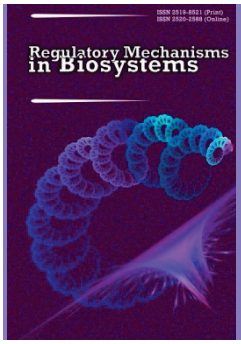

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Comparative clinical and morphometric investigations of cervical stenosis of the spinal canal in humans and dogs

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Acquired stenosis of the spinal canal is a common problem in human and animal pathology. It is defined as a pathological condition that mainly develops as degeneration of the spine with cervical myelopathy development, which is a characteristic manifestation of this pathology. Pain both in the neck and upper back is the leading syndrome of this pathology. 65 human patients aged 20–65 years and 19 dogs weighing more than 20 kg were examined with the aim of comparative clinical and morphometric analysis of stenosis of the spinal canal. The age of the dogs was maximally converted to the age of a person. Computed tomography using the Pavlov-Torg index and the reserve space evaluation supplemented diagnosis of stenosis of the spinal canal. The mass proportion of stenotic changes of the spinal canal against the background of the degenerative-dystrophic process was 21 in males (n = 25) 84.0%, females – 28 persons (n = 40) 70.0%. Pain syndrome was the main complaint in all patients. Cervicalgia prevailed in 60 (92.3%), pain in the upper back was registered in 32 (49.2%) patients. The intensity of pain syndrome was equal to 3.1 ± 0.4 points. Motor deficiency in the form of paresis, mainly of the distal parts of the hands, was registered in 48 patients (73.8%), pyramidal symptoms were noted in the legs in 32 (49.2%) patients, pelvic reservoir dysfunction (7.0–10.8%), and sensory disorders were also found (24.0–36.9%). Such manifestations of cervical myelopathy progressed slowly. Pyramidal symptoms were more frequent and more pronounced in men. According to the computed tomography scan, degenerative changes of the spine were maximal at the level of the C6 vertebra with the maximum clinical correlation (neurological deficit, pain syndrome, etc.). In the course of the research, probable stenosis of the spinal canal was found in people on computed tomography images. In the 19 dogs observed weighing 20 kg or more the presence of pain syndrome was evaluated in all the animals (100.0%) as well as behaviour change (100.0%). During the examination, gait disorder was detected (18.0–94.7%); reaction to palpation of the neck area (15.0–78.9%); the habitus of animals experiencing pain, especially during neck movements (14.0–73.7%), body tension (12.0–63.1%), etc. Bony outgrowths of the edges of the vertebrae and intervertebral joints were found in almost all dogs of 18 (94.7%) large breeds compared to others. Narrowing of the intervertebral openings, deformation and sclerotic changes of the locking plates, thickening of the yellow and elongated ligaments occurred three to four times more in large breeds compared to dogs weighing less than 20 kg, and were absent in cats. Stenosis of the spinal canal was detected in 15 (78.9%) dogs. Therefore, acquired stenosis of the spinal canal probably develops after degenerative-dystrophic changes in the neck in 87.7% of people and in 78.9% of dogs with clinical manifestations of cervical myelopathy and with persistent pain syndrome (equal to 3.1 ± 0.3 points in humans and 2.6 ± 0.4 points in animals according to visual analog scale). This kind of pathological process in the investigated groups developed mainly at the level of the C6 vertebra. Similar clinical and morphometric indexes were obtained in humans (87.7%). It was found that the maximum similarity of pathological processes with stenosis of the spinal canal formation was characteristic in dogs of exclusively large breeds. Therefore, we consider it promising to study the development mechanisms of stenosis of the spinal canal and peculiarities primarily in young generations of humans and animals, to implement modern non-invasive neuroimaging methods, in particular for animals with investigation of morphometric indexes. This will prevent the occurrence of most comorbid syndromes, including chronic pain, neurological deficits as well as help find new opportunities for correction of stenosis of the spinal canal, to suppress the aging processes not only of the muscle-skeletal system but also of the body as a whole. The importance of this work, we suppose, lies in the further identification of adequate models in animals of different breeds and weight categories with stenosis of the spinal canal pathology in which it develops significantly faster, for extrapolation to humans to predict the development of pathological events.

Keywords: stenosis of spinal canal; pain syndrome; dogs; Pavlov-Torg index; computer tomography; neuroimaging methods; visual analog scale; cervical spine.

