Computed tomography findings in a cohort of 169 dogs with elbow dysplasia

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Abstract

Background: Canine elbow dysplasia (CED) is a complex developmental skeletal disorder associated with a number of pathological conditions within the cubital joint in dogs. Complex primary conditions associated with CED included medial coronoid disease without fragmented medial coronoid process, medial coronoid disease with fragmented medial coronoid process, osteochondrosis and/or osteochondrosis dissecans, ununited anconeal process, and joint incongruency and may be identified separately as a singular cause of elbow dysplasia, or occur as a combination of lesions presented simultaneously.

The objective of this study was to assess the percentage prevalence of different components of CED in dogs suffering from this condition with the use of CT imaging. In addition, the correlations between various CED lesions and demographic features of the tested dogs were investigated.

Results: 169 dogs of various breeds met the inclusion criteria. Statistically significant differences were found between the age of affected dogs in individual weight groups. Moreover, the significant correlation between weight and age in the cohort of large-size dogs with CED was noted. In 96 dogs OA of varying severity was found. 11.6% of dogs were diagnosed with unilateral CED and 88.4% suffered from bilateral CED. The majority of dogs diagnosed with CED were young with an average age of 2.26 ± 0.18 years old. Significant differences in the occurrence of CED components in different-size groups were also noted. Males represented the majority in this study population.

Conclusion: CT-imaging allowed for the assessment of the prevalence of CED components in affected dogs of different breeds. The use of CT imaging as a screening test in puppies of the breeds of which CED is the most prevalent facilitates the selection of dogs with joint incompatibility, which increases the risk of MDC, at time when no other changes are present. An early diagnosis of the mentioned pathology may allow for the introduction of less invasive therapeutic strategies, ensuring the improvement of joint biomechanics. The correlation between different components of CED and demographic features found in our study may provide valuable prognostic criteria and help in the future identification of various risk factors or therapeutic strategies.

Background

Canine elbow dysplasia (CED) is a prevalent health issue that affects many breeds, particularly medium to large sized dogs, however it is also reported in smaller chondrodystrophic breeds like the Dachshund and French bulldog [1, 2, 3]. Elbow dysplasia is relatively common in dogs and has a reported prevalence of 17% in UK Labradors [4, 5], 70% in Bernese mountain dogs [6], 13% in Belgium Labradors and 26% in Belgium Newfoundlands [7]. Several research reports confirmed that certain breeds tend to be affected by a particular entity more frequently than others [2, 7, 8].

CED is a complex developmental skeletal disorder associated with a number of pathological conditions within the cubital joint in dogs [1, 9, 10]. Complex primary conditions associated with elbow dysplasia included medial coronoid disease without fragmented medial coronoid process (MCD), medial coronoid disease with fragmented medial coronoid process (FMCP), osteochondrosis (OC) and/or osteochondrosis dissecans (OCD), ununited anconeal process (UAP), and joint incongruency (INC) and may be identified separately as a singular cause of elbow dysplasia, or occur as a combination of lesions presented simultaneously [1, 11].

Elbow dysplasia can cause severe lameness, and arthroscopic treatments do not palliate pain in all affected dogs [12, 13]. Because CED is a heritable disease, it is very important to identify and remove the affected animals from breeding to decrease the prevalence of CED in dogs. Although some lesions, including UAP and OCD of the humerus,

are quite often successfully identified on plain radiographs, appropriate diagnosis of the MCD or FMCP may be less straight-forward due to superimposition of medial epicondyle and muscle tissue [14]. Computed tomographic imaging is recognized as a high-sensitivity tool that allows for a detailed visualization of the skeletal components of the joints [11, 15, 16, 17]. Moreover, computer tomography (CT) enables not only detection but also monitoring of progression in elbow dysplasia [16]. Recently, the use of CT has become increasingly widespread in veterinary medicine. Current data indicate that various components of CED (i.e. MDC) might be detected as early as 14 weeks of age. Early diagnosis is important from a therapeutic point of view, as lesions must be detected before severe osteoarthritis (OA) develops to achieve the most effective treatment outcomes [18]. However, the number of CT - based studies assessing prevalence of different CED lesions in dogs, including dogs of different breeds is limited [19, 20]. Evaluation of potential correlations between certain components of CED and specific demographic and/or phenotypic features may allow for more appropriate research in the future and ultimately lead to the identification of new risk factors and underlying molecular mechanisms [21].

