Ultrasonographic findings of shoulder teno-muscular structures in symptomatic and asymptomatic dogs

Gabriele Barella¹ · Matteo Lodi¹ · Stefano Faverzani²

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Abstract

Purpose B-mode sonographic evaluation of shoulder joint in dogs provides qualitative information concerning mainly tendon and muscles structures. Although the sonographic findings of tenomuscular lesions have been described previously, their frequency in symptomatic and asymptomatic patients has not been reported yet. Aim of the study was to describe and compare qualitative ultrasonographic findings of shoulder joint in clinically symptomatic and asymptomatic dogs and to speculate which lesions might be considered major responsible for lameness.

Methods Fifty-two dogs with shoulder lameness and 58 asymptomatic dogs (both with unremarkable radiographic findings) underwent ultrasonographic B-mode examination of the scapulohumeral joint. Lesions detected were recorded and statistically compared between groups.

Results Significant differences between groups were observed for the number of ultrasonographic abnormalities detected and for fluid accumulation, biceps brachii tendon (BT) lesions and bone surface irregularities. Sonography was considered useful for the determination of lesions absence and for the detection of BT lesions, fluid accumulation, muscle lacerations and bone surface irregularities. The odds for symptomatic dogs were greater than for asymptomatic patients to ultrasonographically diagnose BT lesions, fluid accumulation and bone surface irregularities.

Conclusions Ultrasound has proven to be a useful tool in the evaluation of tenomusculoskeletal structures of shoulder

in dogs with unremarkable radiographic findings. Our results suggest that ultrasonography is useful in the diagnosis of tendon abnormalities, fluid accumulation, muscle lacerations and bone surface irregularities as potential contributors to shoulder lameness in dogs.

Sommario

Scopo L'ecografia B-mode permette la valutazione qualitativa delle strutture tenomuscolari della spalla del cane. Sebbene le alterazioni ecografiche riscontrabili siano già state descritte, la loro frequenza nei soggetti sintomatici ed asintomatici non è ancora stata valutata. Scopo del lavoro è stato descrivere e comparare i riscontri ecografici a carico dell'articolazione della spalla in cani clinicamente sani e cani con zoppia per verificare se esistano alterazioni correlabili alla presenza di sintomatologia.

Metodi Cinquantadue cani con zoppia di spalla e 58 cani asintomatici sono stati sottoposti ad ecografia dell'articolazione scapolo-omerale. Le alterazioni ecografiche osservate nei due gruppi sono state statisticamente confrontate.

Risultati Sono state riscontrate differenze statisticamente significative tra i gruppi per quanto riguarda il numero di alterazioni osservate, per l'accumulo di fluido sinoviale, per le lesioni del tendine bicipite brachiale e per la presenza di irregolarità della superficie ossea. L'ecografia è risultata utile per definire l'assenza di alterazioni, per identificare le lesioni del tendine bicipite brachiale, lacerazioni muscolari, la presenza di un accumulo di fluido sinoviale ed irregolarità della superficie ossea. Per i cani sintomatici si è riscontrata una maggior probabilità di identificare lesioni del tendine bicipite brachiale ed aumento del liquido sinoviale.

Conclusioni L'ecografia si è dimostrata utile nella valutazione delle strutture tenomuscolari dell'articolazione scapolo-omerale di cani con normali studi radiografici della

✉ Stefano Faverzani
stefano.faverzani@unimi.it

¹ Veterinary Teaching Hospital – Small Animal, State University of Milan, Via Celoria 10, 20133 Milan, Italy

² Department of Veterinary Medicine, State University of Milan, Via Celoria 10, 20133 Milan, Italy

spalla. I nostri risultati suggeriscono che l'esame ecografico è in grado di caratterizzare alterazioni patologiche del tendine bicipite brachiale, irregolarità ossee ed accumulo di fluido sinoviale che rappresentano le condizioni patologiche più frequenti in cani sintomatici.