Introduction

Acquired stenosis of the spinal canal is the most common progressive chronic pathological condition (Coates & Wininger, 2010; Amadou et al., 2017; Gandhi et al., 2019) which is characteristic of degenerative changes in the spine (Hautier et al., 2010; Gembruch et al., 2019; Benato et al., 2021). With age, the incidence of stenosis of the spinal canal increases and disability is also increasing (Galbusera & Wilke, 2018; Davison et al., 2020). At the cervical level, non-myelopathic compression of the spinal cord is registered in a quarter of the healthy population (Gandhi et al.,

2019). Possible predictors of progression of stenosis of the spinal canal with subsequent development of neurological deficits require clarification. At the same time, clinically, cervical myelopathy is a vivid manifestation of stenosis of the spinal canal, especially against the background of degenerative spine injuries (Wang et al., 2019; Nouri et al., 2022) and the leading clinical sign is pain syndrome, which accompanies stenosis of the spinal canal during all periods of its development and progression. The frequency of chronic pain is steadily increasing (Hurwitz et al., 2018) and is the fourth most frequent cause of disability (Hautier et al., 2010; Hurwitz et al., 2018). Despite the differences in the structure of the musculoskeletal system of humans and animals (Hautier et al., 2010), the latter also have a pain syndrome in the centre of the cervical spine, which requires further study. Currently, there is isolated information about the occurrence of clinical symptoms in stenosis of the spinal canal in young people. Similarly, it is necessary to study the adequate age range in animals using methods for comparing the age of humans and animals (Ulbrich et al., 2014; Yates, 2021).

Another urgent problem is the tendency to "rejuvenate" degenerative-dystrophic processes in cervical spine. The peak incidence occurs during adolescence and middle age, in which it is more common than alcoholism, drug addiction, and asthma (Gandhi et al., 2019). It is necessary to pay attention to the period in which pain complaints mainly occur. In the sample of animals, it is also necessary to specify the age range. There are ongoing discussions and comparative studies on the ages of humans and animals. New and more accurate examination methods are proposed, age tables of various animals, including breeds, are created. First of all, this concerns the ratio of the age of dogs to the age of a person. Metabolism is studied separately according to biological life expectancy (Yates, 2021). The most popular calculation of the age of a man and a dog is 1:7, in addition to this, special tables and methods have been developed taking into account the difference in life expectancy, habit, breed, functioning of organs, etc. It should be noted that all of them have shortcomings or involve complexity of mathematical calculation (Iyer & Kim, 2016). There are analytical data on the normative dimensions of the spinal canal and spinal cord for SHV according to MRI data. Also, at all levels of the spine, individual factors such as age, gender and height affect the measurement. A cervical vertebral canal in an adult with an anterior-posterior size less than 14–12 mm according to various data is considered stenosed (Pavlov et al., 1987). Thanks to the development of neuroimaging methods, effective non-invasive diagnostic criteria for the diagnosis of stenosis of the spinal canal in a living person have appeared (Pavlov et al., 1987; Amadou et al., 2017). At the same time, it was found that the anatomical indicators of stenosis of the spinal canal may not coincide with its clinical manifestations in humans. These circumstances make it necessary to focus attention on the calculation of morphometric and clinical manifestations of stenosis of the spinal canal in animals (Iyer & Kim, 2016) which have degenerative-dystrophic changes in the cervical spine with manifestations of pain and other symptoms of cervical myelopathy (Vilaça et al., 2016; Witiw & Fehlings, 2017; Patel et al., 2020; Teo et al., 2020; Lannon & Kachur, 2021).

It should be noted that insufficient attention is paid to the investigation of spinal canal stenosis processes of in animals. In fact they are not even diagnosed or are clinically detected in the late stages of the disease with extensive clinical signs of myelopathy, chronic pain syndrome and require urgent, not always effective, surgical intervention. In this way, the study of the above-described pathology in animals can provide the latest information about the pathophysiological mechanisms of the development of stenosis of the spinal canal, assess the dynamics of morphological changes in the cervical spine, and identify additional risk factors for this type of disease. Moreover, animals can serve as a more or less adequate model of its course.

The aim of the study was to make the clinical and morphometric comparative analysis of acquired stenosis of the spinal canal in humans and dogs. To achieve this, it was necessary to perform the complex clinical and laboratory examination of patients with intensive pain syndrome associated with cervical stenosis as well as the complex investigation of dogs in which clinical manifestation also coincided with severe pain. Clinical examination included both pain syndrome determination and digitization together with noninvasive neuroimaging methods.

Materials and methods

65 patients aged from 20 to 65 years and 19 dogs weighing more than 20 kg, aged from 1 to 14 years (6.5 ± 4.8 years), were examined. The examined patients complained of pain in the upper back and neck of varying intensity and frequency, numbness in one or both hands, paresthesia of the forearm and distal parts of the upper limbs.

All the manipulations with animals were verified by the local bioethical committee of the A. V. Palladin Institute of Biochemistry of the NAS of Ukraine for the conformity to the recommendations of the European Convention for the Protection of Vertebrate Animals used for Research and Scientific Purposes (Strasbourg, 1986) and the Law of Ukraine "On Protection of Animals from Cruelty" and were ethically acceptable. This study included data from a medical examination of persons who gave written agreement. All laboratory veterinary studies were performed absolutely with the permission of the dog owners. The complex clinical and laboratory studies performed were painless, non-invasive and took into account the individual condition of each patient and dog. Violations of the norms of bioethics were not observed.

