The Veterinary Journal 190 (2011) e84–e90

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Diffuse idiopathic skeletal hyperostosis (DISH) and spondylosis deformans in purebred dogs: A retrospective radiographic study ☆

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ARTICLE INFO

Article history:
Accepted 6 April 2011

Keywords:
Diffuse idiopathic skeletal hyperostosis
DISH
Spondylosis
Dogs
Radiography

ABSTRACT

A retrospective radiographic study was performed to investigate the prevalence of diffuse idiopathic skeletal hyperostosis (DISH) and spondylosis deformans (spondylosis) in 2041 purebred dogs and to determine association with age, gender and breed. Four cases of DISH provided information on the appearance of canine DISH.

The prevalence of DISH and spondylosis was 3.8% (78/2041) and 18.0% (367/2041), respectively. Of dogs with DISH, 67.9% (53/78) also had spondylosis, whereas 14.0% (53/367) of dogs with spondylosis also had DISH. Dogs with DISH and/or spondylosis were significantly older than those without spinal exostosis. The prevalence of DISH and spondylosis was 40.6% (28/69) and 55.1% (38/69), respectively, in Boxer dogs. Nineteen smaller breeds were not affected by DISH, but showed signs of spondylosis; only standard Poodles appeared not to be affected by either disorder. Radiography, computed tomography (CT), magnetic resonance imaging (MRI), and/or histopathology were used to investigate four DISH cases.

It was concluded that spondylosis and DISH can co-occur in dogs. DISH has probably been previously under-diagnosed and mistaken for severe spondylosis. The diagnosis can be made using radiography, CT or MRI. On histology, DISH can be distinguished from spondylosis by the location (ventral longitudinal ligament) and extent of new bone formation.

Introduction

Different types of osteophyte formation can coexist in the canine and human spine. Wright (1982a,b) recognized that the different types signified two distinct disorders, namely, spondylosis deformans (spondylosis) and ankylosing hyperostosis. The latter is currently referred to as diffuse idiopathic skeletal hyperostosis (DISH) (Belanger and Rowe, 2001; Morgan and Stavenborn, 1991; Resnick and Niwayama, 1976; Woodard et al., 1985) and is considered a disorder distinct from spondylosis (Haller et al., 1989; Julkunen et al., 1981; Kiss et al., 2002; Mata et al., 1997; Resnick, 1985).

The systemic disease, DISH, affects the axial and appendicular skeleton and results in ossification of soft tissues, including the spinal ventral longitudinal ligament (Fig. 1) and sites of attachment of tendons and capsules to bone (Forestier and Rotes-Querol, 1950; Resnick and Niwayama, 1976). In humans, DISH is associated with symptoms that vary from mild back pain to spinal cord compression or even spinal fractures (Belanger and Rowe, 2001; Callahan and Aguillera, 1993; Olivieri et al., 2007; Sreedharan and Li, 2005). Occasionally, DISH has been described in the veterinary literature (Morgan and Stavenborn, 1991; Woodard et al., 1985). Extreme stiffness and pain in the axial and appendicular skeleton, presumably due to DISH, has been reported in two dogs, which were subsequently euthanased (Morgan and Stavenborn, 1991; Woodard et al., 1985).

Spondylosis is a non-inflammatory, degenerative disease of the peripheral endplate region associated with new bone formation (Carnier et al., 2004; Langeland and Lingaas, 1995; Levine et al., 2006; Morgan et al., 1989; Resnick, 1985). Osteophytes vary from small spurs to bony bridges across the disc space, leaving at least part of the ventral surface of the vertebral body unaffected (Fig. 1). Spondylosis was detected on computed tomography (CT) images in 62% of dogs with degenerative lumbosacral stenosis (DLS) (Suwankong et al., 2008). Although the presence of spondylosis is suggested to be associated with Hansen type II herniated nucleus pulposus (HNP) (Levine et al., 2006), spondylosis is also found in combination with healthy intervertebral discs.

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doi:10.1016/j.tvjl.2011.04.008