Keywords Shoulder · Lameness · Ultrasound · Tenomuscular · Scapulohumeral

Introduction

The causes of shoulder lameness in dogs are not fully understood: the most frequent causes reported in literature include intra-articular and extra-articular diseases. Instability, osteochondrosis and biceps brachii tendon disease are considered main causes of intra-articular pathology [1] while frequency of extra-articular diseases is not clearly described. The scapulohumeral joint includes stabilizing structures (passive and active) [1] that should be responsible for lameness when damaged. These abnormalities have been described using ultrasound evaluation as a complementary diagnostic imaging modality to survey radiographs. Except from the subscapularis muscle, this imaging technique can assess the tenomuscular structures that are considered the active stabilizers: supraspinatus tendon (SST), infraspinatus tendon (IST), biceps brachii tendon (BT) and teres minor muscle. Some authors report that the passive stabilizers such as medial glenohumeral ligament, lateral glenohumeral ligament and joint capsule cannot be sonographically evaluated [1]. A few publications, report that these relatively thin structures can be difficult to image but may be sometimes recognized [2–4]. Although the sonographic findings of tenomuscular lesions have been described previously [3], their frequency in symptomatic and asymptomatic patients has not been reported yet.

Aim of the study was to describe and compare qualitative ultrasonographic findings of shoulder joint in clinically symptomatic and asymptomatic dogs. Rate of recorded lesions was compared to determine the possible association with clinical lameness. From a clinical point of view, the possibility to find some lesions even in healthy patients might be helpful in excluding these injuries as the major responsible for lameness, or to consider them as less important and to continue in the diagnostic workup.

Methods

One-hundred-ten dogs referred to our hospital, between January 2015 and January 2016, were selected for this study and divided in two groups. Inclusion criteria for group 1 (G1) were: the presence of a thoracic limb

lameness for at least 2 weeks, absence of orthopedic or neurologic problems in remote history, a clinical orthopedic evaluation suggestive for shoulder lameness, an unremarkable radiographic study (at least two orthogonal projections of both elbows and shoulders). Dogs with clinically suspected medial shoulder instability were excluded. Group 2 (G2) inclusion criteria included: absence of thoracic limb lameness, negative anamnesis for orthopedic diseases and an unremarkable orthopedic clinical evaluation. Fifty-two dogs (58 shoulders: 46 dogs with unilateral and 6 with bilateral lameness) were included into G1 while G2 included 58 asymptomatic dogs (116 shoulders). All subjects underwent ultrasound B-mode examination (without the need of pharmacological restraint) performed with an Esaote MyLab 70 (Genova, Italy) equipped with a multifrequency linear transducer (7.5–13 MHz). All scanning procedures were performed by the same operator (GB). Frequency, depth, focus and gain were set and optimized for each patient. Dogs were evaluated in lateral recumbency with the affected limb upward, after hair clipping and ultrasonographic gel applied. The tenomuscular structures of biceps brachii, supraspinatus, infraspinatus, teres minor and sonographically accessible bone surfaces of humeral head and intertubercular groove were evaluated according to the scanning techniques previously described [3]. For the assessment of the biceps brachii tendon the affected thoracic limb was pulled and supinated facilitating the approach to the bicipital groove [3]. For each patient both scapulohumeral joints were scanned and compared. In G1 the ultrasonographic findings belonging to unaffected shoulders were not included in statistical analysis to avoid the bias related to the subjective interpretation of lesions that can be considered as a result of an altered load due to contralateral pathology. All images and videos were evaluated by the authors simultaneously and classified as reported below.

Muscular structures were considered normal if hypoechoic with fine, hyperechoic striations or hyperechoic foci [5]. Tendons were considered normal if homogeneous structures with fine, parallel, hyperechoic lines due to organization of collagen fibers into bundles. Any appearance dissimilar from these descriptions were considered abnormal and were recorded. The presence of synovial effusion was recorded and classified concerning its localization (both at the level of the proximal insertion of BT and its distal portion, next to the tenomuscular junction). The amount of fluid was recorded in transverse section and classified according to its distribution in BT sheath as circumferential or not circumferential. The fluid was also classified as homogeneous or heterogeneous if there were mild hyperechoic foci suspended. Bone surfaces were considered normal if appearing as smooth hyperechoic lines with normal acoustic shadowing.

The Fisher exact test and the Pearson Chi-square were used to compare type and rate of detected lesions between groups. A $p < 0.05$ was considered as statistically significant. Positive and negative likelihood ratios were calculated to determine the diagnostic value of ultrasound in detecting lesions in the 2 groups. Likelihood ratios provide a statistical method for assessing the clinical usefulness of a diagnostic test for ruling out (negative likelihood ratio, $NLR < 0.25$) and ruling in (positive likelihood ratio, $PLR > 4$) a disease [6]. To avoid extreme calculated values, the results with zero false positives or false negatives were modified by adding 1 subject into each cell of the 2×2 table [7]. Odds ratios (OR) among the ultrasonographic abnormalities were also calculated for determining the presence of SST lesions, IST lesions, BT lesions, fluid accumulation, muscular lacerations and bone surface irregularities. Symptomatic subjects (G1) were considered as the *exposed group*. A $p < 0.05$ was considered as statistically significant.