Randomization by age in animals coincided with the average age of humans (respectively, 43.4 ± 6.7 versus 41.5 ± 5.2 years), that is, the age of dogs was converted to the age of humans (Tjahjadi & Onibala, 2010; Patel et al., 2020; Teo et al., 2020; Yates, 2021).

The age of dogs was recalculated to human age using the developed formula: human age = 16 x (the natural logarithm of the dog's age) + 31. The calculation of the formula is based on the quantitative translation of aging from dogs to humans by conservative remodeling of epigenetic networks (Wang et al., 2020; Yates, 2021). Thus, the average age of dogs when converted to human age was equal to 41.5 ± 5.2 years, which corresponded to the average human age – 43.4 ± 7.0 years.

We used the control groups to obtain adequate statistical comparative data, which consisted of 14 clinically healthy patients who underwent a preventive medical examination before being hired, as well as 11 clinically healthy dogs, whose owners brought them for vaccinations. The study and control groups of patients and dogs were statistically comparable.

Computed tomography of cervical spine was added to the diagnosis of stenosis of the spinal canal. "Philips MX 8000" ("Philips", Amsterdam, Netherlands) equipment in DICOM mode was used in experimental CT measurement.

For human computed tomography we used "CT Somatom Definition AS" ("Siemens", Munich, Germany) in Dicom mode with the technology of optimal organization of the workflow WorkStream 4D™ and the technology of optimizing the radiation load Care Dose 4D and the standard image processing program Syngo Osteo (Pavlova et al., 2019).

All human and animal computed tomography scans were post-processed to construct multiplanar 3D reconstructions using "Horos Viewer" software for animals and WorkStream 4D™ for image processing. The computed tomography processing algorithm in DICOM mode for examination of the muscle-skeletal system and the spine in particular created the best visualization, which can change patient management and optimize the method of treating patients using additional software options, such as MPR, MIP, MIP thin VRT (multiplanar reconstructions). Morphometric-densometric density measurement of bodies was carried out in Hounsfield units (HU), in the localization of the maximum impact of intervertebral osteochondrosis, which is the peak of physiological lordosis, level C5–C7. The choice of scanning protocols for humans and animals was used according to the generally accepted recommendations of the manufacturer of computed tomography scanners and standardized.

In humans, the position was on the back, arms along the body, maximally extended dorsally, to avoid artifacts when scanning the cervical spine from the denser bones of the shoulder girdle. The position of the animal's body was standard: a dog in sedation with muscle relaxation, lying on its stomach, legs in a physiological position extended, front-forward, rear – along the body. For very large dogs (more than 20 kg), a position on the side is possible, with a pad between the front and rear limbs. In any case, the limbs should be at the same level to achieve maximum symmetry. It is important that in humans, the scanning of the cervical spine is performed at the depth of inspiration with a breath hold, in animals – between phases of breathing, observing the maximum immobi-

lity of the scanning area, which is achieved by general anesthesia with muscle relaxation. In order to obtain the most accurate data during the computed tomography study, all the rules of placing patients with the exact location of the region of interest in the center of the gantry aperture (which is achieved with the help of a laser in two planes) were taken into account in order to reduce the artifacts of the conical X-ray (XR) beam. All human images were obtained with the patients supine relative to the computed tomography table, maximally inspiratory, and the animals were positioned either prone or on their sides in a comfortable position for scanning, under sedation and muscle relaxation.

The subject of the study was comparative characteristics of computed tomography data of the cervical spine in humans, analysis of vertebral bodies – sagittal size (Sag) morphometric data related to the spinal canal diameter (SagD) at the C6 level. When measuring the dimensions of the vertebral canal with a value of 12 mm or less, stenosis of the spinal canal in people was confirmed, in addition, the Pavlov-Torg index was used, which normally amounted to 1 (Tjahjadi & Onibala, 2010; Morales-Avalos et al., 2018). The reserve space was calculated by subtracting the sagittal diameter of the spinal cord from the sagittal size of the spinal canal. As a conditional norm, for each specific patient, the measurement of the Sag morphometric data of the diameter of the body of the C3 vertebra and the width of the spinal canal at this level, which is the widest part of the structure of the C3 spinal canal, was taken. This level, statistically, is the least prone to manifestations of the degenerative-dystrophic process. Level C6–C7, the peak of physiological lordosis, both in humans and in animals, is the most affected and the narrowest anatomically.