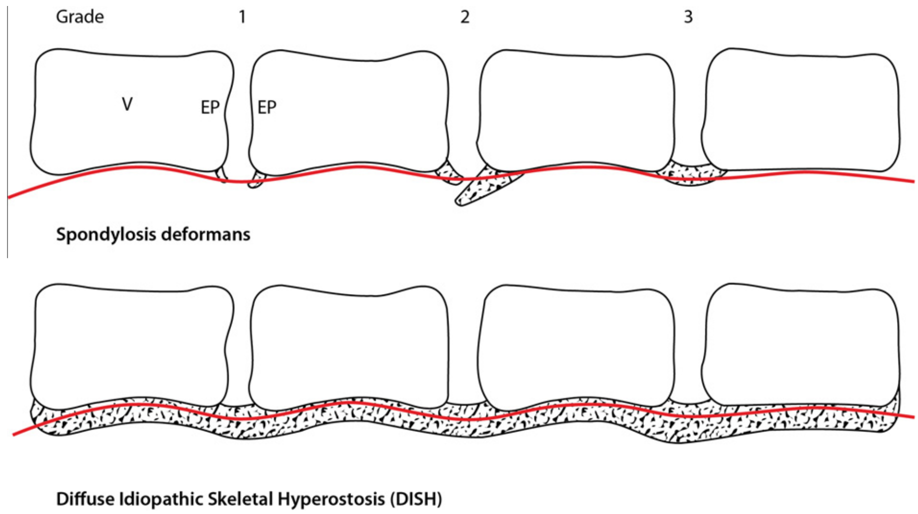

Fig. 1. Schematic presentation of a sagittal cross section of vertebral bodies with spinal new bone formation showing different grades of spondylosis deformans (grades 1–3) and diffuse idiopathic skeletal hyperostosis (DISH). V, vertebral body; EP, end plate; flowing (red) line, ventral longitudinal ligament.

Spondylosis is more prevalent in aging dogs with a breed predilection for German Shepherds and Boxers, and can be diagnosed on radiographic or (histo)pathological examination (Carnier et al., 2004; Langeland and Lingaas, 1995; Morgan et al., 1967, 1989; Morgan, 1967a,b; Read and Smith, 1968). Spondylosis is not generally considered to be of great clinical relevance, except in working dogs in which the diminished spinal flexibility might limit activity (Morgan et al., 1989; Vaughan, 1990). Osteophyte formations extending dorsolaterally can compress spinal nerve roots at the level of intervertebral foraminae (Morgan et al., 1989). Signs reported to be related to severe spondylosis are stiffness in the back, lameness, changes in gait, and pain (Carnier et al., 2004). Since DISH is relatively unknown in the veterinary community, it may have been previously mistaken for severe spondylosis on radiographic examination (Kranenburg et al., 2010; Morgan and Stavenborn, 1991).

In humans, DISH and spondylosis can occur independently and simultaneously (Haller et al., 1989; Julkunen et al., 1981). No studies of the co-occurrence of DISH and spondylosis in dogs have yet been described. The aims of this study were (1) to determine the prevalence and spinal distribution of spondylosis in a radiographic study of a large group of purebred dogs and to study its association with age, gender, and breed; (2) to combine the outcome with the prevalence of DISH as previously reported (Kranenburg et al., 2010; with kind permission of Springer Science and Business Media), and (3) to enhance our understanding of canine DISH using four dogs with DISH for which a descriptive imaging and histological study was conducted.

Materials and methods

Radiographic study

Radiographs including the spine and medical reports of dogs older than 1 year, referred to the Utrecht University Veterinary Medical Teaching Hospital between February 2003 and January 2008 were retrieved from the hospital database. For statistical purposes, breeds were included if radiographs of more than 20 dogs of a certain breed were available. All dogs were referred by veterinarians for various medical conditions not necessarily related to the spine. The indications for radiographic examination were thoracic (75%), orthopaedic or neurological complaints (18%) and abdominal problems (7%).

Radiographs of the cervical, thoracic and/or lumbar spine were eligible for review. The radiographs were examined by the principal investigator according to a scoring and grading system for both disorders (Table 1). A diagnosis of DISH was made if the diagnostic Resnick criteria were met (Table 2) (Resnick and Niwayama, 1976). These criteria were developed to differentiate DISH from spondylosis, ankylosing spondylitis, osteoarthritis of the facet joints, and vertebral osteochondrosis. The radiographs that were scored positive for DISH were re-reviewed by a medical researcher trained in diagnosing DISH in humans to confirm or refute the diagnosis of DISH. Spondylosis was diagnosed if radiographic signs of new bone formation were found adjacent to the endplate region and classified in three stages (mild, moderate or severe) according to Langeland and Lingaas (1995) (Table 1). Thus, in spondylosis osteophytes do not affect the complete ventral surface of the vertebral body in the typical flowing manner as in DISH (Fig. 1).

Statistical analysis of the data was performed using SPSS software version 16.0. Data were assessed for normality of the residuals and homogeneity of the variances. Student's *t* test was performed on the mean ages of dogs with and without spondylosis and/or DISH. One-way ANOVA with Bonferroni correction was performed on the mean age of the dogs with spondylosis of different severity (grade) and/or DISH. Univariate analysis was performed to analyze the association between age, gender, neutering status, and breed, and spondylosis. Variables that were significantly associated with spondylosis in the univariate analysis were subsequently analyzed in a multiple logistic regression model. Odds of <1.0 were indicative of a protective factor that made dogs less likely to develop the disease and odds of >1.0 were indicative of a predisposing factor that made dogs more likely to develop the disease. When calculating the odds for spondylosis the sum of dogs scored as grades 1, 2, 3, D1, D2 and D3 is used. For calculating the odds for DISH, the sum of grades D0, D1, D2 and D3 represents the dogs scored positive for DISH. Significance was set at $P < 0.05$.