The objective of this study was to assess the percentage prevalence of different components of CED in dogs suffering from this condition with the use of CT imaging. In addition, the correlations between various CED lesions and demographic features of the tested dogs were investigated.

Methods

Animals

The study was conducted on 169 dogs of different breeds admitted to the small animal veterinary clinic (Klinika Psia i Kota, Wrocław, Poland) from February 2012 to November 2018, for diagnostic CT imaging due to bilateral or unilateral elbow lameness. Only dogs diagnosed with CED were included in the study. Animals with non-CED associated elbow lameness, were excluded from the investigation. The exclusion criteria were non-CED associated elbow lameness (i.e. traumatic bone or soft tissue injury within this region, lameness due to neurological conditions). In addition, dogs with coexisting metabolic conditions that may have resulted in significant risks for anesthesia were also excluded from the study.

Study design

For each dog the following data were gathered: breed, age, sex and weight. Detailed characteristics of dogs included in the study are presented in Table 1. 169 dogs with CED were divided into three different size categories: medium (11–25 kg, n = 16), large (26–44 kg, n = 120) and extra-large (≥ 45 kg, n = 31).

Table 1

Characteristics of dogs included in the study. Data were collected from 169 dogs with canine elbow dysplasia

Breed	Number of included dogs	Median age years (range)	Sex (number) males/females	Median weight kg (range)
Labrador Retriever	43	1.5 (0.4–10)	36/7	35.16 (25–47)
German Shepherd Dog	40	0.91 (0.4-9.0)	29/11	36.74 (29–50)
Bernese Mountain dog	15	1 (0.5–6.5)	12/3	42.4 (33–55)
Chow Chow	6	1.04 (0.4-3.0)	4/2	22.5 (15–28)
Boxer	5	6 (2.0–9.0)	2/3	33 (19–40)
Golden Retriever	5	0.58 (0.4–3.5)	3/2	28.6 (19–36)
Dog de Bordeaux	5	3.5 (0.5–6.0)	3/2	52.4 (27–70)
Cane Corso	5	0.83 (0.4–3.0)	4/1	39.8 (26–50)
White Swiss Shepherd	4	0.7 (0.5–1.0)	4/0	31 (28–33)
Rottweiler	4	1.4 (0.5–6.0)	3/1	44 (39–52)
American Staffordshire Terrier	3	4.5 (1–10)	3/0	30.3 (29–32)
Polish Tatra Sheepdog	3	0.66 (0.58–3.0)	2/1	44.3 (32–61)
Bouvier des Flandres	3	0.83 (0.4–3.0)	2/1	37.3 (35–41)
English Bulldog	3	0.83 (0.8–3.0)	3/0	33.3 (24–44)
Mix-breed	2	3 & 7.5	2/0	37 & 35
Newfoundland	2	0.66 & 1.0	2/0	61 & 60
Caucasian Shepherd	2	0.4 & 1.5	2/0	20 & 50
Eurasian Shepherd	2	0.5 & 2.0	1/1	47 & 68
Pitbull	2	0.4 & 0.5	1/1	20 & 25
Argentinian Mastiff	2	1 & 3.0	2/0	58 & 59
Border Collie	1	1.5	1/0	23
Bullmastiff	1	0.66	1/0	50
Australian Cattle dog	1	2.0	0/1	23