Given the complexity of objectification and assessment of pain by the researcher, most methods are based on the patient's statements. The intensity of the pain syndrome in humans was recorded using a 10-point visual analog scale (Stoyanov et al., 2015). It is the most convenient for the patient due to its ease of use, and for the researcher – for fast statistical processing. To assess pain, the patient is offered a scale with a graduation from 0 to 10. To help in assessing pain, explanations were added along the following line "weak, moderate, severe". The distance between the end of the line ("no pain") and the mark made by the patient was measured in cm and rounded. The patient indicates the place on the digital canvas of the ruler, which, in his opinion, corresponds to the intensity of the pain. If the pain is weak, it is registered on the section of the ruler – 1–4 points, moderate – 5–6; strong – 7–10 points (Kharchenko, 2014).

The intensity of the pain syndrome in dogs was recorded according to a five-point visual analog scale (from 0 to 4 points) (Hielm-Björkman et al., 2011), while paying attention to habitus, gait, behaviour, reaction to palpation, body tension (Mathews et al., 2014; Hernandez-Avalos et al., 2019). The scale is actively used in practical veterinary medicine. There is a specialized scale for scoring the severity of pain in dogs. The pain severity score has a range from 0 to 4, i.e. 0 means complete absence of pain, and 4 points – the most severe pain (Hielm-Björkman et al., 2011).

The Pavlov-Torg index ratio was calculated digitally from the two previous measurements to obtain the ratio between the anteroposterior diameter of the vertebral canal and the anteroposterior diameter of the vertebral body (Morales-Avalos et al., 2018). In the same way, a one-way analysis of variance (ANOVA) was conducted to compare different age groups of the same sex (18–39 years vs. 40–59; 18–39 years vs ≥ 60; 40–59 years vs. ≥ 60) for each vertebral level, interpreting a value of $P < 0.05$ as significant.

The data obtained were presented as mean (x) and the standard error of the mean (SE) and were calculated statistically using parametric Bonferroni multiple t-test. The Nonparametric Kruskal-Wallis test was used in the case of statistical calculation of the absolute indexes. The minimum statistical probability was determined at $P < 0.05$.

Results

51 patients (78.5%) were diagnosed with deforming spondyloarthrosis in all those examined on the computed tomography scan; narrowing of intervertebral openings – 47 (72.3%); deforming spondylolisthesis in 30 (46.1%); hypertrophy of the longitudinal and yellow ligaments in 42 (64.6%). The above and the presence of disc protrusion dorsally or dorsolaterally (100.0%), bony outgrowths of the edges of vertebrae and intervertebral joints contributed to stenotic changes of the spinal canal and intervertebral foramina with the development of persistent pain syndrome and neurological deficit (Fig. 1 and Table 1).

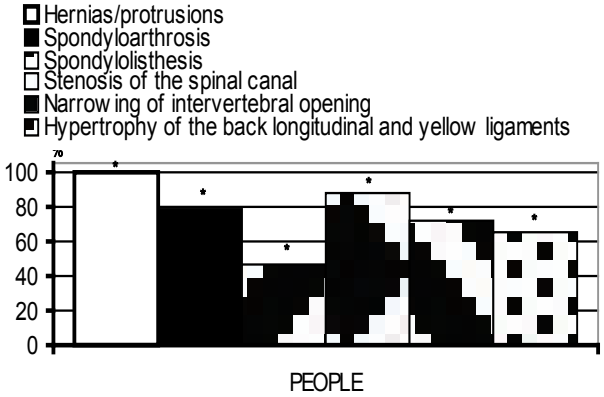

Fig. 1. Relative frequency of registration of degenerative-dystrophic changes in the cervical spine in the people examined: * – $P < 0.05$ – significant differences of the investigated indexes compared with those in clinically healthy patients who were chosen as controls, which were equal to zero index (Bonferroni multiple t-test)

It is important that most patients had a combination of this kind of pathomorphological degenerative change in the bone-cartilage apparatus of the neck, compressing the vertebral artery, ganglia and nerve roots. In addition to static computed tomography scans, 3D standard post-processing multiplanar reconstructions were performed in order to more reliably diagnose the number of spondylolistheses.

Table 1
Organic changes in the degenerative-dystrophic process of cervical spine in humans (absolute indexes)

People	Hernias/ protrusions	Deform. spondyloarthrosis	Deform. spondylolisthesis	Stenosis of the spinal canal	Narrowing of intervertebral openings	Hypertrophy of the posterior longitudinal and yellow ligaments
1. Group of clinical examination, n = 65	36**	51***	30**	49***	47***	42**
2. Control group, n = 14	1	1	1	0	1	2

Notes: ** – $P < 0.01$, *** – $P < 0.001$ – significant differences of the investigated indexes compared with those in clinically healthy patients (Kruskal-Wallis test).

