 articulation at CT is a sum of the result of CdR3, CdL3, CrR4 and CrL4 and expressed in a percentage of appearance.

For measuring the size of the vertebral canal and therefore detection of generalized vertebral stenosis it is important to determine the intravertebral sagittal ratio (ISR) [1,10]. The ISR is obtained by dividing the minimal sagittal diameter of the vertebral canal (MSD) by the widest part of the corresponding vertebral body at the cranial side, the sagittal diameter (SD). The MSD is the narrowest point of the vertebral canal, mostly cranial and at the level of the SD (Figure 2). CT images are first reconstructed to transverse plane and the intersection is placed in the middle of the vertebral body. Thereafter, the measurements are done in sagittal (dus zoals hier beneden in het plaatje…) plane, like radiographic images.

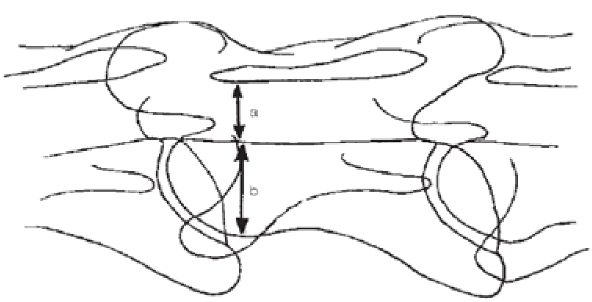

Figure 2: a = Minimal Sagittal Diameter (MSD), b = Sagittal Diameter (SD) [1]

The space between adjacent vertebral bodies has been determined by measuring the intervertebral disc space (IDS) at two points. One at the dorsal aspect of the IDS, a few millimetres underneath the vertebral canal. Second, at the ventral aspect of the IDS, a few millimeters above the most caudodorsal point of the IDS (Figure 3). The reason for this is to get a more reliable result and reduce the difference of IDS size by the position of the adjacent vertebrae. With SPSS20.0 [11] the mean and standard deviation are calculated.

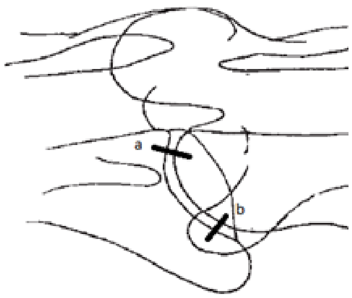

Figure 3: a = dorsal side where the IDS distance has been measured. b = ventral side where the IDS has been measured (Figure from Biervliet et al. 2007*, adapted in Paint).*

Position of the cervical column might influence the IDS width. Therefore CT images are divided in three groups: neutral position, moderate flexion of 20° and flexion of 40° [16]. The IDS of the radiographic images are measured as well. The IDS results of each cervical vertebra has been separately documented (Table 2 and Appendix IV).

To extricate the IDS differences of the most diversified positions, five horses of Sleutjens *et al.* 2010 are compared in neutral and flexed positions (Table 3). To get a better survey, the results are added up, averaged and plotted in two charts documented in Appendix V. To examine the correlation of age and IDS, Appendix VI has been made. For this part of the study, all the IDS results of all the images are mediated and compared with the age of the horses. The three different positions are separately plotted to minimalize the difference between adjacent vertebra positions.

Results

Osteoarthritis

Nineteen radiographic images were studied by a radiologist (SV). (hierna over CT) The examination results of osteoarthritis of the caudal APs of C2 till the cranial APs of Th1 are shown in Figure 4a and Appendix III. The caudal AP of C6 and the cranial AP of C7, show the most osteoarthritis changes. Characteristics of osteoarthritis at CT images are; sclerosis, subchondral lysis and osteophyte formation. Comparing these characteristics, sclerosis, in general, is more frequently observed then subchondral lysis and osteophyte formation (Figure 4b, 4c and 4d). The highest results of sclerosis are observed at the caudal APs of C3 and C4 and the cranial APs of C5 and C6.