Statistical analysis included calculation of sensitivity, specificity, positive and negative predictive values.

Results

The mean weight $\pm$ standard deviations of dogs was 25 kg (± 12 kg) in G1 and 21 kg (± 11 kg) in G2. The mean age of dogs was 6 years old (± 4 years) in G1 and 5.5 years old (± 3.4 years) in G2.

Statistically significant differences were found between groups as 52/58 (89.7%) shoulders were positive for one or more lesions in G1 while 26/116 (22.4%) in G2 ($p < 0.0001$). Six of 58 cases in G1 (10%) and 90/116

(77%) in G2 were negative for any identified ultrasound abnormalities. In G1: 31/58 (53%) fluid accumulation, 25/58 (43%) BT lesions, 8/58 (14%) SST lesions, 4/58 (7%) IST lesions, 4/58 (7%) bone irregularities and 3 (5%) biceps brachii muscle lacerations were recorded. In G2: 14/116 (12%) fluid accumulation, 9/116 (8%) SST lesions, 2/116 (2%) BT lesions, 2/116 (2%) IST lesions, 1/116 (1%) bone irregularities were recorded. No alterations of the teres minor muscle and tendon were found in any group. Significant differences between groups were observed for fluid accumulation ($p < 0.0001$), BT lesions ($p < 0.0001$) and bone irregularities ($p < 0.05$). Concerning fluid localization, BT sheath distention in G1 was classified as proximal 25/31 (80.6%), distal 3/31 (9.6%) and proximo-distal 3/31 (9.6%). Only proximal accumulation, 14/14 (100%), was recorded in G2. The circumferential pattern of BT sheath fluid distention was recorded in 10/31 (32%) cases in G1 while it was never identified in G2. The fluid was heterogeneous in 12/31 (38.7%) in G1 and 2/14 (14.3%) in G2. The only significant difference concerning fluid characteristics between groups was its distribution ($p < 0.02$). No significant differences were observed between groups considering the frequency of SST lesions, IST lesions and biceps muscles lacerations ($p > 0.05$). The sonographic lesions detected were confirmed by surgical findings, MRI, CT or arthroscopy, in respectively, 2, 3, 7 and 13 patients in G1 (25/58; 43% of subjects). Concerning the other 33/58 (57%) dogs in G1: 5/58 (8%) were lost at follow-up and 28/52 (48%) recovered after therapy based on the sonographic diagnosis. Diagnostic sensitivity, specificity, positive and negative likelihood ratios, positive and negative predicting values and odds ratios (OR) are reported in Table 1.

Table 1 Statistical data concerning the ultrasonographic abnormalities described

	Se (%) (95% CI)	Sp (%) (95% CI)	PLR	NLR	PPV	NPV	OR (95% CI)	<i>p</i>
All lesions	89.7	77.6	4	0.1	66.7	93.8	30	< 0.05
SST	13.8	92.2	1.8	0.9	47.1	68.2	1.9	> 0.05
IST	6.9	98.3	4	1	66.7	67.9	4.2	> 0.05
BT	43.1	98.3	25	0.6	92.6	77.6	43.2	< 0.05
Fluid accumulation	53.5	87.9	4.4	0.5	68.9	79.1	8.4	< 0.05
Heterogeneous fluid	20.7	98.3	12	0.8	85.7	71.3	15.1	< 0.05
Proximal fluid	43.1	87.7	3.5	0.7	64.1	75.2	5.5	< 0.05
Distal fluid	6.7	99.2	7.9	0.9	80	67.7	14.7	> 0.05
Proximo-distal fluid	6.7	99.2	7.9	0.9	80	67.7	14.7	> 0.05
Circumferential fluid	18.3	99.2	21.7	0.8	91.7	70.5	50	< 0.05
Muscle lacerations	6.7	99.2	7.9	0.9	80	67.7	14.7	> 0.05
Bone surface irregularity	6.9	99.1	8	0.9	80	68.1	8.5	> 0.05

Significant values are reported in bold. *Se* sensitivity, *Sp* specificity, *PLR* positive likelihood ratio, *NLR* negative likelihood ratio, *PPV* positive predictive value, *NPV* negative predictive value, *OR* odds ratio, *SST* supraspinatus tendon lesion, *IST* infraspinatus tendon lesion, *BT* biceps brachii tendon lesion

Discussion

Group 1 included mainly adult medium size dogs of numerous breeds rather than large breeds which are considered to be mostly involved in shoulder pathologies [8].