Descriptive study

Four dogs, referred between 2008 and 2010, were selected to investigate the imaging and histological appearance of canine DISH. CT used for imaging of the lumbar and lumbosacral vertebral column was a single slice helical CT scanner (Philips Secura, Philips NV) with 120 kV, 260 mA and 1 s scanning time per rotation. Magnetic resonance imaging (MRI) was done using a low-field (0.2 Tesla) open magnet (Magnetom Open Viva, Siemens AG) with a 16 cm-diameter multipurpose flex coil. The imaging protocol included T1-weighted (TR 510 ms, TE 26 ms) and T2-weighted (TR 4455 ms, TE 117 ms) 3-mm-thick sagittal slices. Histopathological examination of the vertebral column is shown for one dog.

Results

Radiographic study

Of the 2041 dogs from 33 breeds, 51.3% (1046/2041) were males and 48.7% (995/2041) were females. The mean age ± standard error (SE) of all dogs was 7.2 ± 0.2 years (range 1–17 years).

The prevalence of DISH was 3.8% (78/2041) (95% confidence interval [CI], 3.0–4.7) and of spondylosis 18.0% (367/2041) (95% CI, 16.3–19.7%) (Table 1). Of the dogs with spondylosis, grade 1 spondylosis was seen in 25.6% (94/367) (95% CI, 21.1–30.1%), grade 2 in 14.7% (54/367) (95% CI, 11.3–13.4%), and grade 3 in 59.7% (219/367) (95% CI, 54.7–64.7%). Fourteen percent (53/367) (95%

Table 1
Criteria and prevalence of grades of spondylosis deformans and diffuse idiopathic skeletal hyperostosis (DISH).

Grade		Criteria	Number of dogs (percentage; 95% confidence interval)	Age Mean ± SE (Range)	Male dogs (percentage; 95% confidence interval)	Female dogs (percentage; 95% confidence interval)
0	No spondylosis or DISH	No ossifications	1649 (80.8; 79.1–82.5)	6.8 ± 0.16 (1–17)	831 (79.4;77.0–81.9)	818 (82.2; 79.8–84.6)
1	Mild spondylosis, no DISH	Bony spur not protruding beyond the caudal/cranial edge of the vertebral border, no DISH	91 (4.5; 3.6–5.4)	8.7 ± 0.51 (3–15)	46 (4.4; 3.2–5.6)	45 (4.5; 3.2–5.8)
2	Moderate spondylosis, no DISH	Bony spur protruding beyond the caudal/cranial edge of the vertebral border, no DISH	37 (1.8; 1.2–2.4)	9.0 ± 0.91 (2–14)	20 (1.9; 1.1–2.7)	17 (1.7; 0.9–2.5)
3	Severe spondylosis, no DISH	1or 2 non flowing and/or contiguous bridges, no DISH	186 (9.1; 7.9–10.4)	8.9 ± 0.42 (2–16)	104 (9.9; 8.1–11.8)	82 (8.2; 6.5–10.0)
D0	DISH, no spondylosis	3 or more flowing contiguous bridges, no spondylosis	25 (1.2; 0.7–1.7)	8.9 ± 1.1 (3–12)	14 (1.3; 0.6–2.1)	11 (1.1; 0.5–1.8)
D1	DISH and mild spondylosis	3 or more flowing contiguous bridges and bony spur not protruding beyond the caudal/cranial edge of the vertebral border	3 (0.2; 0.0–0.3)	10.2 ± 5.1 (5–13)	2 (0.2;-0.1–0.5)	1 (0.1; −0.1–0.3)
D2	DISH and moderate spondylosis	3 or more flowing contiguous bridges and bony spur protruding beyond the caudal/cranial edge of the vertebral border	17 (0.8; 0.4–1.2)	8.4 ± 1.2 (5–13)	9 (0.9; 0.3–1.4)	8 (0.8; 0.3–1.4)
D3	DISH and severe spondylosis	3 or more flowing contiguous bridges and 1 or more non flowing and/or contiguous bridges	33 (1.6; 1.1–2.2)	10.0 ± 1.0 (2–16)	20 (1.9; 1.1–2.7)	13 (1.3; 0.6–2.0)
	Total		2041 (100.0)	7.2 ± 0.2 (1–17)	1046 (100.0)	995 (100.0)

Table 2
Diagnostic **c**riteria for diffuse idiopathic skeletal hyperostosis (DISH) according to Resnick and Niwayama (1976).