After analyzing the retrospective computed tomography data of humans according to gender, it was determined that the sagittal diameter of the vertebral body depends on gender in all examined subjects (n = 65; the average figure: in men it was 17.8 ± 0.8 mm and in women 14.9 ± 0.5 mm; $P < 0.8$). The mass proportion of stenotic changes of the spinal canal against the background of the degenerative-dystrophic process was found in 21 male persons (n = 25) 84.0%, female – 28 persons (n = 40) 70.0%. Thus, the average width of the spinal canal in men is smaller than in women, so it is possible to assume that stenotic changes in the cervical spine occurred 14.0% more often. According to the Pavlov-Torg index, stenosis of the cervical spine was detected in 75.0% of cases. Morphometric computed tomography data of the cervical spine in people with clinical symptoms of the degenerative-dystrophic process of the cervical spine with signs of stenosis are interpreted as organic changes and may require neurosurgical correction of the pain syndrome (Table 2).

Pain syndrome was the main complaint in all patients. Cervicalgia prevailed in 60 (92.3%), pain in the upper back was registered in 32 (49.2%) patients, irradiation in the upper limbs was characteristic in 32 (49.2%). The intensity of pain according to visual analog scale (Table 3) ranged from 1 to 5 points, the average score was 3.1 ± 0.4 points.

Table 2
Average morphometric measurements in humans (x ± SE)

People	The average (Sag) size of the body of the C_6 vertebra	Diameter (Sag) of the spinal canal at the C_6 level	The number of stenosis according to the Pavlov-Torg index (P < 0.8)
1. Group of clinical examination, n = 65	16.1 ± 0.6*	10.0 ± 0.7*	49 (75.4%)*
2. Control group, n = 14	17.4 ± 0.5	14.2 ± 0.8	1 (7.1%)

Notes: * – P < 0.05 – significant differences of the investigated indexes compared with those in clinically healthy patients (Bonferroni multiple t-test).

Table 3
Average values of pain assessment in people according to visual analog scale (absolute indexes)

People	Cervicalgia	The pain of cervical spine	Irradiation	Visual analog scale x ± SE, point
1. Group of clinical examination, n = 65	60***	32**	32*	3.1 ± 0.3#
2. Control group, n = 14	1	0	2	0.7 ± 0.1

Notes: * – P < 0.05, ** – P < 0.01, *** – P < 0.001 – significant differences of the investigated indexes compared with those in clinically healthy patients (Kruskal-Wallis test); # – P < 0.05 – significant differences of the investigated indexes compared with those in clinically healthy patients (Bonferroni multiple t-test).

In addition to the above-mentioned complaints, weakness in one (14.0–21.5%) or two upper limbs (34.0–52.3%) was found, that is, a total of 48 patients (73.8%). In addition, the following were recorded: muscle atrophy (14.0–21.5%), gait changes (12.0–18.5%), weakness in the legs (13.0–20.0%), fascicular twitching (2.0–3.1%) of people, which is summarized in Table 4.

Table 4
Neurological symptoms in the degenerative-dystrophic process of cervical spine (absolute indexes)

People n=65	Stenosis	Weakness in hands		Numbness	Myalgia	Muscle atrophy	Gait change	Weakness in the legs	Fasciculations
		one	both						
1. Group of clinical examination, n = 65	57***	14**	34**	30**	15**	14**	12**	13*	2*
2. Control group, n = 14	0	1	0	0	1	0	0	1	0

Notes: * – P < 0.05, ** – P < 0.01, *** – P < 0.001 – significant differences of the investigated indexes compared with those in clinically healthy patients (Kruskal-Wallis test).

Motor deficiency in the form of paresis, mainly of the distal parts of the hands, was registered in 48 patients (73.8%), pyramidal symptoms were noted in the legs in 32 (49.2%) patients, pelvic reservoir dysfunction (7.0–10.8%), and sensory disorders were also found (24.0–36.9%). Such manifestations of cervical myelopathy progressed slowly (Table 5). Pyramidal symptoms were more frequent and more pronounced in men.

Table 5
Pyramidal and segmental disorders in stenotic changes of the cervical spine (absolute indexes)

People	Paresis of the upper limbs	Pyramidal symptoms	Disorders of pelvic reservoirs	Sensory disorders
1. Group of clinical examination, n = 65	48***	32**	7*	24**
2. Control group, n = 14	0	0	0	1

Notes: * – P < 0.05, ** – P < 0.01, *** – P < 0.001 – significant differences of the investigated indexes compared with those in clinically healthy patients (Kruskal-Wallis test).

According to the computed tomography scan, degenerative changes of the spine were maximal at the level of the C6 vertebra with the maximum clinical correlation (neurological deficit, pain syndrome, etc.). Taking into account these circumstances, a morphometric analysis of this level was carried out using the Pavlov-Torg index (P < 0.8), which was previously used in MRI studies and X-ray images. In the course of the research, probable stenosis of the spinal canal was found in people on computed tomography images.

