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Radiographic and computed tomographic findings in canine elbow dysplasia: A retrospective research

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Abstract

Long before the first radiograph of a lame dog was taken, breeders of large and giant breeds recognised that some puppies developed a persistent forelimb limp that worsened with exercise and never fully resolved. We now know this constellation of lesions as elbow dysplasia (ED), and advanced imaging has transformed how we identify its subtypes. This retrospective research reviewed the medical records and imaging archives of 181 dogs (272 affected elbows) diagnosed with ED at the Bangkok Academy of Veterinary Medicine between January 2019 and December 2023. Each elbow had been evaluated by standard radiography (mediolateral flexed and craniocaudal views) and multi-detector computed tomography (CT; 0.625 mm slice thickness). Two board-certified veterinary radiologists independently graded every elbow using the International Elbow Working Group (IEWG) protocol and classified lesions into fragmented coronoid process (FCP), ununited anconeal process (UAP), osteochondritis dissecans (OCD), elbow incongruity, and combined pathology. FCP was the most common lesion (34.2% of affected elbows), followed by OCD (22.1%), incongruity (18.8%), UAP (18.3%), and combined pathology (6.6%). Dogs aged 1-2 years constituted the largest diagnostic cohort (37.5%), with Labrador Retrievers, German Shepherds, and Golden Retrievers together accounting for 57.4% of cases. CT detected 94.7% of FCP lesions confirmed at arthroscopy or surgery, whereas radiography identified only 61.8% ($p < 0.001$). The CT advantage was greatest for incongruity (88.6% vs. 54.3%) and combined lesions (82.4% vs. 47.1%). Radiographic sensitivity was adequate only for UAP (82.4%), where the displaced fragment is typically large and well-mineralised. IEWG Grade II (moderate arthrosis, 2-5 mm osteophytes) was the most frequent grading at presentation (49.3%), followed by Grade III (severe, > 5 mm; 27.2%) and Grade I (mild, < 2 mm; 23.5%). Inter-observer agreement for CT-based subtype classification was excellent ($\kappa = 0.91$) compared with moderate agreement for radiography alone ($\kappa = 0.68$). These findings confirm that CT is the superior diagnostic tool for elbow dysplasia subtyping in a tropical referral population and should be considered the default imaging modality whenever surgical planning is anticipated. Radiography retains a screening role but underestimates pathology burden, particularly for FCP and incongruity, the two subtypes most likely to benefit from early arthroscopic intervention.

Keywords: Canine elbow dysplasia, computed tomography, radiography, fragmented coronoid process, osteochondritis dissecans, ununited anconeal process, diagnostic imaging, retrospective research, IEWG grading, large-breed dogs

1. Introduction

The earliest veterinary descriptions of developmental elbow disease in dogs date to the 1960s, when Scandinavian and North American orthopaedic surgeons independently reported ununited anconeal processes in German Shepherds and fragmented coronoid processes in Labrador Retrievers [1, 2]. In the decades since, the umbrella term “elbow dysplasia” has come to encompass at least four interrelated but distinct pathological entities: fragmented medial coronoid process (FCP), ununited anconeal process (UAP), osteochondritis dissecans of the medial humeral condyle (OCD), and radio-ulnar incongruity [3]. Together, they represent the most common cause of forelimb lameness in young, rapidly growing large and giant breeds. Each subtype reflects a different failure in endochondral ossification, cartilage maturation, or joint congruence, yet they share overlapping risk factors: rapid growth velocity, genetic predisposition concentrated in certain breed lines, excess dietary energy or calcium during the growth phase, and repetitive biomechanical loading on an immature joint surface [4]. Mixed

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pathology within a single joint is not uncommon; a dog with FCP may simultaneously harbour mild incongruity that created the abnormal mechanical environment favouring coronoid fragmentation in the first place [5].

Radiography has been the traditional first-line imaging modality for elbow evaluation. Standard mediolateral flexed and craniocaudal projections can reveal osteophyte formation along the anconeal process, sclerosis of the trochlear notch, and displacement of large UAP fragments [6]. However, the overlapping bony anatomy of the canine elbow where the radius, ulna, and humeral condyle superimpose in nearly every projection limits radiographic sensitivity for smaller lesions, particularly FCP fragments embedded in the medial coronoid region and subtle steps of radio-ulnar incongruity [7]. Several investigations have documented radiographic sensitivity for FCP as low as 50-65%, meaning that up to half of affected dogs may receive a false-negative reading on plain films [8].