Breed	Number of included dogs	Median age years (range)	Sex (number) males/females	Median weight kg (range)
Beagle	1	5.0	1/0	23
St. Bernard	1	0.5	1/0	40
American Bully	1	0.58	1/0	26
Great Dane	1	1.5	0/1	36
Greater Swiss Mountain	1	1.0	1/0	51
Flat Coated Retriever	1	1.0	1/0	30
Spanish Mastiff	1	0.75	0/1	60
Shar-pei	1	1.0	0/1	25
Giant Schnauzer	1	1.5	1/0	42
Spanish Alano	1	0.5	0/1	52

All dogs underwent physical and orthopedic examinations followed by a complete blood count and serum biochemistry tests. The assessment of mobility function and presence of lameness was performed by a veterinary surgeon. All study participants were able to walk without assistance.

Owners obtained a written description of the study and they provided written informed consent for the inclusion of their dogs in the study.

CT imaging and analysis

The prevalence of lesions such as: UAP, OCD, MCD, FMCP, radio-ulnar incongruence (INC R-U); humero-ulnar incongruence (INC H-U) and panosteitis (PANOS) was estimated on the basis of the results of CT imaging. MCD and FMCP lesions were analyzed separately. The degree of OA was also assessed based on International Elbow Work Group (IEWG) guidelines [22]. A total of 338 elbow joints was screened with CT-imaging.

CT images were obtained with a 2-slice helical scanner (Twin, Elscint, Israel) and 16-slice helical scanner (Somatom, Siemens, Germany) using 120 kVp or 110 kVp, 100 mA, pitch 0.8 and reconstructed slices were 0.6 mm with an overlapping slice index of 0.5 mm for reconstructing the imaging planes, after initial the scan. Dogs were sedated with intramuscular injection (*i.m.*) of medetomidine in a dose of 5–20 µg (micrograms)/kg and butorphanol (0.1–0.4 mg/kg). Induction was obtained with propofol in a dose of 3.2 mg/kg of body weight administered intravenously followed by endotracheal tube placement. Isoflurane and 100% oxygen were used for anesthesia maintenance. Dogs were placed in sternal recumbency with both thoracic limbs extended cranially and head was shifted out of the gantry to avoid potential artefacts. DICOM files of each scan were analyzed by an experienced veterinary radiologist using 3D MPR tool in OsiriX (64-bit software, Pixmeo, Geneva, Switzerland) to evaluate the scans in sagittal and dorsal planes.

The level of OA in each elbow joint was scored according to IEWG [22] and the following scores were assigned: 0 - normal elbow joint (no evidence of incongruity, sclerosis or arthrosis); 1- mild arthrosis or suspect primary lesion (presence of osteophytes < 2 mm, sclerosis of the base of the coronoid processes - trabecular pattern still visible); 2-

moderate arthrosis (presence of osteophytes 2–5 mm, obvious sclerosis (no trabecular pattern) of the base of the coronoid processes, step of 3–5 mm between radius and ulna (incongruity), indirect signs for other primary lesion (UAP, FMCP/coronoid disease, OCD); 3- severe arthrosis or evident primary lesion (presence of osteophytes > 5 mm, step of > 5 mm between radius and ulna (obvious incongruity), obvious presence of a primary lesion (UAP, FMCP, OCD) (8).

Statistical Analysis

The obtained data were subjected to the W. Shapiro-Wilk test for normality and the Levene's test for equality of variances. The Welch's test with Dunnett's post-hoc test for multiple groups, and two-way ANOVA with Tukey's post-hoc test were used. Correlation was determined using Spearman's rank correlation. Differences were considered as significant with $\alpha < 0.05$. All calculations were performed with GraphPad 8 Software (Prism, La Jolla, CA)

Results

Dogs characteristics

169 dogs of various breeds met the inclusion criteria (41 females and 128 males). Thirty one pure breeds were represented. In addition, two mix-breed dogs were included. Dogs ranged in age from 0.4 to 10.0 years (median age 2.26) and in body weight from 15.0 to 70.0 kg (median weight 36.0 kg). Demographic features of each dog are presented in Table 1. Sixteen dogs were classified as medium in weight, 120 as large, and 31 as extra-large dogs. Statistically significant differences were found between the age of affected dogs in individual weight groups (medium vs. large $p = 0.02$; medium vs. extra-large $p = 0.036$). Moreover, the significant correlation between weight and age in the cohort of large-size dogs with CED was noted (Spearman $r = 0.31$, $p = 0.0004$).