In addition to humans, 19 dogs weighing 20 kg or more were examined, whose owners indicated the presence of a pain syndrome in animals (100.0%); behaviour change (100.0%). During the examination, a gait disorder was detected (18.0–94.7%); reaction to palpation of the neck area (15.0–78.9%); the habitus of animals experiencing pain, especially during neck movements (14.0–73.7%), body tension (12.0–63.1%), etc.

In our previous studies, it was found that protrusion of the intervertebral discs (P < 0.05) is significantly more frequent than in small breeds of dogs, and it almost never happens in cats. Thus, the neurological and morphometric condition of the supporting apparatus of the neck of large dog breeds was carefully studied.

Bony outgrowths of the edges of the vertebrae and intervertebral joints were found in almost all dogs of 18 (94.7%) large breeds (P < 0.05) compared to others (see our previous studies). Narrowing of the intervertebral openings, deformation and sclerotic changes of the locking plates, thickening of the yellow and elongated ligaments occurred three to four times more in large breeds compared to dogs weighing less than 20 kg (P < 0.01), and were absent in cats. Stenosis of the spinal canal was detected in 15 (78.9%) dogs (Fig. 2). Manifestations of stenotic changes are regarded as an important factor in the degenerative-dystrophic process and, probably, it is this organic pathology that causes the persistent pain syndrome (Table 6).

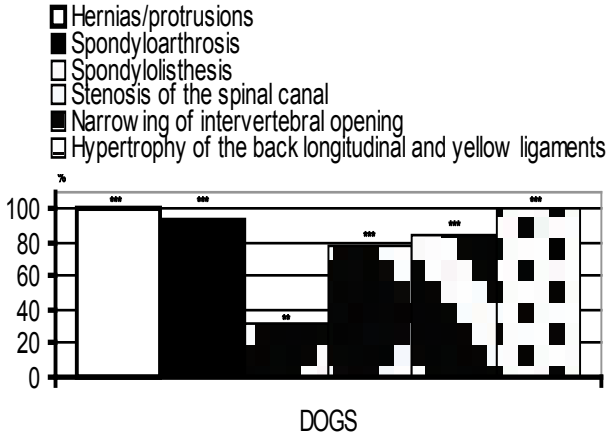

Fig. 2. Relative frequency of registration of degenerative-dystrophic changes in the cervical spine in examined dogs compared with those in clinically healthy dogs which were chosen as controls and were equal to zero index: * – P < 0.05 – significant differences of the investigated indexes compared with those in clinically healthy patients (Bonferroni multiple t-test)

The ratio of the average size of the vertebra to the average diameter was 1.6:1, which is quite similar to the indicators in humans.

As in cases of humans, the pain syndrome was also recorded in animals, and the intensity of pain and behaviour, state and habitus, according to the five-point visual analog scale for dogs, corresponded to the state of algia in humans (Table 7).

Table 6
The number of stenoses, the diameters of the spinal canal at the C6 level in the examined animals (x ± SE)

Dogs, > 20 kg	The average (Sag) size of the body of the C_6 vertebra	Diameter (Sag) of the spinal canal at the C_6 level	The number of stenoses according to the Pavlov-Torg index (P < 0.8)
1. Group of clinical examination, n = 19	14.5 ± 0.9*	9.0 ± 0.7*	17 (89.5%)**
2. Control group, n = 11	16.3 ± 0.6	13.6 ± 0.7	1 (9.0%)

Notes: * – P < 0.05, ** – P < 0.01 – significant differences of the investigated indexes compared with those in clinically healthy patients (Kruskal-Wallis test).

Table 7
Mean values of pain assessment in dogs according to visual analog scale (absolute indexes)

Dogs, > 20 kg	Gait disorder	Palpation reaction	Habitus	Body tension	Behaviour change	Visual analog scale x ± SE, point
1. Group of clinical examination, n = 19	18**	15**	14**	12*	19**	2.6±0.4#
2. Control group, n = 11	1	1	1	2	3	0.5±0.1

Notes: * – P < 0.05, ** – P < 0.01 – significant differences of the investigated indexes compared with those in clinically healthy patients (Kruskal-Wallis test); # – P < 0.05 – significant differences of the investigated indexes compared with those in clinically healthy patients (Bonferroni multiple t-test).

Densification of the locking plates, their deformation and signs of sclerotic changes were found in all examined large breed dogs. Visually and during the objective examination of the animals, changes in habitus, gait, lameness of various types and intensity, depressed behaviour, painful reaction to palpation were revealed (Table 7).

Analysis of dynostatic data in dogs showing discomfort when getting up from a "sitting" or "lying" position was noted in 10 (52.6%) of the examined large dogs; change in statolocomotor function in 8 (42.1%); disorders of pelvic reservoirs in 3 (15.8%). In 15 (78.9%) – a local pain syndrome was detected during palpation of the SCV, probably associated with stenotic changes, root syndrome (Table 8).