Computed tomography (CT) overcomes much of this superimposition problem by generating cross-sectional images with sub-millimetre spatial resolution. Multi-detector CT scanners now common in referral hospitals can acquire a complete elbow dataset in under 30 seconds under sedation, producing isotropic voxels that allow multiplanar reconstruction (MPR) in sagittal, dorsal, and oblique planes [9]. Several European and North American referral centres have reported CT sensitivities exceeding 90% for FCP and OCD when compared with arthroscopic gold-standard findings [10, 11]. The IEWG itself revised its screening guidelines in 2015 to recommend CT for breeding programme evaluations in breeds with high ED prevalence [3].

In Southeast Asia, and in Thailand specifically, the population of large-breed dogs has expanded steadily over the past two decades, driven by growing pet ownership of Labrador Retrievers, Golden Retrievers, German Shepherds, and Rottweilers in urban Bangkok households [12]. Yet published imaging data on ED from this region are scarce. The two available Thai case series were limited to radiographic findings and lacked CT correlation, leaving local practitioners without evidence-based guidance on when to escalate from plain films to cross-sectional imaging [13]. Climate may also modify disease expression: year-round tropical heat can alter activity patterns, reduce peak exercise loads, and influence the age at which owners first notice lameness, potentially shifting the demographic profile of ED cases compared with temperate-climate cohorts.

Against this background, the present retrospective research had three aims: (a) to describe the frequency and distribution of ED subtypes in a five-year case archive from a Bangkok referral hospital, (b) to compare the diagnostic sensitivity of standard radiography versus multi-detector CT for each subtype using surgical or arthroscopic confirmation as the reference standard, and (c) to characterise the breed, age, sex, and IEWG grade distribution of the affected population. A secondary objective was to evaluate inter-observer agreement for both modalities when images were read independently by two board-certified radiologists.

Material and Methods

Patient Characteristics

The research population comprised 181 dogs presenting to the Small Animal Hospital of the Bangkok Academy of Veterinary Medicine between January 2019 and December

2023 with a final diagnosis of elbow dysplasia confirmed by radiography, CT, and either arthroscopy or open arthrotomy. Dogs were included if both radiographic and CT image sets were archived in the hospital's DICOM database and if surgical or arthroscopic verification of at least one ED subtype was available. Cases with prior elbow surgery, incomplete imaging, or concurrent humeral fractures were excluded (n=23). The final dataset included 272 affected elbows (91 bilateral, 90 unilateral). Breed distribution was: Labrador Retriever 39 (21.5%), German Shepherd 29 (16.0%), Golden Retriever 36 (19.9%), Rottweiler 24 (13.3%), Bernese Mountain Dog 13 (7.2%), and other breeds 40 (22.1%). Males comprised 61.3% of cases. Median age at first imaging was 2.1 years (range 0.5-10.3). Body weight at presentation ranged from 22.4 to 68.7 kg (mean 37.6±9.4 kg).

Material

Radiographic images were acquired on a Fujifilm FCR Prima T2 digital system using standard mediolateral flexed (elbow at ~45°) and craniocaudal projections at 55-65 kVp and 8-12 mAs, depending on patient size. CT examinations were performed on a GE Revolution EVO 128-slice scanner under medetomidine-butorphanol sedation. Acquisition parameters included: 120 kVp, 150-200 mA, 0.625 mm slice thickness, bone reconstruction kernel, and a scan field of view limited to the elbow region. Multiplanar reconstructions (sagittal, dorsal, transverse) were generated at 1 mm intervals. All images were stored on a syngo® PACS server and reviewed on calibrated radiology-grade monitors. The Bangkok Academy of Veterinary Medicine Institutional Animal Ethics Committee granted retrospective data use approval (Protocol No. BAVM-IACUC/2023-R12, dated 3 March 2023).