German Shepherd dogs (GSD), Labrador Retrievers and Bernese Mountain Dogs were most frequently presented with CED-associated lameness. In addition, patients belonging to these breeds represented the majority of the subjects within the cohort of large-size dogs, with weights ranging between 29.0 and 50.0 kg for GSD, 20.5 and 47.0 kg for Labrador Retrievers, and 33.0 and 50.5 kg for Bernese Mountain Dogs. The significant correlation between weight and age within these breeds (Spearman correlation: GSD $r = 0.39$, $p = 0.0125$; Labrador Retrievers $r = 0.56$, $p = 0.0001$; Bernese Mountain Dogs $r = 0.45$, $p = 0.0342$) were found.

In 73 dogs no signs of OA were observed, while in the other 96 animals OA of varying severity was found. Within dogs with OA, 48/169 (28.40%) were assigned a grade 1; 21/169 (12.43%) were assigned a grade 2; 27/169 (15.97%) were assigned a grade 3.

11.6% of dogs were diagnosed with unilateral CED and 88.4% suffered from bilateral CED. Two dogs (1.18%) were identified with bilateral panosteitis and four (2.37%) with unilateral panosteitis in addition to CED lesions.

The percentage distribution of CED lesions across the population of dogs included in the study is shown in Fig. 1.

The majority of dogs diagnosed with CED in our study were young with an average age of 2.26 ± 0.18 years old. Several breeds, including Boxers, Dog de Bordeaux, American Staffordshire terriers and Mix-breeds, were presented later in the course of their lifespan. Mean age in these groups was: 5 ± 1.3 years for boxers; 5.2 ± 2.25 years for crossbreed dogs; 5.16 ± 2.6 years for American Staffordshire terriers and 3.1 ± 1.1 years for Dog de Bordeaux group. Significant differences in the occurrence of CED components in different-size groups were found ($p < 0.0001$).

Prevalence of CED components within breeds and in single-digit breed representants is presented in Tables 2 and 3, respectively.

Table 2
Prevalence (%) of CED components within breeds

Breed	Prevalence of CED lesions within breeds (%)											
	Left elbow joint						Right elbow joint					
	INC R-U	INC H-U	OCD	MCD	FMCP	UAP	INC R-U	INC H-U	OCD	MCD	FMCP	UAP
Labrador Retriever	20.9	48.8	9.3	44.1	39.5	0	23.2	48.8	11.6	30.2	48.8	0
German Shepherd Dog	45	77.5	0	32.5	30	15	47.5	80	2.5	35	42.5	15
Bernese Mountain dog	53.3	86.6	6.6	33.3	53.3	13.3	60	86.6	6.6	13.3	66.6	6.6
Chow Chow	50	100	33.3	0	100	0	33.3	100	33.3	0	100	0
Golden Retriever	0	40	40	20	0	0	20	60	40	40	0	0
Boxer	33.3	16.6	0	33.3	33.3	0	33.3	33.3	0	16.6	50	0
Cane Corso	40	80	0	0	60	20	20	100	0	0	60	40
Dog de Bordeaux	0	60	40	40	40	0	0	80	40	60	20	0
Rottweiler	25	75	25	50	25	0	25	100	25	100	0	0
White Swiss Shepherd	25	50	0	25	0	0	0	75	0	25	50	0
American Staff. Terrier	66.6	33.3	100	100	0	0	33.3	0	0	33.3	0	0
Bouvier des Flandres	66.6	100	33.3	33.3	66.6	0	33.3	66.6	66.6	66.6	33.3	0
Polish Tatra Sheepdog	33.3	66.6	33.3	0	66.6	0	33.3	66.6	0	33.3	33.3	0
English Bulldog	33.3	0	0	33.3	0	0	0	0	0	33.3	66.6	0
Eurasian Shepherd	0	50	0	50	0	0	50	100	0	50	0	50
Mix-breed	0	50	0	50	50	0	50	100	0	50	50	50
Caucasian Shepherd	0	100	0	0	50	50	0	100	0	100	0	50
Newfoundland	100	100	50	50	50	0	100	100	50	50	50	0