The sonographic evaluation revealed no lesions in six cases in G1 (6/58, 10%) and 90 in G2 (90/116, 77%). Considering limits of ultrasonographic scanning of the scapulohumeral region, we emphasize how lesions absence in symptomatic dogs is extremely low. NLR were considered useful ($NLR < 0.25$) for determining the ultrasonographic absence of ultrasonographic shoulder abnormalities. PLR were considered almost useful ($PLR = 4$) for determining the presence of ultrasonographic shoulder abnormalities. The odds for ultrasonographic abnormalities in G1 were greater than for G2 (OR 30).

According to literature [1] the most frequent cause of shoulder lameness is an intra-articular disease. The most frequent abnormality in G1 was fluid accumulation (31/58, 53%) and the majority of effusions (25/31, 80.6%) were classified as proximal. As *proximal* we refer to the presence of effusion contiguous to the insertion of the BT on the supraglenoid tubercle, that can be related to any intra-articular disease (instability, OCD and BT disease). In G1 there were also 3/31 (9.6%) dogs showing extra-articular fluid accumulation next to the tenomuscular junction of BT (classified as distal). Only 3/31 (9.6%) dogs in G1 had fluid accumulation in both locations (proximo-distal). The odds for ultrasonographic fluid accumulation for G1 were greater than for G2 (OR 8.4) as well as for proximal fluid accumulation (OR 5.5). Considering the distal and proximo-distal fluid accumulation we observed that the OR was greater for G1 than for G2 (OR 14.7). Increment of synovial effusion in symptomatic patients could suggest inflammatory response producing proximo-distal distention of BT sheath. Moreover, the high Sp (99.2%), PLR (7.9) and PPV (80) demonstrates that these sonographic findings belong to symptomatic patients.

In literature, the presence and amount of fluid in shoulder joint had been classified in a qualitative and quantitative method, in association with BT appearance [9]. Landmarks to measure BT sheath distention are not reported and it is not elucidated how the cut-off values are applicable to dogs of different size. According to this classification [9] a dog with a normal BT and effusion of tendon sheath less than 2 mm can be classified as grade I bicipital tenosynovitis; the cut-off values from grade I to III are of a few mm difference (associated to BT alterations). In our opinion, a few mm difference in fluid accumulation in dogs of different size (small, medium or large breed dogs) may have different clinical interpretation. It has been reported that observers measurements are no more accurate than subjective assessment alone and evidence that imaging measurements are useful for diagnosis is weak [7]. For these reasons, we decided

to consider only qualitative aspects of fluid accumulation and classify subjectively the amount of synovial effusion as circumferential or not circumferential. The circumferential pattern corresponds to a 360° of BT sheath distention in transverse images (Fig. 1).

In G1, circumferential pattern was recorded in 10/31 dogs (32%). In the 14/116 asymptomatic shoulders in G2 circumferential distribution of fluid around the tendon was never observed. This sonographic sign appears to be highly associated to lameness (Sp 99.2%, PLR 21.7, PPV 91.7) and the odds for this finding are greater for G1 than for G2 (OR 50).

Sonography has proven to be a useful technique in determining fluid aspect (heterogeneous fluid accumulation; PLR 12) and the odds for revealing it was greater in G1 than G2 (OR 15.1). No statistically significant difference in its rate was found between groups; however, it should be considered clinically relevant for its Sp (98.3%). The fluid appearance alone is not suggestive for a specific disease; the presence of hyperechoic foci suspended could be even related to microbubbles of gas due to cavitation phenomena consequent to manipulation during the forelimb handling of dogs. The cavitation is, therefore, a phenomenon consisting the formation of gaseous cavities within a liquid. It occurs when fluid is subjected to an acoustic wave (ultrasound) that passing through a fluid it generates expansion (negative pressure) and compression waves (positive pressure). If the intensity of the ultrasound is high enough it can cause the formation, growth, and a rapid decompression of gas bubbles in the fluid. Bubbles resist only until they reach a zone of low hydrostatic pressure where they may collapse and implode [10–12]. However, arthrocentesis could represent a useful procedure in distinguishing the possible cause of effusion (i.e., inflammatory or degenerative) [13].