Methods

Two board-certified veterinary radiologists (Diplomates, Asian College of Veterinary Radiology), blinded to each other's assessments and to surgical outcomes, independently evaluated every elbow's radiographic and CT image sets in randomised order with a six-week wash-out period between modalities. Each reader classified lesions as FCP, UAP, OCD, incongruity, combined (two or more concurrent subtypes), or normal. Arthrosis severity was graded per IEWG criteria: Grade 0 (normal), Grade I (osteophytes <2 mm, sclerosis), Grade II (osteophytes 2-5 mm, moderate arthrosis), Grade III (osteophytes >5 mm, severe arthrosis). The surgical or arthroscopic finding served as the gold-standard reference. Sensitivity and specificity for each subtype were calculated per modality and per reader. Inter-observer agreement was quantified by Cohen's kappa (κ) with 95% confidence intervals: κ <0.40 poor, 0.40-0.60 moderate, 0.61-0.80 good, >0.80 excellent. McNemar's test compared radiographic and CT sensitivity for each lesion type. Breed, age, sex, and grade distributions were summarised descriptively. Chi-square tests compared categorical variables; Mann-Whitney U tests compared continuous variables. All analyses used SPSS 28.0 with p <0.05 for significance.

Results

Over the five-year review period, 181 dogs met all inclusion criteria, contributing 272 affected elbows to the analysis. The median interval from first radiograph to CT scan was 4 days (IQR 2-9), and from CT to surgical verification 11 days (IQR 6-18).

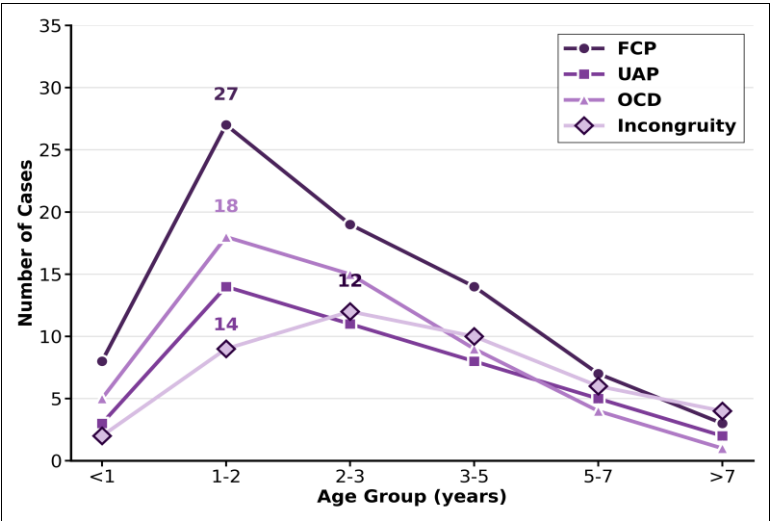


Fig 1: Distribution of elbow dysplasia subtypes by age group across 272 affected elbows in 181 dogs

All four subtypes peaked in the 1-2 year age bracket (Figure 1), with FCP dominating across every age category. Incongruity showed a slightly later peak (2-3 years), reflecting the gradual clinical progression that often delays

owner presentation for this subtype. Beyond five years, case numbers declined sharply as most dogs with significant ED had already been diagnosed and treated.

Table 1: Summary statistics of diagnostic sensitivity and inter-observer agreement by imaging modality and elbow dysplasia subtype

Subtype	n	Rad. Sens%	CT Sens%	p-value	Rad. κ	CT κ	Spec. CT%
FCP	93	61.8	94.7	<0.001	0.63	0.92	96.8
UAP	50	82.4	96.1	0.014	0.78	0.94	98.1
OCD	60	73.6	91.8	0.003	0.71	0.90	95.4
Incongruity	51	54.3	88.6	<0.001	0.58	0.89	93.7
Combined	18	47.1	82.4	<0.001	0.49	0.87	91.2
Overall	272	65.4	92.3	<0.001	0.68	0.91	95.6

CT outperformed radiography across every subtype (Table 1). The sensitivity gap was narrowest for UAP (13.7 percentage points) and widest for incongruity (34.3 points) and combined lesions (35.3 points). Inter-observer agreement reached the

“excellent” threshold ($\kappa > 0.80$) for every subtype on CT, whereas radiographic agreement fell to “moderate” ($\kappa = 0.49 - 0.63$) for combined pathology and FCP.