Signs of spinal cord damage were observed in the presence of stenosis in 15 examinees (78.9%). Slight weakness of one front limb in 12 (63.1%) examined animals or both front limbs in 3 (15.8%), one and both hind limbs in 4 dogs (21.0%) was detected. Shaking was detected in 10 animals (52.6%; Table 8). Less significant neurological symptoms were also registered, which indicated damage to conductors of the central nervous system, which are located in the spinal cord.

Table 8
Clinical neurological signs of spinal cord injury in a group of dogs (absolute indexes)

Dogs, > 20 kg	Stenosis	Weakness of limbs				Shaking	Problems with getting up	Change in statolocomotor	Disorders of pelvic reservoirs	Fasciculations
		Front		Hind						
		one	both	One	Both					
1. Group of clinical examination, n = 19	15**	12**	3*	2	2	10**	10**	8**	3*	1*
2. Control group, n = 11	0	1	0	1	0	0	1	0	1	0

Notes: * – P < 0.05, ** – P < 0.01 – significant differences of the investigated indexes compared with those in clinically healthy patients (Kruskal-Wallis test).

When morphometry of the width of the spinal canal in animals and calculations were made taking into account the Pavlov-Torg index, most often (78.9%) stenotic pathology was found at the top of the physiological lordosis in the neck area (C6), which was similar to humans. With degenerative changes of the spine on computed tomography scans and segmental neurological deficit clinical pain syndrome, it was determined that in humans, the C6 level had the most computed tomography manifestations (Table 8).

Neurological symptoms in most of their manifestations practically coincided with complaints and objective examination of people and animals. On the basis of the received data on neurological symptoms, a comparison of the complaints of patients and dog owners was made. And also, neurological examination of groups. One could see a significant ratio of these indicators is registered, excluding those clinical manifestations in humans and dogs that are difficult to interpret (Fig. 3).

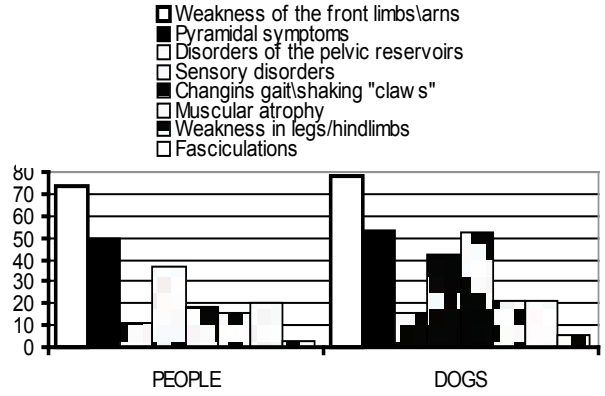

Fig. 3. Neurological symptoms in humans and large breed dogs; relative distribution

Discussion

According to specific indicators, the mass share of stenotic changes of the spinal canal of the cervical spine according to the Pavlov-Torg stenosis index was found in large breed dogs (n = 19) to be 78.9%, which completely coincided with the clinical picture. It was established that the greater the weight of the animal, the more the ventro-dorsal size of the vertebra increases proportionally compared to the sagittal diameter of the spinal canal. Moreover, stenotic pathology was found at the top of the physiological lordosis in the neck area (C6), which was similar to humans, with the maximum clinical correlation.

Most people examined had a combined degenerative-dystrophic pathology of the cervical spine – 100.0% protrusion of the intervertebral discs in the form of circles and protrusions in combination with other manifestations of bone-cartilage tissue damage. Thus, all structures of the musculoskeletal system of the neck are involved in the pathological process.

In dogs of large breeds, similar combined degenerative-dystrophic changes were registered, and in almost all cases, manifestations of spondylolisthesis (94.7%) and hypertrophy of the elongated and yellow ligaments (100.0%) reliably prevailed.

Thus, the studies performed confirm equal pathomorphological processes in the cervical spine, damage to similar structures of the spine (Gembruch et al., 2019; Rahyussalim et al., 2019), especially given the same age in humans and animals (in terms of human age). Such damage to the musculoskeletal system of the neck has an altering compressive effect on a large number of vessels, nerves and ganglia, muscles and directly affects the functional state of the spinal cord as a result of stenosis of the bone case where it is located.

The data obtained clarify the well-known thesis that this type of cervical muscle-skeletal system damage mainly develops in the older age category in humans (Gembruch et al., 2019) and animals (Coates et al., 2010).

In our observations, the average age did not exceed 45 years in humans and animals (in terms of humans), which indicates a significant rejuvenation of degenerative changes in the cervical spine in humans and occurred in almost all large breed dogs. In addition to this, as in humans, stenotic pathology occurred at the top of the physiological lordosis of the neck (C6).