In G1 a statistically significant number of BT lesions (Fig. 1) was recorded versus G2. The odds for this finding is greater for G1 than for G2 (OR 43.2) and sonography has proven to have a high clinical utility for ruling in this abnormality (PLR 25). According to literature [9], tenosynovitis classification considers also the BT appearance. In our study, considering inhomogeneity of tendon appearance, we recorded three different aspects: hypoechoic areas, hyperechoic areas with acoustic shadowing and hyperechoic areas without acoustic shadowing. These findings were identified occasionally in association (Table 2). A qualitative ultrasonographic classification of BT lesions has been proposed, without considering hyperechoic lesions [14]. Referring to a presumptive pathogenesis of BT alterations, an acute injury and consequent increase in fluid component (edema), can lead to hypoechoic appearance of some areas (core lesions, Fig. 1) within the tendon [14–16]. Hyperechoic areas (suggestive of chronicity) can be interpreted as scars [9] if they do not produce distal attenuation, or as mineralizations if an acoustic shadowing is present. An accurate description

Fig. 1 **a** Transverse section of a mid-portion of a normal biceps brachii tendon (BT, *); **H** humerus. **b** Transverse section of a heterogeneous BT (*) with a hypoechoic area corresponding to a core lesion (arrowhead) and a mineralization of the tendon sheath (arrow) associated to not circumferential effusion. **c** Transverse section of a circumferential effusion (e) surrounding BT (*). **d** Longitudinal section of BT (*) at its proximal insertion; a hyperechoic area producing acoustic shadowing is evident within the tendon structure (arrow). (=>:

supraspinatus tendon, SST). **e** Longitudinal section of a normal BT at its tenomuscular junction (**). **f** Longitudinal section of a normal BT at its tenomuscular junction associated to a moderate synovial effusion (e). In transverse section, the left side of the image corresponds to the medial side of the limb. In longitudinal section, the left side of the image corresponds to the proximal part of the limb. Images A and E belongs to group 2. Images B, C, D and F belong to group 1

of BT lesions should be important to define a presumptive onset and progression of the disease (acute or chronic) leading to different prognoses. Probably the introduction of standardized quantitative parameters (i.e. cross-sectional area of tendons) as proposed for German Shepherd [17] could be used to gain a more accurate diagnosis. In the present study, these parameters were not considered due to the different breeds present in our population.

In 5 dogs, a partial BT rupture was identified and classified as insertional; in these cases, BT appeared in tension but

a loss of fiber was observed in a limited portion (from 1/3 to 2/3) of their proximal insertion and the parallel-running appearance of fibers was no longer present. No complete ruptures were reported.

The retrospective nature of our research recorded two hypoechoic BT lesions in G2; we cannot exclude that these findings belonged to an unintentional selection of acoustic windows that led to anisotropy artifact [18]. This artifact occurs when the ultrasound beam hits the tendon at a non-perpendicular angle. In fact, if the angle between the

Table 2 Sonographic appearance, type of BT lesions in the 25 affected dogs in group 1

Sonographic appearance	Type of lesion	Number of dogs
Hyperechoic areas WAS	Mineralization	7
Hyperechoic areas WAS, Loss of fibers	Mineralization and partial rupture	4
Hyperechoic areas WoAS	Scar	4
Hyperechoic areas WoAS, Hypoechoic areas	Scar and core lesions	4
Hypoechoic areas	Core lesion	3
Hyperechoic areas WAS, Hypoechoic areas	Mineralization and core lesion	1
Hyperechoic areas WAS, Hyperechoic areas	Mineralization and scar	1
Hyperechoic areas WAS, Hyperechoic areas, Loss of fibers	Calcification, scar and partial rupture	1

Lesions producing acoustic shadow (WAS); lesions without acoustic shadow (WoAS)

ultrasound beam and the long axis of the structure is perpendicular the tendon presents a hyperechoic appearance; if the angle becomes non-perpendicular, the image gradually becomes hypoechoic to anechoic. Anisotropy can be accidentally misinterpreted as the presence of lesion. Moving the transducer using heel–toe or toggle maneuvers can help the interpretation, making this artifact disappear [19].

Muscle tearing is assumed as an obvious cause of lameness and the odds for this lesion was greater for G1 than for G2 (OR 14.7). The *p* value observed, in our opinion belongs to the low rate of this finding in G1 and should be interpreted in association with Sp (99.2%), PLR (7.9) and PPV (80).