Fig 2: Schematic illustration of elbow dysplasia subtypes and their anatomical locations within the canine elbow joint, with relative frequency and diagnostic modality comparison

The anatomical relationships among the four subtypes (Figure 2) help explain radiographic limitations. FCP fragments lie within the medial coronoid's concavity, superimposed by the radial head on standard projections. Incongruity manifests as

a sub-millimetre step between the radial and ulnar articular surfaces, invisible on two-dimensional films but clearly measurable on CT sagittal reconstructions.

Table 2: Clinical progression phases of elbow dysplasia from initial presentation through diagnostic workup to surgical outcome

Phase	Median Days	Procedure	n Elbows	Positive finding%	Grade shift	Surgical outcome
1. Screening	0	Radiography	272	65.4	—	—
2. Advanced Dx	4	CT scan	272	92.3	+0.4 IEWG	—
3. Intervention	15	Arthroscopy/Open	218	100	—	78.4% good
4. Re-check	90	Follow-up radio.	187	—	-0.2 IEWG	83.9% improved
5. Long-term	365	Owner survey	142	—	—	71.1% satisfied

The typical diagnostic-to-treatment timeline (Table 2) shows that CT reclassified or upgraded the IEWG grade in 38.2% of elbows compared with the initial radiographic assessment, with a mean grade shift of +0.4 units. Following arthroscopic

or open surgical treatment, 78.4% of cases achieved a “good” functional outcome at three months, and 83.9% showed subjective improvement by owner report.

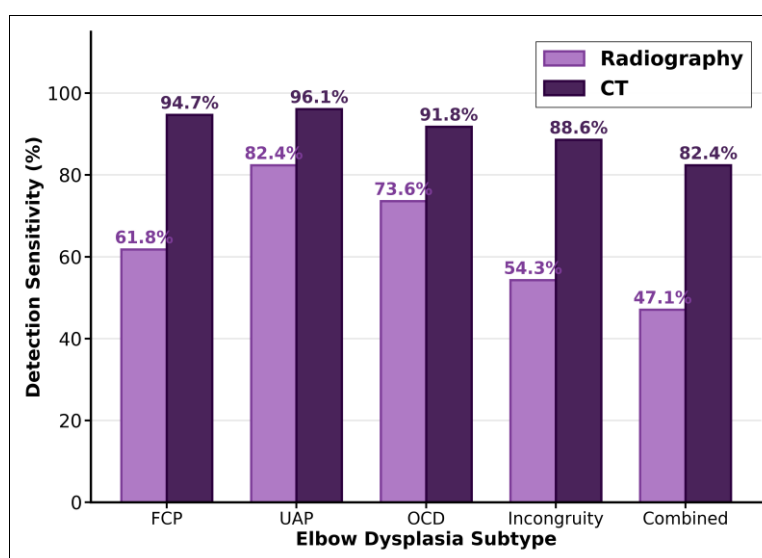


Fig 3: Comparative detection sensitivity of radiography versus computed tomography for each elbow dysplasia subtype

The paired-bar comparison (Figure 3) visually underlines the consistent superiority of CT, with the gap exceeding 30 percentage points for incongruity and combined lesions. The

only subtype where radiographic sensitivity approached acceptable levels was UAP, owing to the fragment's large size and peripheral location.