CED – canine elbow dysplasia; INC R-U – radio-ulnar incongruence; INC H-U – humero-ulnar incongruence; FMCP – medial coronoid disease with fragmented medial coronoid process; OCD – osteochondrosis dissecans within the medial compartment of humeral condyle coronoid process; MCD – medial coronoid disease without fragmented medial coronoid process (pathological cartilage and or subchondral bone); UAP – ununited anconeal process; 0 – no lesion.

Breed	Prevalence of CED lesions within breeds (%)											
	Left elbow joint						Right elbow joint					
	INC R-U	INC H-U	OCD	MCD	FMCP	UAP	INC R-U	INC H-U	OCD	MCD	FMCP	UAP
Argentinian Mastiff	50	100	0	100	0	0	50	100	0	100	0	0
Pitbull	0	0	0	0	0	0	0	0	0	50	0	0
CED – canine elbow dysplasia; INC R-U – radio-ulnar incongruence; INC H-U – humero-ulnar incongruence; FMCP – medial coronoid disease with fragmented medial coronoid process; OCD – osteochondrosis dissecans within the medial compartment of humeral condyle coronoid process; MCD – medial coronoid disease without fragmented medial coronoid process (pathological cartilage and or subchondral bone); UAP – ununited anconeal process; 0 – no lesion.												

Table 3
Types of CED lesions in single-digit breed representants.

	Left elbow joint						Right elbow joint					
Flat Coated Retriever	0	INC H-U	0	MCD	0	0	0	0	0	0	0	0
Bullmastiff	INC R-U	INC H-U	0	0	0	0	INC R-U	INC H-U	0	MCD	0	0
Spanish Mastiff	0	INC H-U	0	0	FMCP	0	0	INC H-U	0	0	FMCP	0
Border Collie	0	0	0	0	0	0	0	INC H-U	0	MCD	0	0
Shar-pei	0	INC H-U	0	0	0	UAP	INC R-U	0	0	MCD	0	0
Giant Schnauzer	0	0	0	MCD	0	0	0	INC H-U	0	MCD	0	0
Spanish Alano	INC R-U	INC H-U	OCD	MCD	0	0	INC R-U	INC H-U	OCD	MCD	0	0
American Bully	0	INC H-U	0	MCD	0	0	INC R-U	0	0	MCD	0	0
Australian Cattle dog	INC R-U	0	0	MCD	0	0	0	0	0	0	0	0
Beagle	INC R-U	0	0	0	FMCP	0	0	0	0	MCD	0	0
St. Bernard	0	INC H-U	0	0	0	UAP	0	INC H-U	0	0	0	UAP
Great Dane	0	INC H-U	0	0	FMCP	0	0	0	0	MCD	0	0
Greater Swiss Mountain	0	0	0	MCD	0	0	0	INC H-U	0	MCD	0	0
CED – canine elbow dysplasia; INC R-U – radio-ulnar incongruence; INC H-U – humero-ulnar incongruence; FMCP – medial coronoid disease with fragmented medial coronoid process; OCD – osteochondrosis dissecans within the medial compartment of humeral condyle coronoid process; MCD – medial coronoid disease without fragmented medial coronoid process (pathological cartilage and or subchondral bone); UAP – ununited anconeal process; 0 – no lesion.												