Analysis of the Pavlov-Torg Index, which in the literature was previously used for the analysis of MRI scans and X-ray images, revealed probable stenosis of the spinal canal on computed tomography scans in both humans and dogs (Pavlov et al., 1987; Slynko et al., 2019).

According to the clinical symptoms, first of all, pain syndrome prevailed in the examined groups, which can be interpreted as combined compressions on the neurovascular structures of the neck, vegetative formations. In people, it manifested itself in the form of cervical pain, deep pain in the spine, acute radicular pain with irradiation mainly in the upper limbs. And in animals – by a change in behaviour, antalgic posture, tension of the whole body, the so-called protective gait and reaction to palpation. It is known from the literature that stenosis of of the spinal canal can be confirmed by the manifestations of neurological symptoms in humans (Zhang et al., 2012; Fehlings et al., 2017; Khachatryan & Robinson, 2018) as well as isolated animal sources (Fernandes et al., 2019; Bonelli et al., 2021). Our studies confirmed these propositions and revealed the presence of neurological deficits in humans and expanded the range of symptoms in animals, especially large breed dogs. First of all, clinical manifestations in the form of paresis in the hands come to the fore, which we consider to be the leading syndrome of myelopathy in stenosis of the spinal canal in humans (73.8%) and front paws in dogs (78.9%), at the same time motor deficit as the manifestation of conduction disorders in the spinal cord was less pronounced in the forelegs (20.0%) and hind legs (21.0%) in dogs with gait changes, statolocomotor disorders, etc. It should be noted that the examined groups were less concerned with sensitive disorders, which are also described by Gibson et al. (2018).

Although the way of life of animals is different from the way of life of humans and they have anatomical and physiological differences, they have similarities in pathophysiological processes. Thus, in our study, it was noted that the pain syndrome is influenced by degenerative, stenotic changes occurring in the cervical spine. All these factors interact with each other, affect structural, ischemic, clinical and other manifestations, accelerate aging. Stenotic, organic, pathophysiological and pathomorphological changes in the cervical spine cause dorsalgia, neurological symptoms worsen people's quality of life. If we believe that the degenerative-dystrophic process of the cervical spine can be a predictor of premature aging of young and middle-aged people, then the study of new etiological and pathogenetic mechanisms and the use of large-breed dogs as models can become the most relevant possibility, taking into account the fact that that the age of a dog and the age of a person can be recalculated, which means that physiological processes in dogs take place many times faster. With such modeling, the results of new methods of treating people, with a high probability, can be very promising and useful for studying the etiology and pathophysiological mechanisms of pain, which is likely to improve people's lives.

Conclusions

According to the results of the comparative analysis of cervical spine muscle-skeletal system morphometric data it was found that the acquired stenosis of the spinal canal reliably accompanies neck degenerative-dystrophic changes both in humans and in large-breed dogs. In addition to the elderly, destruction of the muscle-skeletal system was recorded in people already at a young and middle age as well as in a similar age range, mainly in dogs of large breeds. At the same time, clinical manifestations of cervical myelopathy with predominant persistent pain syndrome are likely to develop in the examined people and animals. Most often, stenotic changes were registered at the level of the body of the C6 vertebra in humans and dogs. According to morphometric parameters – the Pavlov-Torg stenosis index, they reliably coincided with clinical manifestations: 87.7% in humans and 78.9% in large breed dogs.

It was found that for modeling degenerative-dystrophic changes in the cervical spine, it is necessary to involve dogs of large breeds weighing more than 20 kg. At the same time, it is possible to significantly reduce the time of experimental research and the cost of it, as well as to adequately extrapolate the obtained data to people.

The obtained data indicate the expediency of introducing computed tomography methods, modifying existing ones, including morphometric indices, into veterinary practice, which is effective, economically beneficial and has the most humane approach.

Despite the fact that degenerative-dystrophic processes are an age-dependent pathology in both humans and animals, it is necessary to pay special attention to the mechanisms of their formation and features at an earlier age, to find predictors of their occurrence, etc.

Further studies on the stenosis of the spinal canal model against the background of degenerative-dystrophic processes in large breed dogs will allow one to predict the course and progression of damage to the cervical spine, because physiological and pathophysiological processes in dogs are much faster than in humans. In addition, in order to increase the reliability of the research, it is promising to take into account that the degree of expressiveness of the process, clinical and morphometric data of the cervical spine of animals depend on the species, breed, weight, and age of animals. It is also advisable to experimentally study the processes of aging in the spine using morphometric data in animals because they may be common factors in the development of degenerative-dystrophic changes in humans and some groups of animals that can be predictors of aging of the organism as a whole.

The authors declare that they have no conflict of interest.

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