- The presence of flowing calcification and ossification along the ventrolateral aspects of at least four contiguous vertebral bodies with or without localized pointed excrescences at intervening vertebral body-disc junctions
- The relative preservation of disc height in the involved areas and the absence of extensive radiographic changes of degenerative disc disease (intervertebral osteochondrosis), including vacuum phenomena and vertebral body marginal sclerosis
- The absence of apophyseal joint bony ankylosis and sacroiliac joint erosion, sclerosis or intra-articular bony fusion

CI, 14.0–14.8%) of the dogs with spondylosis also had DISH. Of the dogs with DISH, 67.9% (53/78) (95% CI, 57.6–78.3%) also had spondylosis. DISH and spondylosis were significantly associated (Odds Ratio [OR], 11.13; 95%, CI 6.82–18.18).

Due to the retrospective nature of the study, not the entire vertebral column of all dogs was available for review. For 80 dogs only the cervical spine was available; for 131 dogs only the cervical and thoracic spine was available; for 3 dogs only the cervical and lumbar spine was available; for 1488 dogs only the thoracic spine was available; for 162 dogs only the thoracic and lumbar spine was available; for 140 dogs only the lumbar spine was available, and for 37 dogs the entire spine was present on the radiographs. As a percentage of screened segments, the thoracic T4–T7 and T9–T10, lumbar L2–L4 and lumbosacral L7–S1 vertebrae were most frequently affected by spondylosis. Vertebral levels of T6–T10 and L2–L6 were mostly affected by DISH and the cervical spine was least affected (Fig. 2).

The dogs with DISH and/or spondylosis were significantly older than the dogs without these disorders ($P < 0.01$), but there was no significant difference in age between dogs with different grades of spondylosis (grade 1 vs. grade 2, $P = 1.00$; grade 1 vs. grade 3, $P = 0.74$) and/or DISH. Although more male dogs had DISH or spondylosis, this difference was not statistically significant ($P = 0.25$ for DISH and $P = 0.17$ for spondylosis) (Table 1).

The standard Poodle was the only breed included in this study not affected by either DISH or spondylosis (95% CI, 0.0–13.0%). Nineteen breeds were not affected by DISH but showed signs of spondylosis. All breeds in which DISH was prevalent were also affected by spondylosis (Table 3). The prevalence of DISH and spondylosis in Boxers was 40.6% (28/69) and 55.1% (38/69), respectively. Almost 68% (19/28) of the Boxers with DISH also had signs of spondylosis at other spinal segments than those affected by DISH; 27.5% (19/69) of the Boxers with spondylosis did not show signs of DISH. All radiographs scored positive for DISH by the principal investigator were also scored positive for DISH by the medical investigator specialized in diagnosing DISH in humans.

Eleven individual breeds and age were significantly associated with spondylosis on univariate analysis. In a multiple logistic regression model, the variable Bernese Mountain dog was no longer statistically significant. The remaining 10 breeds acted as protective or predisposing factors for spondylosis. Age and the breeds Boxer and Flat-coated Retriever were predisposing factors for both DISH and spondylosis (Table 4).

Descriptive study

Results of the radiography (Fig. 3a), CT (Figs. 3b and 4), MRI (Fig. 3c), gross pathology (Fig. 5a) and histopathology (Fig. 5b) of the four DISH cases are summarized in Table 5.

Discussion

This is the first large-scale radiographic study in the veterinary literature of the prevalence of DISH and spondylosis in a population of purebred dogs. A combined scoring system was used since both disorders can co-occur in one dog. Unfortunately, only 37/2041 dogs had the entire vertebral column available for examination. This may have influenced the outcome and resulted in an underestimation of the prevalence of both disorders. To report the prevalence of both disorders for the canine population at large,