Discussion

In the present study the CT imaging was used for assessing the prevalence of various CED components in dogs affected by CED. Moreover, the relationship between specific demographic features and CED components in a cohort

of 169 dogs was analyzed. Taking into account the hereditary occurrence of elbow dysplasia in dogs [23], it is very important to have diagnostic techniques allowing for a precise diagnosis of all CED cases, which will ensure a proper identification of animals with dysplasia and their elimination from breeding. Particularly, some earlier studies have demonstrated that CT is more sensitive in detection of MCD compared to radiographs [15, 16, 17]. It is widely accepted that CT is of a higher diagnostic quality for diagnosing elbow dysplasia, the IEWG currently does not recognize a standardized method of obtaining CT images of the elbow to be used in the screening process [1]. On the other hand it is known, that the joint congruency may be affected by positioning and slice thickness of the CT used. The researches within this area are needed to evaluate and elaborate the most accepted and accurate protocol for CED screening using CT. The prevalence of CED could be decreased with more widespread and accurate screening of the parents and/or more cautious selection of dogs for breeding. The early diagnosis will also contribute to better treatment outcomes [18].

Computed tomography imaging performed in a large cohort of CED - affected dogs allowed for assessment of prevalence of different CED components for each breed and across the whole population of dogs included in this study. In accordance with previous findings, in the present study the elbow dysplasia was more common in males than in females. [20]. It is hypothesized that sex distribution is associated with dominant inheritance within male lineage [24]. The demographic data demonstrate inclusion of dogs of typical breeds (mostly large breeds) affected by CED, with wide range in age and severity of pathology. In our study, similarly to data presented previously [25], Labrador Retrievers and GSD were within the most represented breeds in the veterinary clinic due to CED-associated lameness. In addition to CED, approximately 75% of dogs included in our study have been diagnosed with concurrent OA of different degrees. Previous findings indicated that OA may develop as a primary lesion, although presence of degenerative changes is often directly associated with development and progression of CED [26].

Our study showed that 11.6% of dogs were diagnosed with unilateral CED and 88.4% suffered from bilateral CED. Humero-ulnar incongruence was identified as the most frequently identified CED-lesion across all breeds of dogs included in our study population. In our study, approximately 40% of dogs diagnosed with humero-ulnar incongruence were identified with MCD via CT imaging. Similar results were observed by Mostafa et al. (2019) in the study investigating populations of Labrador Retrievers and Golden Retrievers with the use of radiograph evaluation. In the mentioned study, the co-presence of humero-ulnar incongruence with MCD was also observed [14].

Radio-ulnar incongruence was detected in 39.6% of dogs included in the present study, and approximately 50% of dogs with this lesion exhibited co-presence of fragmented medial coronoid process. Previous studies conducted by Eljack et al. (2013) showed, that up to 60% of dogs diagnosed with radio ulnar incongruence were simultaneously affected by the medial coronoid disease, which complies with our findings [27]. Interestingly, 100% of the Chow Chow's recruited into our study (n = 6) were simultaneously identified with humero-ulnar incongruence and fragmented medial coronoid process. This may be associated with generally higher heritability values for this breed as has been shown previously [1]. Osteochondrosis dissecans (OCD) was detected in 11.24% of dogs and was always accompanied by other CED lesions. United anconeal process (UAP) was the least frequently identified lesion in our study population and accounted for approximately 9.46%. Similar prevalence for both OCD and UAP was reported in previous reports [8]. Concurrent occurrence of FCMP and UAP was previously reported to be rather sporadic findings [28, 29, 30]. In the present study similar results were found. The simultaneous presence of FCMP and UAP was observed only in 3 dogs (GSD, Bernese Mountain Dog, Cane corso). Interestingly, several breeds were presented with CED - associated lameness in older age than others in the present study. Specifically, Boxers, Dog de Bordeaux, American Staffordshire Terriers and crossbreed dogs have been identified as a late-life CED onset group. The age-associated peak for CED has been reported previously [31]; however, the data describing specific breeds are

limited. Due to a small number of dogs from breeds which represented late-onset of CED in our study (5 Boxers, 5 Dog de Bordoux, 3 American Staffordshire Terriers and 2 crossbreed dogs) more research is needed to confirm these findings.