The range of appearance of subchondral lysis is very scattered and much lower than sclerosis but note the similarity with sclerosis of the highest results of the caudal APs of C2-C4, and the left C5. The chart with osteophyte formation shows that the caudal APs of C2-C4 are the highest as well. The cranial APs of C3- C5 shows very little osteophyte formation. Therefore, there is a huge difference in osteophyte formation of the cranial and caudal APs. Concerning left and right comparison, there is no significant difference in all of the measurements.

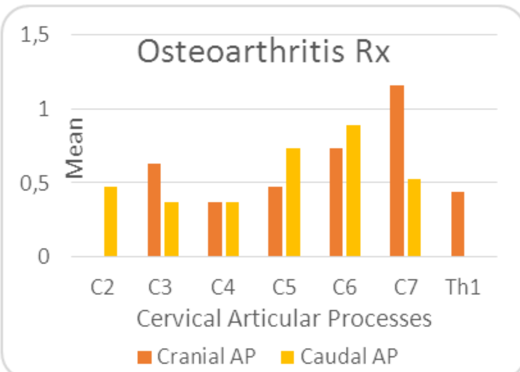

Figure 4a: osteoarthritis seen on radiographic images and scored by the radiologist SV.

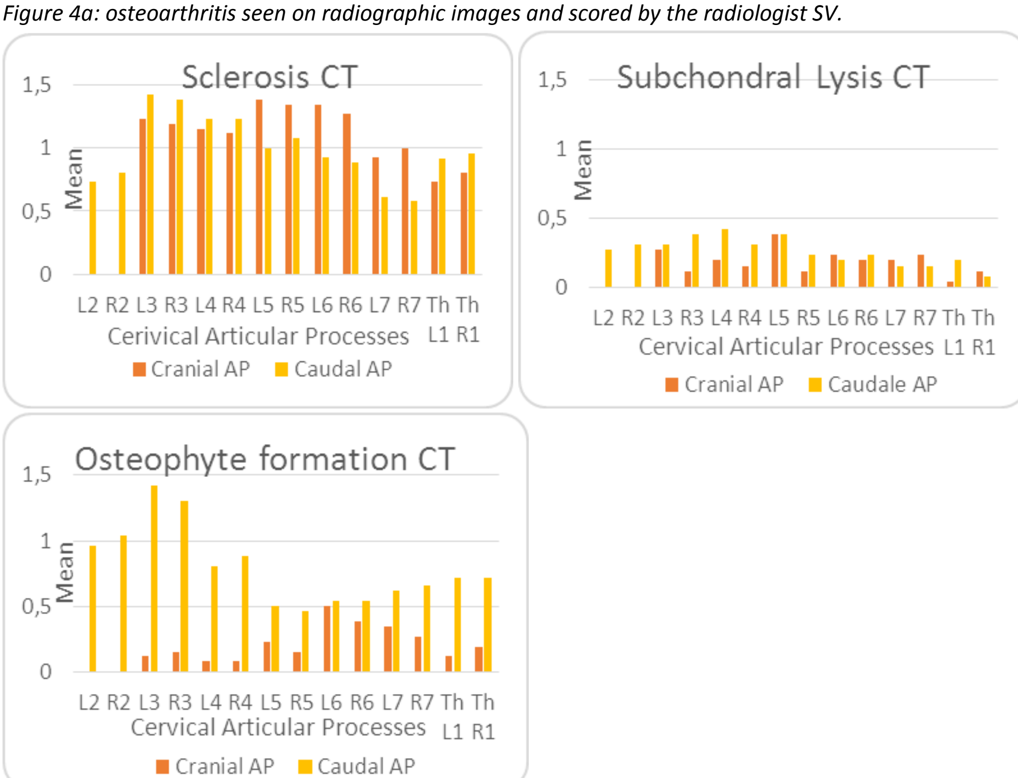

Figure 4b, 4c and 4d: X-as = left and right APs of the cervical vertebrae. Columns = cranial AP and caudal AP. Data is used from Appendix I and II.

Table 3a at Appendix I shows the scoring results of all the cranial APs of all the horses. Only 4,5% of the results are without any indication of osteoarthritis. Therefore, the other 95,5% of the cranial APs shows more or less deviations. Table 3b shows the scoring results of the caudal APs and a percentage of 5,8% with no deviations of osteoarthritis. This is an overall result of 5,2% of no osteoarthritis seen at APs on the CT images and 94,8% of the Aps do show some osteoarthritis.