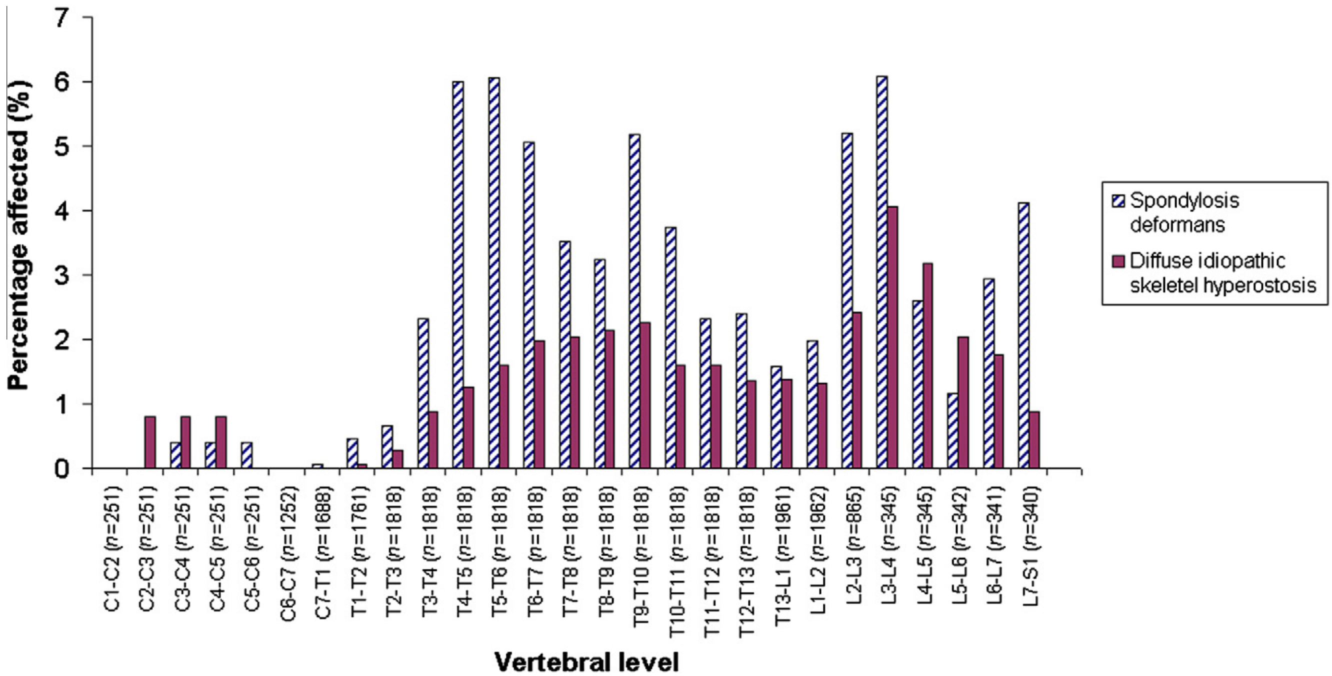

Fig. 2. Spinal distribution of levels affected by spondylosis deformans ($n = 367$) and diffuse idiopathic skeletal hyperostosis (DISH; $n = 78$) depicted as a percentage of screened vertebral levels.

Table 3
Prevalence grades of spondylosis deformans and diffuse idiopathic skeletal hyperostosis (DISH) according to breed.

Breed	Grades: *n* (%)[a]								Total
	0	1	2	3	D0	D1	D2	D3	
Beagle	39 (95.1)	1(2.4)	0	1 (2.4)	0	0	0	0	41
Belgian Shepherd, Malinois	42 (79.2)	2 (3.8)	3 (5.7)	5 (9.4)	1 (1.9)	0	0	0	53
Bernese Mountain dog	173 (86.9)	8 (4.0)	4 (2.0)	10 (5.0)	2 (1.0)	0	2 (1.0)	0	199
Border Collie	20 (76.9)	2 (7.7)	2 (7.7)	1 (3.8)	0	0	1 (3.8)	0	26
Bouvier des Flandres	52 (82.5)	3 (4.8)	1 (1.6)	3 (4.8)	1 (1.6)	1 (1.6)	1 (1.6)	1 (1.6)	63
Boxer	22 (31.9)	3 (4.3)	1 (1.4)	15 (21.7)	9 (13.0)	1(1.4)	8 (11.6)	10 (14.4)	69
Bullmastiff	10 (83.3)	1 (8.3)	0	1 (8.3)	0	0	0	0	12
Cairn Terrier	28 (84.8)	2 (6.0)	1 (3.0)	2 (6.0)	0	0	0	0	33
Dachshund	84 (97.7)	1 (1.2)	0	1 (1.2)	0	0	0	0	86
Doberman	24 (66.7)	3 (8.3)	2 (5.6)	7 (19.4)	0	0	0	0	36
Dogue de Bordeaux	27 (79.4)	2 (5.9)	1 (2.9)	4 (11.8)	0	0	0	0	34
Dutch Partridge dog	16 (80.0)	1 (5.0)	1 (5.0)	2 (10.0)	0	0	0	0	20
English Bulldog	19 (70.3)	0	1 (3.7)	8 (29.6)	0	0	0	0	27
English Cocker Spaniel	40 (93.0)	1 (2.3)	0	2 (4.7)	0	0	0	0	43
Flat-coated Retriever	35 (57.4)	5 (8.2)	1 (1.6)	12 (19.7)	4 (6.6)	0	3 (4.9)	1 (1.6)	61
French Bulldog	55 (90.2)	0	2 (3.3)	4 (6.6)	0	0	0	0	61
German Pointer	32 (84.2)	2 (5.3)	0	1 (2.6)	0	0	1 (2.6)	2 (5.3)	38
German Shepherd	73 (64.6)	11 (9.7)	1 (0.9)	20 (17.7)	2 (1.8)	0	0	6 (5.3)	113
Golden Retriever	126 (80.8)	7 (4.5)	2 (1.3)	15 (9.6)	1 (0.6)	0	1 (0.6)	4 (2.6)	156
Great Dane	24 (80.0)	0	2 (6.7)	4 (13.3)	0	0	0	0	30
Irish Setter	20 (90.9)	0	1 (4.5)	0	0	0	0	1 (4.5)	22
Jack Russell Terrier	153 (93.9)	5 (3.1)	0	5 (3.1)	0	0	0	0	163
Labrador Retriever	181 (74.2)	18 (7.4)	6 (2.5)	33 (13.5)	1 (0.4)	0	0	5 (2.0)	244
Leonberger	18 (72.0)	1 (4.0)	0	3 (12.0)	2 (8.0)	0	0	1 (4.0)	25
Maltese	70 (98.6)	0	0	1 (1.4)	0	0	0	0	71
Newfoundland	19 (86.4)	1 (4.5)	0	0	1 (4.5)	0	0	1 (4.5)	22
Poodle	25 (100.0)	0	0	0	0	0	0	0	25
Rhodesian Ridgeback	21 (77.8)	1 (3.7)	0	5 (18.5)	0	0	0	0	27
Rottweiler	98 (81.7)	9 (7.5)	2 (1.7)	9 (7.5)	1 (0.8)	0	0	1 (0.8)	120
Staffordshire Bull Terrier	16 (80.0)	0	2 (10.0)	2 (10.0)	0	0	0	0	20
Weimaraner	18 (81.8)	0	1 (4.5)	3 (13.6)	0	0	0	0	22
West Highland White Terrier	34 (81.0)	1 (2.4)	0	6 (14.3)	0	1 (2.4)	0	0	42
Yorkshire Terrier	36 (97.3)	0	0	1 (2.7)	0	0	0	0	37
All breeds in total	1649 (80.8)	91 (4.5)	37 (1.8)	186 (9.1)	25 (1.2)	3 (0.2)	17 (0.8)	33 (1.6)	2041