Bone surface irregularities detected were subjectively interpreted as superficial irregularities belonging to intertubercular groove and suggestive of chronic degenerative joint disease and/or bicipital tenosynovitis [3]. The statistically significant difference between G1 and G2 concerning bone lesions can be explained by the frequent association between osteophytes and tenosynovitis. Sonography has proven to be clinically useful for ruling in this finding in symptomatic dogs (PLR 8, PPV 80 and Sp 99.1%). No osteochondrosis lesions were reported in our sample. Even if it is possible to identify osteochondrosis lesions with sonography [20], the lack of them in our groups is probably due to our inclusion criteria that considered only patients with unremarkable radiographic findings.

No statistically significant differences were observed between groups considering the frequency of SST and IST lesions, maybe due to their low prevalence in our sample.

The clinical significance of SST pathology in dogs is debated. In our population, these lesions, mainly represented by mineralization, suggest their minor clinical relevance. In one symptomatic dog, SST mineralizations contiguous to BT were the sole alterations identified. We cannot exclude that lameness in this dog was possibly due to impingement of the SST on the BT [21, 22] (Fig. 2). It is reported that SST has a poor blood supply and that indirect and repetitive trauma to the shoulder region (jumping and digging) and overuse

exercise can be interpreted as the causes of supraspinatus pathology [21]. In our sample, SST mineralizations were reported in 2/8 dogs that performed continuative sport activity (agility dog and disc dog) in G1, while in 4/9 sport dogs in G2.

A high frequency of SST lesions have been described in some breeds such as Labrador retriever and Rottweiler [21]. We cannot confirm this breed predisposition as, limited to our population, 1 affected Labrador retriever was present (G1). The sonographic evaluation of shoulder joint revealed no lesions in six cases in G1 (6/58, 10%). To our knowledge, the sonographic exam could be negative due to the incapability of complete evaluation of shoulder joint or due to cognitive, inevitable or multifactorial errors [23]. Nevertheless, we emphasize that a correct valuation is strictly dependent on operators experience and equipment.

The absence of a definitive diagnosis for every diseased shoulders as confirmations of our findings is the main limitation of our study. However, we can remark that a considerable number of patient underwent advanced imaging techniques (CT, MRI), arthroscopy or surgery that confirmed the ultrasonographic diagnosis. Moreover, a high number of subject recovered completely after medical or surgical therapy based on ultrasonographic diagnosis (mainly muscle lacerations and fluid accumulation suggestive of synovitis). Finally, we can speculate that even if ultrasonography is a complementary technique for shoulder imaging, it gives many information concerning tenomuscular structure and it may be considered as an important step toward diagnosis (considering that even CT, MRI and arthroscopy may not provide a definitive diagnosis if performed alone).

Conclusions

Ultrasonography has proven to be a useful tool in the evaluation of tenomusculoskeletal structures of shoulder in dogs with unremarkable radiographic findings. Our results

Fig. 2 **a** Longitudinal section of a normal supraspinatus tendon (=>, SST) and a normal biceps brachii tendon (*, BT) at the intertubercular groove of the humerus (H). **b** Longitudinal section of SST (=>) with a hyperechoic round-shaped lesion (arrowhead), producing acoustic shadowing not contiguous to BT (*). **c** Longitudinal section of SST (=>) with a hyperechoic lesion (arrowhead), producing acoustic shadowing, contiguous to BT (*). **d** Transverse section of SST (=>) and BT (*) of the same subject in figure C. Note the hyper-

echoic lesion of SST (arrowhead) and the circumferential fluid accumulation around BT partially hidden by shadowing. In transverse section, the left side of the image corresponds to the medial side of the limb. In longitudinal section, the left side of the image corresponds to the proximal part of the limb. Images A and B belong to group 2. Images C and D belong to group 1. The white bar in B and C indicates the distance between biceps brachii tendon and supraspinatus tendon mineralization

suggest that ultrasonography appears to be very specific to identify scapulohumeral joint pathological changes in lame dogs. Some lesions are more frequently associated with lameness than others; specifically the finding of BT lesions, fluid fillment of BT sheath (specially with a circumferential pattern) and bone surface irregularities can be associated with shoulder lameness while SST calcifications alone are probably not.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights statement All the described animal-related procedures were conducted according to the Directive 2010/63/EU of the European Parliament and of the Council of September 22nd 2010 on the protection of animals used for scientific purposes (Art. 1, Par. 1, letter “b”) and the Italian legislation (D. Lgs. N. 26/2014, Art. 2, Par. 1, letter “b”), which does not require any approval by the competent Authorities.

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