Figure 5 shows the results from figure 4a, 4b, 4c and 4d together whereby scoring the abnormal changes are documented as a percentage of the total cervical articulations. For radiography, a total of nineteen cervical vertebrae are used and for CT a total of twenty-six. On average, 29,5% of the radiographic images show osteoarthritic changes (average of: C2-C3; 28% + C3-C4; 18% + C4-C5; 21% + C5-C6; 38% + C6-C7; 51% + C7-Th1; 21%) Osteoarthritis is mostly observed on radiographic images at C6-C7 articulation, at which 51% of all the horses show osteoarthritis. At C5-C6 articulation, 37% of all the horses show osteoarthritic changes. At CT images, sclerosis is observed more than 35% at every cervical articulation. At C3-C4 and C4-C5 cervical articulation even more than 70%. Subchondral lysis is observed in every articulation between 6% - 16%. The highest result is at C4-C5 articulation. For osteophyte formation this result lies between 21% and 36% and is mostly seen at C3-C4 articulation.

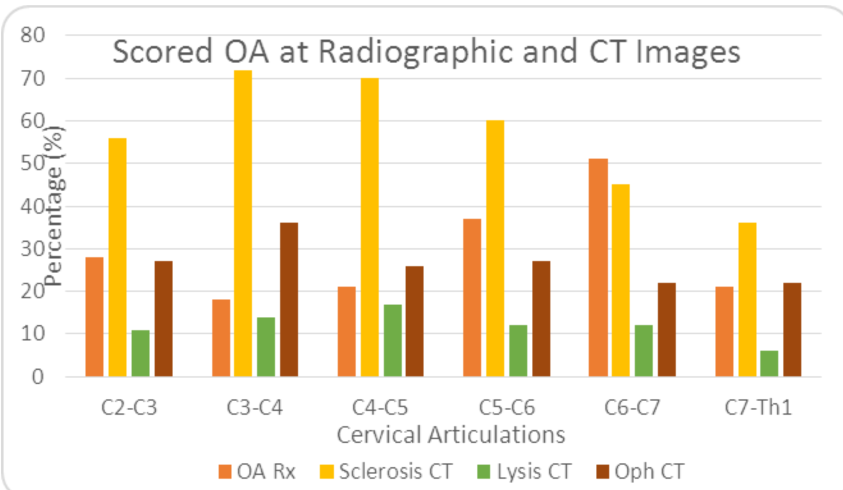

Figure 5: Radiographic- and CT-scan results of osteoarthritis at cervical vertebral column articulations.

Intravertebral Sagittal Ratio

The MSD and SD were measured in all the CT images. With these results the ISR is calculated and documented in Table 1. By comparing the MSD and SD results in CT and radiographic images, it is remarkable that the radiographic results are much higher. But despite this difference, the ISR in radiographic images (0.54-0.57 ± 0.059-0.082) and CT (0.52-0.56 ± 0.046-0.089) did not significantly differ from each other ($t(38) = 0.4518$, $p = 0.654$), 95% CI [-0.0348, 0.0548] The ISR of C7 in both diagnostic tests are slightly larger. This is documented as normal in literature [1].

The ISR of C4 and C6 differ between radiography and CT results, but it is not significant.

MSD	C3 (mm)	C4 (mm)	C5 (mm)	C6 (mm)	C7 (mm)
Rx	24.66 ± 2.86	24.59 ± 3.39	24.93 ± 3.59	26.39 ± 3.77	29.52 ± 2.75
CT	20.72 ± 2.08	19.27 ± 2.18	20.31 ± 2.77	20.15 ± 1.95	22.55 ± 1.08
SD	C3 (mm)	C4 (mm)	C5 (mm)	C6 (mm)	C7 (mm)
Rx	45.53 ± 4.48	44.68 ± 4.68	45.89 ± 4.33	48.32 ± 3.37	51.73 ± 2.73
CT	38.14 ± 2.90	37.12 ± 2.87	37.58 ± 2.71	38.87 ± 2.67	40.46 ± 2.51
ISR	C3	C4	C5	C6	C7
Rx	0.54 ± 0.070	0.55 ± 0.082	0.55 ± 0.076	0.55 ± 0.069	0.57 ± 0.059
CT	0.55 ± 0.084	0.52 ± 0.089	0.54 ± 0.081	0.52 ± 0.070	0.56 ± 0.046

Table 1: the MSD, SD an ISR measured in CT- and radiographic images (mean ± s.d).