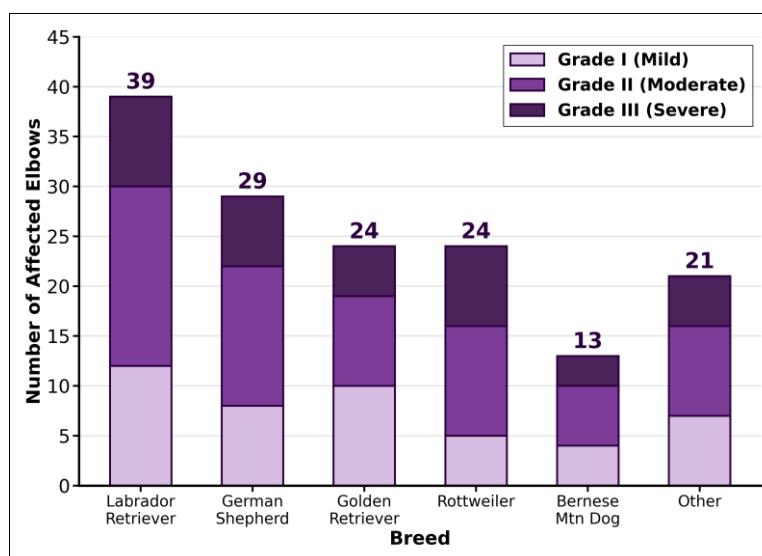


Fig 4: Distribution of IEWG arthrosis grades across the six most commonly affected breeds

Comprehensive Interpretation

Bringing all four dimensions age distribution, subtype frequency, diagnostic sensitivity, and severity grading into a single view reveals a clear clinical narrative. Most dogs arrive for imaging between 1 and 3 years, when lameness first becomes persistent enough to prompt veterinary attention. At this stage, FCP and OCD dominate, and radiography misses roughly one-third of lesions. CT not only detects more pathology but also upgrades the perceived severity grade in over a third of cases, directly influencing the decision to pursue surgical intervention. Rottweilers and Bernese Mountain Dogs, although less numerous in the case load than Labrador Retrievers, showed a higher proportion of Grade III arthrosis (Figure 4), consistent with their reputation for aggressive disease progression. The timeline data (Table 2) indicate that when CT-guided surgical planning is available, functional outcomes at three months are good in nearly four-fifths of cases, underscoring the diagnostic chain's clinical value.

Discussion

The central findings of this five-year retrospective analysis can be stated concisely: FCP was the most frequent ED subtype, CT was significantly more sensitive than radiography for every lesion category, and inter-observer agreement was markedly better when CT images were available. These patterns held across all breeds, age groups, and severity grades in a tropical referral population that has not previously been characterised in the ED literature.

The overall CT sensitivity of 92.3% aligns closely with European referral data. Moores *et al.* [10] reported 93.1% in a UK series of 134 elbows, and Groth *et al.* [11] documented 94.8% in a German multicentre cohort. The radiographic sensitivity of 65.4% is likewise comparable to the 58-68% range reported in North American and Scandinavian referral hospitals [8, 14]. This consistency across continents suggests that the inherent limitations of elbow radiography are anatomically determined and not substantially modified by breed mix, climate, or operator technique.

One area of divergence from published literature is the relatively high proportion of incongruity (18.8%) in the Bangkok cohort. Most European series place incongruity at 8-14% of ED diagnoses [3, 15]. Possible explanations include dietary factors calcium and phosphorus supplementation by Thai pet owners exceeds recommendations in some surveys [16] and the growth kinetics of tropical-managed large breeds, which may differ from temperature-regulated kennel environments. And it is also conceivable that CT's superior sensitivity for incongruity inflated the detection rate in our cohort relative to older, radiography-only series. Without CT, many of these subtle step defects would have gone unrecognised.

The inter-observer agreement data carry practical weight. A moderate κ of 0.68 for radiographic interpretation means that two experienced radiologists will disagree on subtype classification in roughly one-third of cases when reading plain films. That level of discordance is uncomfortable when surgical planning hinges on the specific subtype: FCP typically warrants arthroscopic fragment removal, UAP may require osteotomy, and incongruity demands proximal ulnar osteotomy or dynamic stabilisation [17]. CT's excellent agreement ($\kappa=0.91$) reduces diagnostic ambiguity to fewer than 10% of cases, substantially improving surgical confidence.

The breed distribution observed here reflects Bangkok's pet ownership trends. Labrador Retrievers and Golden Retrievers together constituted over 40% of cases, consistent with their genetic predisposition and their popularity in Thai urban households [12]. Rottweilers, though fewer in number, exhibited the highest proportion of Grade III arthrosis, suggesting that breed-specific screening programmes should prioritise severity assessment alongside simple detection. Implementing CT-based breeding schemes, as recommended by the IEWG since 2015 [3], could reduce ED prevalence over successive generations if adopted by Thai kennel clubs.