[a] 0 = no spondylosis or DISH, 1 = mild spondylosis, no DISH, 2 = moderate spondylosis, no DISH, 3 = severe spondylosis, no DISH, D0 = DISH, no spondylosis, D1 = DISH and mild spondylosis, D2 = DISH and moderate spondylosis, D3 = DISH and severe spondylosis.

Table 4
Significant protective and predisposing factors for spondylosis and diffuse idiopathic skeletal hyperostosis (DISH) in dogs.

Factor	Spondylosis		DISH	
	Odds[a]	*P*	Odds[a]	*P*
Increasing age (per year)	1.300	<0.001	1.320	<0.001
Flat-coated Retriever	2.834	<0.001	7.671	<0.001
Boxer	9.237	<0.001	51.270	<0.001
Labrador Retriever	1.465	0.037	–	–
Doberman	3.082	0.003	–	–
German Shepherd	3.327	<0.001	–	–
Leonberger	–	–	9.880	<0.001
Beagle	0.213	0.039	–	–
Dachshund	0.106	<0.001	–	–
Jack Russell Terrier	0.245	<0.001	–	–
Maltese	0.043	0.002	–	–
Yorkshire Terrier	0.080	0.014	–	–

[a] Odds <1.0 protective (i.e., less likely to develop DISH or spondylosis); Odds >1.0 predisposing (i.e., more likely to develop DISH or spondylosis).