Intervertebral Disc Space

The width of the dorsal and ventral side of the IDS are calculated in mean and standard deviation and documented in table 2a. Appendix IV shows the plotted results of table 2a. On radiographic images, the dorsal side results (4,75-6,57 ± 0,68–1,22) are smaller than on CT images (5,41-7,24 ± 0,79-1,90). On the other hand, the range of the ventral side results of CT (3,64-5,45 ± 0,57–1,57) is much larger than at radiographic images (4,28-5,33 ± 0,60-0,77). Remarkable is the smaller ventral side despite the cervical column position or diagnostic technique.

Dorsaal	C2-C3 (mm)	C3-C4 (mm)	C4-C5 (mm)	C5-C6 (mm)	C6-C7 (mm)	C7-Th1(mm)
Neutral CT	6.22 ± 1.15	6.15 ± 1.26	6.25 ± 1.29	7.24 ± 1.33	7.08 ± 1.65	5.89 ± 1.46
Moderate CT	5.49 ± 1.18	5.64 ± 0.94	5.98 ± 0.87	6.10 ± 1.63	6.09 ± 1.96	6.11 ± 1.86
Fexion CT	5.88 ± 0.79	6.06 ± 1.45	6.03 ± 1.55	6.27 ± 1.21	6.20 ± 1.10	5.41 ± 1.52
Rx	4.74 ± 0.75	5.04 ± 0.82	5.57 ± 0.68	6.35 ± 1.22	6.57 ± 1.16	5.81 ± 1.02

Ventral	C2-C3 (mm)	C3-C4 (mm)	C4-C5 (mm)	C5-C6 (mm)	C6-C7 (mm)	C7-Th1 (mm)
Neutral CT	4.02 ± 1.02	4.37 ± 1.10	4.52 ± 0.99	5.27 ± 1.57	5.45 ± 1.52	5.26 ± 1.46
Moderate CT	3.93 ± 0.73	3.81 ± 0.61	4.19 ± 0.57	4.78 ± 0.94	4.64 ± 1.10	5.22 ± 0.79
Fexion CT	4.12 ± 1.08	3.87 ± 0.99	3.64 ± 1.10	4.39 ± 1.23	4.83 ± 0.68	4.80 ± 0.63
Rx	4.28 ± 0.60	4.63 ± 0.67	4.93 ± 0.72	5.33 ± 0.77	5.30 ±0.77	4.83 ± 0.66

Table 2a: IDS width in mean and standard deviation of the dorsal- and ventral side of each articulation at radiography and CT

Observing the overall results of CT images in Appendix IV, a neutral cervical column position shows a larger IDS than flexed or moderate flexed positions. The IDS results of the last two mentioned are approximately similar. The highest IDS results of neutral position are at C5-C6 and C6-C7 articulations.

Table 2b shows the IDS width results of the most diversified cervical column positions on CT images. To get a better survey of these results, a chart is made in Appendix V with the average outcome of Table 2b. The IDS width of neutral positions are larger (4,14mm – 8,1mm) than the IDS width in flexed positions (3,52mm – 6,68mm) . The widest IDS in both positions and both sides of measuring is analyzed at C6-C7 articulation.