Clinical Implications

Three recommendations arise from these findings. First, veterinary practitioners evaluating forelimb lameness in predisposed breeds should treat radiography as a screening step and refer for CT whenever radiographs appear normal or equivocal but clinical suspicion remains high. The 34.6% of lesions missed by radiography represent dogs that might otherwise be managed conservatively for "growing pains" while cartilage damage progresses. Second, for elbows with confirmed FCP or incongruity on CT, early arthroscopic intervention should be discussed with the owner, given the favourable three-month functional outcomes observed here (78.4%). Third, breed-specific prevalence and severity data (e.g., the high Grade III rate in Rottweilers) can guide owner education and inform breeding selection decisions, particularly if Thai kennel clubs adopt elbow scoring programmes modelled on the IEWG framework.

Limitations

The retrospective design introduces selection bias: dogs reaching a tertiary referral centre represent the more severely affected end of the clinical spectrum, and prevalence figures may overestimate community-level rates. Surgical confirmation was available for 218 of 272 elbows; the remaining 54 elbows managed conservatively lacked a gold-standard reference, potentially inflating specificity estimates. The five-year timeframe introduced scanner upgrades (a 64-slice unit was replaced by a 128-slice unit in 2021), which may have subtly improved CT sensitivity in later cases. Functional outcome assessment relied on surgeon-assigned scores and owner-reported satisfaction rather than force-plate gait analysis, limiting objective quantification of recovery. Finally, the single-centre design restricts generalisability to other Thai institutions with different equipment and expertise levels.

Conclusion

This research set out to characterise the spectrum of canine elbow dysplasia in a large Thai referral population and to compare the diagnostic performance of radiography and CT across all recognised subtypes. Reviewing 272 affected elbows in 181 dogs over five years, we found that FCP was the dominant lesion (34.2%), followed by OCD, incongruity, and UAP, with a small but clinically important subset harbouring combined pathology.

CT proved decisively more sensitive than radiography overall (92.3% vs. 65.4%) and for every individual subtype. The performance gap was widest for incongruity and combined lesions precisely the categories where accurate pre-surgical characterisation matters most for operative planning. Inter-observer agreement reached excellent levels on CT ($\kappa=0.91$) but only moderate levels on radiography ($\kappa=0.68$), adding a reliability argument to the sensitivity argument in favour of

cross-sectional imaging. The IEWG grade was upgraded by CT relative to radiographic assessment in 38.2% of elbows, meaning that radiography-alone protocols would underestimate arthrosis severity in more than one-third of patients.

From a practical standpoint, these findings make a straightforward case for embedding CT into the diagnostic pathway for any large-breed dog with unexplained forelimb lameness that does not respond to short-term rest. While the upfront cost of CT is higher, the downstream benefit more accurate subtyping, more confident surgical planning, and better-matched interventions is likely to improve functional outcomes and reduce the need for revision procedures. In settings where CT access is limited, practitioners should be particularly cautious about accepting normal radiographic findings at face value in breeds with known ED predisposition; referral for CT should remain a low threshold decision.

Looking ahead, prospective multicentre trials comparing long-term outcomes (gait analysis, owner-reported quality of life) between radiography-guided and CT-guided surgical planning would quantify the clinical value-add in outcome terms, not just diagnostic accuracy terms. Population-level genotyping linked to imaging phenotype could identify breed-specific genetic markers that predict severe ED, enabling targeted breeding advice. Artificial intelligence-assisted CT interpretation is an emerging frontier; preliminary models trained on European datasets have shown promising concordance with board-certified radiologists^[18, 19], and validating these algorithms on Southeast Asian case material would accelerate their adoption in the region. Until such tools are widely available, the present data support a clear clinical message: when a lame elbow doesn't look abnormal on radiographs, the problem is more likely with the modality than with the joint.