To summarize, the various CED lesions were found across the population of dogs included in the present study. INC H-U, FMCP and MCD were found to be the most common (in 129, 92 and 89 dogs, respectively). OCD and UAP were the least frequently identified pathologies (in 19 and 16 dogs, respectively). The correlation between different components of CED and demographic features found in our study may provide valuable prognostic criteria and help in the future identification of various risk factors and relevant therapeutic strategies. The use of CT imaging as a screening test in puppies of the breeds of which CED is the most prevalent (Labrador, GSD, Bernese Mountain Dog) facilitates the selection of dogs with joint incompatibility, which increases the risk of MDC, at time when no other changes are present. An early diagnosis of the mentioned pathology may allow for the introduction of less invasive therapeutic strategies, ensuring the improvement of joint biomechanics [32].

List Of Abbreviations

3D MPR – 3D multiplanar reconstruction

CED – canine elbow dysplasia

CT – computed tomography

FMCP - fragmented medial coronoid process (as a medial coronoid disease with fragmented medial coronoid process)

IEWG - international elbow work group guidelines

INC H-U – humero-ulnar incongruence

INC R-U – radio-ulnar incongruence

MCD - medial coronoid disease (without fragmented medial coronoid process)

PANOS – panosteitis

OA - osteoarthritis

OC - osteochondrosis

OCD – osteochondrosis dissecans

UAP - ununited anconeal process

Declarations

Ethics approval and consent to participate

According to the Act on the Protection of Animals Used for Scientific or Educational Purposes in Poland adopted on 15th January 2015 and according to earlier regulations the study described in this manuscript did not require

permission of the Local Ethical Commission for Investigations on Animals. Written informed consent to participate was obtained from the all participants.

Consent for publication

Written informed consent for publication of their clinical details and images was obtained from all the owners of the patients.

Availability of data and material

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Authors' contributions

MH - participated in designing and coordination of the study, performed clinical examination, blood tests, computed tomography scans, collected the data, writing – original draft, writing - review & editing; WKP - participated in designing, coordination of the study and drafting the manuscript, writing - review & editing; JJR - did research on available knowledge about the topic, writing – original draft, writing - review & editing; MN - performed statistical analysis, writing - review & editing, DN - collected the data, writing - review & editing; KCP - performed statistical analysis, writing - review & editing; AMN - participated in designing, coordination of the study, writing - review & editing; MK - participated in the data collection, writing – original draft, MPM - analysis and interpretation of data, writing - review & editing, critical revision. All authors read and approved the final manuscript.

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Not Applicable

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Figures

Figure 1

Frequency of CED-lesions (%) across tested population of dogs included in the study. INC R-U – radio-ulnar incongruence; INC H-U – humero-ulnar incongruence; FMCP – fragmented medial coronoid process; OCD – osteochondrosis dissecans within the medial compartment of humeral condyle coronoid process; MCD – medial coronoid disease without fragmented medial coronoid process (pathological cartilage and or subchondral bone); UAP – ununited anconeal process.

Figure 2

Sagittal MPR image was established via alignment of external borders of humerus and ulna on a dorsal plane (red lines).

Figure 3

Sagittal and dorsal plane MPR reconstructions (A and B) were used for the evaluation of radio-ulnar incongruence.

Figure 4

Transverse plane MPR reconstruction (C) at the level of medial coronoid process of the ulna (borders marked with red line) was used for the assessment of MCP pathology.

Figure 5

Sagittal CT slice (MPR reconstruction), showing three ulnar measurement loci (distances measured between green lines) for the assessment of humero-ulnar incongruence (INC H-U). Same slice has been used to evaluate ununited anconeal process (UAP), (borders marked with red dotted line).