	C2-C3 Dorsal		**C2-C3 Ventral**		**C3-C4 Dorsal**		**C3-C4 Ventral**		**C4-C5 Dorsal**		**C4-C5 Ventral**	
	Neutra	**Flexion**	**Neutral**	**Flexion**	**Neutral**	**Flexion**	**Neutral**	**Flexion**	**Neutral**	**Flexion**	**Neutral**	**Flexion**
Horse 1	*5,41*	*4,82*	4,10	5,09	*7,21*	*6,42*	4,30	3,75	*6,53*	*5,10*	4,55	3,21
Horse 2	*5,74*	*6,20*	4,31	3,80	*7,24*	*6,60*	3,75	4,10	*7,26*	*7,13*	4,25	3,30
Horse 3	*5,84*	*5,90*	4,13	2,80	*6,32*	*5,00*	2,93	2,50	*5,83*	*5,60*	2,72	1,90
Horse 4	*7,70*	*6,50*	5,92	5,18	*8,60*	*9,01*	4,83	5,60	*8,90*	*9,24*	5,91	4,95
Horse 5	*6,35*	*5,20*	5,50	4,46	*6,36*	*5,26*	4,87	3,64	*7,62*	*6,26*	5,30	4,25
Gem	*6,21*	*5,72*	4,79	4,26	*7,15*	*6,46*	4,14	3,91	*7,23*	*6,66*	4,55	3,52

	C5-C6 Dorsal		**C5-C6 Ventral**		**C6-C7 Dorsal**		**C6-C7 Ventral**		**C7-Th1 Dorsal**		**C7-Th1 Ventral**	
	Neutra	**Flexion**	**Neutral**	**Flexion**	**Neutral**	**Flexion**	**Neutral**	**Flexion**	**Neutral**	**Flexion**	**Neutral**	**Flexion**
Horse 1	*8,11*	*8,04*	6,57	3,49	*7,22*	*8,04*	7,15	5,09	*6,99*	*5,38*	6,58	4,29
Horse 2	*6,99*	*6,65*	5,70	4,52	*7,24*	*6,41*	6,00	5,70	*7,00*	*4,98*	6,00	4,51
Horse 3	*7,05*	*4,70*	2,78	2,50	*10,20*	*5,60*	4,14	4,39	*5,11*	*5,60*	4,62	4,47
Horse 4	*9,18*	*8,10*	8,85	6,50	*7,78*	*7,88*	8,32	5,60	*7,53*	*7,88*	7,79	5,40
Horse 5	*8,89*	*4,85*	5,33	4,26	*8,05*	*5,46*	7,19	5,05	*6,14*	*5,86*	6,56	4,64
Gem	*8,04*	*6,47*	5,85	4,25	*8,1*	*6,68*	6,56	5,17	*6,55*	*5,94*	6,31	4,66

Table 2b: IDS distances of the dorsal and ventral side (in mm) compared in neutral and flexed positions.

To answer the hypotheses that the IDS width will decrease in correlation to age, three charts in Appendix VI have been made from table 6a, 6b and 6c. The IDS results are an average number of all the IDS widths of each horse. The result for neutral position with the age between 4,1 and 16 years is 4,34 – 7,61mm IDS. Remarkable, the oldest horse (16 years) has the widest IDS (7,61mm). For moderate position, horses with ages between 3 and 17 years give results between 4,2 – 5,68mm IDS. For flexed positions, the IDS results are between 4,25 – 6,82mm for horses of 3,9 till 22 years of age. Remarkable, the widest IDS (6,82mm) is seen at a CT scan of a sixteen year old horse and the smallest IDS (4,25mm) is also seen at another sixteen year old horse.

Discussion

The primary aim of this study was to compare radiography to CT in the evaluation of cervical vertebral column variations. According to Whiters *et al.* 2009 and Thrall *et al.* 2012 it is more difficult to detect osteoarthritis in radiographic images than in CT images due to the overlap of structures and 2D presentation in radiographic images. Turmezei *et al.* 2011 used CT images for his study and prefers the use of CT because it provides more information about bone structure, volume and thickness. According to the results in our study, the statements described above are confirmed. However, as 94,8% of the APs in CT analysis showed osteoarthritis alterations along the joint margins, doubt should be taken into account about the clinical relevance of these findings because CT imaging might yield high rates of false positives.
Remarkable are the different locations where osteoarthritis is observed in radiographic and CT images. At radiographic images C5-C6 and C6-C7 articulations are the most common locations. At CT images, C3-C4 and C4-C5 articulations show the most osteoarthritis characteristics. Most likely, osteoarthritis changes seen at 3D CT images are not seen at 2D radiographic images. Furthermore, sclerosis is scored between 35% and 70%. These high results could be caused by a very strict scoring method. Hyper attenuation can be a physiological process due to normal cervical vertebral column movement. Therefore, minimal sclerosis might be acceptable [5, 8]. Osteophyte formation is observed more significant at the caudal APs. Goldring *et al.* 2010 documented that the localization of osteophytes depends on joint loading and there is evidence that osteophytes contribute to the maintenance of joint stabilization. This study also shows minimal difference of the left and right AP in every vertebra, concluding that osteophyte formation depends on compression forces from cranial and caudal.