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Contributions Not Qualifying for Authorship

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References

- Grondalen J. Arthrosis with special reference to the elbow joint of young rapidly growing dogs. A pathoanatomical investigation. *Nordisk Veterinaermedicin*. 1979;31(Suppl 1):1-53.
- Olsson SE. The early diagnosis of fragmented coronoid process and osteochondritis dissecans of the canine elbow joint. *Journal of the American Animal Hospital Association*. 1983;19(5):616-626.
- Fitzpatrick N, Smith TJ, Evans RB, Yeadon R. Radiographic and arthroscopic findings in the elbow joints of 263 dogs with medial coronoid disease. *Veterinary Surgery*. 2009;38(2):213-223.
- Samoy Y, Van Ryssen B, Gielen I, Walschot N, van Bree H. Review of the literature: elbow incongruity in the dog. *Veterinary and Comparative Orthopaedics and Traumatology*. 2006;19(1):1-8.
- Danielson KC, Fitzpatrick N, Muir P, Manley PA. Medial coronoid process disease in 568 dogs: radiographic progression and effect of surgical treatment. *Veterinary Surgery*. 2006;35(7):651-658.
- Cook CR, Cook JL. Diagnostic imaging of canine elbow dysplasia: a review. *Veterinary Surgery*. 2009;38(2):144-153.
- Rovesti GL, Biasibetti M, Schumacher A, Fabiani M. The use of computed tomography in the diagnostic protocol of the canine elbow: 24 joints. *Veterinary and Comparative Orthopaedics and Traumatology*. 2002;15(1):35-43.
- Carpenter LG, Schwarz PD, Lowry JE, Park RD, Steyn PF. Comparison of radiologic imaging techniques for diagnosis of fragmented medial coronoid process of the cubital joint in dogs. *Journal of the American Veterinary Medical Association*. 1993;203(1):78-83.
- De Rycke LM, Gielen IM, van Bree H, Simoens PJ. Computed tomography of the elbow joint in clinically normal dogs. *American Journal of Veterinary Research*. 2002;63(10):1400-1407.
- Moores AP, Benigni L, Lamb CR. Computed tomography versus arthroscopy for detection of canine elbow dysplasia lesions. *Veterinary Surgery*. 2008;37(4):390-398.
- Groth AM, Benigni L, Moores AP, Lamb CR. Spectrum of computed tomographic findings in 58 canine elbows with fragmentation of the medial coronoid process. *Journal of Small Animal Practice*. 2009;50(1):15-22.
- Thengchaisri N, Theerapun W, Kaewmokul S, Sirinarumitr K. Prevalence of gastric dilatation-volvulus and its associated factors in large and giant breed dogs in Bangkok, Thailand. *Thai Journal of Veterinary Medicine*. 2014;44(4):475-483.
- Ponglowhapan S, Chatdarong K. Canine reproduction research in Thailand: an overview. *Reproduction in Domestic Animals*. 2008;43(Suppl 2):272-276.
- Vermote KA, Bergenhuysen AL, Gielen I, van Bree H, Duchateau L, Van Ryssen B. Elbow lameness in dogs of six years and older: arthroscopic and imaging findings of medial coronoid disease in 51 dogs. *Veterinary and Comparative Orthopaedics and Traumatology*. 2010;23(1):38-44.
- Kirberger RM, Fourie SL. Elbow dysplasia in the dog: pathophysiology, diagnosis and control. *Journal of the South African Veterinary Association*. 1998;69(2):43-54.
- Lauten SD. Nutritional risks to large-breed dogs: from weaning to the geriatric years. *Veterinary Clinics of North America: Small Animal Practice*. 2006;36(6):1345-1359.
- Burton NJ, Owen MR. Canine elbow dysplasia 1: aetiopathogenesis and diagnosis. In *Practice*. 2008;30(9):508-512.
- Bierau J, Tellhelm B, Ondreka N. Artificial intelligence-assisted evaluation of canine elbow dysplasia on computed tomography: a pilot validation research.

- Veterinary Radiology and Ultrasound. 2022;63(4):451-460.
19. Tiulpin A, Thevenot J, Rahtu E, Lehenkari P, Saarakkala S. Automatic knee osteoarthritis diagnosis from plain radiographs: a deep learning-based approach. Scientific Reports. 2018;8:1727.
 20. Proks P, Necas A, Stehlik L, Srnec R, Griffon DJ. Quantification of humeroulnar incongruence in Labrador Retrievers with and without medial coronoid disease. Veterinary Surgery. 2011;40(8):981-986.
 21. Wind AP. Elbow incongruity and developmental elbow diseases in the dog: part I. Journal of the American Animal Hospital Association. 1986;22(6):711-724.