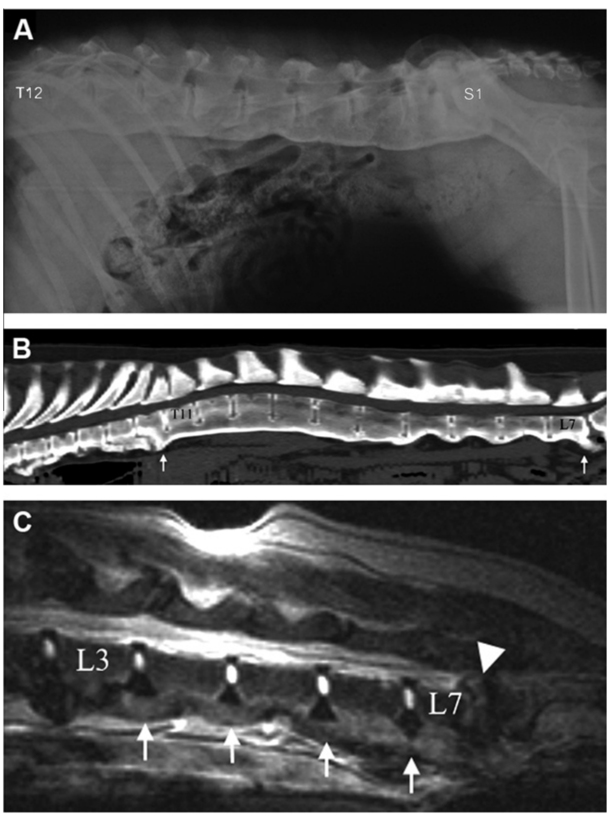

Fig. 3. Comparison of three imaging modalities. (A) Lateral radiograph of an 8-year-old male Boxer (Case 1) with diffuse idiopathic skeletal hyperostosis (DISH) at spinal level T12–S1; (B) sagittal CT reconstruction of a 5-year-old neutered female mixed-breed (Case 2) with contiguous new bone formation of the ventral longitudinal ligament of at least T10–L7 (arrows) and non-continuous new bone formation possibly due to spondylosis deformans from T5–T10; (C) T2-weighted MRI of the canine lumbar spine of a 10-year-old Border Collie (Case 3) with DISH (arrows) from vertebra L3 to L7 and degenerative lumbosacral stenosis with black disc at L7–S1 (arrowhead). Note the intact normal nucleus pulposus water signal (white) at the lumbar intervertebral disc spaces between L2 and L7 and the absence of this signal at L7–S1. The flowing and contiguous new bone formation is clearly visible on the ventral side of the vertebral bodies (arrows).

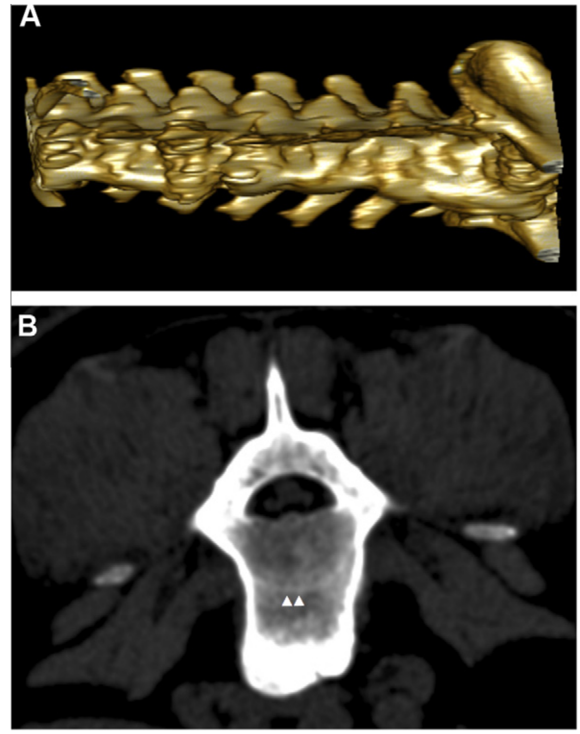

Fig. 4. (A) Ventrolateral 3D CT reconstruction of L1–S1 of a 16-year-old Border Collie (Case 4) with diffuse idiopathic skeletal hyperostosis (DISH). Note the flowing ossification continuously along all lumbar vertebrae; (B) transverse CT of L5 of the same Border Collie, note the original ventral border (arrowheads) of the vertebral body.

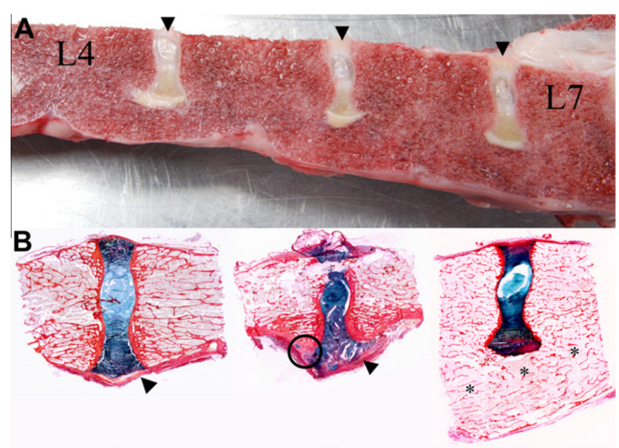

Fig. 5. (A) Gross morphology of a sagittal section (dorsal part including the spinal cord are removed) of a 16-year-old Border Collie (Case 4) with diffuse idiopathic skeletal hyperostosis (DISH). Note the extensive new bone formation at the ventral side of four contiguous intervertebral bodies in combination with three healthy intervertebral discs (arrowheads); (B) histological pictures of (I) healthy canine intervertebral disc (IVD), the arrowhead corresponds with the location of the ventral longitudinal ligament, (II) moderately degenerated IVD with spondylosis deformans and (III) healthy disc with DISH from Case 4. In spondylosis (II) the localized osteophyte (circle) originates from the region adjacent to the endplate. In contrast, in DISH (III) there is diffuse new bone formation (asterisks) along the ventral side of the vertebral body. Picrosirius red/Alcian blue stain.

a prospective study including orthogonal radiographs of the entire vertebral column would be ideal.