Butler *et al.* 2008 and Biervliet *et al.* 2007 used the intravertebral sagittal ratio to estimate the relative size of the vertebral canal. This measurement is important to diagnose stenosis of the vertebral canal or cervical vertebral compressive myelopathy. Although this method of analyzing generalized narrowing of the vertebral canal is useful, it is not reliable for measuring the potential sites of spinal cord compression. Furthermore, it is harder to diagnose less severe alterations [1,2,13]. The hypothesis in this part of the study is confirmed. The ISR of radiographic images is the same as CT images. This is expected because the magnification can differ but the dimensions of cervical vertebrae are the same. The ISR standard deviation of CT is very low, what means the dataset is pretty constant and therefore this method is very reliable for use in CT images.

Butler *et al.* 2008 studied radiographic changes including changes in joint surfaces, narrowing of the intervertebral joint space (AFJ? Of IDS), and changes in subchondral bone opacity as well. That study and Lacourt *et al.* 2012 documented that these degenerative changes may occur secondary to trauma and the IDS width decreases with age. This correlation is not found in our study. The reason for this result is unknown. Dyson *et al.* 2011 documented the study of Whitwell *et al.,* who studied cervical intervertebral discs of 103 horses and suggests that intervertebral disc space width decreased with age and that it is not referable to clinical signs.
Evaluation of Appendix V shows C6-C7 articulation has the widest IDS in neutral and flexed position of the cervical spine. On average, neutral position shows a wider IDS than flexed position. According to Claridge *et al.* 2010, there are no IDS differences comparing neutral and flexed cervical column positions because the AFJs has large joint capsules to absorb movement changes of adjacent vertebrae. Comparing the dorsal and ventral side of the IDS, the dorsal side has higher results. This method of measuring has not been described in literature jet. But what is your conclusion why this can happen…e.g. post-mortem study and therefore no musculature tension etc?!

There are several limitations in this study. First, the number of horses in the radiographic and CT group differ because some horses do have a CT image of the cervical spine but no radiographic image. This leads to different group sizes. Secondly, scores of the severity of osteoarthritis alterations have to be edit and less strict in the next study to reduce the prevalence of osteoarthritis in CT images to get a more clinical useful result. Third, the measurements are done by one observer and one radiologist. For a more reliable study you have to increase the number of observers [15]. Furthermore, there were twenty horses with signs of ataxia or neurological problems and six horses of Sleutjens et al. 2010 which were healthy but included in the study group because the cause and diagnose of ataxia or neurological problems in the other horses were mostly described as doubtful. At last, some cervical spines are not totally scanned whereby measurements are missing which can influence the results by comparing cervical vertebral column parts. The biggest disadvantage for now is the fact that this study is performed post-mortem and the caudal cervical spine of a living horse will not fit into the bore of the CT. But with the growing technology and knowledge of the CT also in companion animals and humans, this goal is not far away [4].

Further studies should be performed to determine which variations at CT images could be clinically relevant and liberalize the severity when necessarily. Also useful in the future is to determine the best cervical spine position for performing CT. Another study with newborn foals might be useful to see which changes in the cervical vertebral column are already going on in the uterus before compression forces are involved.

Legend

AP	Articular Process
CT	Computed Tomography
C	Cervical Vertebra
FJ	Drs. Femke Jansen
IDS	Intervertebral Disc Space
ISR	Intravertebral Sagittal Ratio
MSD	Minimal Sagittal Diameter
OA	Osteoarthritis
SD	Sagittal Diameter
SV	Mw. Drs. Stefanie Veraa
Th	Thoracic Vertebra

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