This is also the first report describing the appearance of canine DISH on CT, MRI, gross and histopathological examination. The clinical diagnosis of DISH based on imaging findings can be confirmed on post-mortem examination by its characteristic gross and histological features, which are distinct from those of spondylosis. Post-mortem histology showed the classical features of DISH,

Table 5
Clinical, imaging and pathological characteristics of four cases of canine diffuse idiopathic skeletal hyperostosis (DISH).

Case	Breed	Gender	Age (years)	Orthopaedic and neurologic complaints and signs	Diagnostics (figure)	Diagnosis	Treatment and follow up
1	Boxer	NF	8	Stiffness, pain reaction on palpation of caudal lumbar spine	Radiography (Fig. 3A)	DISH	Euthanasia due to co-morbidity (multicentric lymphoma)
2	Mixed breed	NF	5	Lameness left pelvic leg, difficulty walking up and down stairs, pain on palpation of the caudal lumbar spine, patellar pseudohyperreflexia	CT (Fig. 3B)	DISH	Decompressive foraminotomy and enthesiophytectomy. Less painful and able to walk up and down stairs
3	Border Collie	M	10	Urinary and faecal incontinence, absent anal sphincter and tail tone, and pain of caudal lumbar spine,	MRI (Fig. 3C)	DISH and DLS	Decompressive laminectomy and partial discectomy at L7–S1. Pain resolved but incontinence remained.
4	Border Collie	NF	16	Stiffness, urinary and faecal incontinence, unable to clean perineal region and painful on palpation of caudal lumbar spine	CT (Fig. 4) and (histo)pathology (Fig. 5)	DISH and OA	Euthanasia

NF, neutered female; M, male; CT, computed tomography; MRI, magnetic resonance imaging; DLS, degenerative lumbosacral stenosis; OA, osteoarthritis.

i.e. continuous solid bone bridge formation ventral to the vertebral body and bridging a healthy intervertebral disc.

In the Boxer, DISH, spondylosis, or a combination of both was present in high proportion (41%, 55%, and 28%, respectively). Dog breeds can be considered closed gene pools with a high degree of kinship maintained by constrained breeding. This makes the dog very useful for dissecting the genetic contribution to a disease (Karlsson and Lindblad-Toh, 2008). Since the prevalence of DISH and spondylosis was high in the Boxer, this appears the preferential breed to identify the gene(s) involved in the pathogenesis of both disorders (Kranenburg et al., 2010).

Comparing the present study with earlier reports, spondylosis in the thoracic region was found slightly more cranially but the lumbar distribution was comparable to previous studies (Carnier et al., 2004; Morgan et al., 1967; Read and Smith, 1968; Wright, 1982a,b). The ossification of DISH occurred less often in the more flexible cervical and caudal-lumbar spinal segments (Benninger et al., 2004; Hofstetter et al., 2009). Spinal flexibility may protect against ossification of the ventral longitudinal ligament.

Earlier studies of canine vertebral hyperostosis did not distinguish between spondylosis and DISH (Carnier et al., 2004; Langeland and Lingaas, 1995; Morgan et al., 1967; Read and Smith, 1968; Wright, 1982b). In these studies, all bridging ossifications were thought to be severe spondylosis. Although radiographic differentiation between DISH and severe spondylosis is challenging, the two disorders differ in radiographic appearance (Kranenburg et al., 2010; Morgan and Stavenborn, 1991). The new bone formation in DISH, consisting of enthesiophytes affecting the ventral longitudinal ligament, continues along the entire ventral plane of at least four contiguous vertebral bodies (Resnick and Niwayama, 1976). In spondylosis, the osteophytes originate from the region adjacent to the ventral endplate and thus the new bone formation will mostly be confined to the intervertebral disc junction. As DISH is relatively unknown in the veterinary community, it is likely that in earlier publications some cases diagnosed as severe spondylosis were in fact cases of DISH.

In practice, canine DISH may be widely under-diagnosed and mistaken for severe spondylosis. As spondylosis is not considered to be of great clinical relevance, possible clinical symptoms might not be attributed to the ossifications or may even be overlooked by veterinarians. When a dog, especially a Boxer, Leonberger or Flat-coated Retriever, shows signs of spinal stiffness and/or pain of the caudal lumbar spine, DISH should be considered as a possible cause. If DISH is incidentally found during radiographic examination, the veterinarian should be aware that it might cause spinal stiffness and/or pain of the caudal lumbar spine. Over one third (28/78) of the medical records of dogs with DISH in our study contained reports of stiffness, pain, neurological and/or orthopaedic signs that were not necessarily explained by the most prominent disease diagnosed in the animal.

In DISH, involvement of the innervated periosteum may contribute to spinal pain. The massive and extensive new bone formation in dogs with DISH may dislocate and compress surrounding soft tissues, such as ventral lumbar muscles, more than do the spurs or bony bridges of spondylosis, thereby producing more pain. The contiguous new bone formation may result in loss of spinal flexibility and mobility, ultimately resulting in a higher pressure load on adjacent segments. This may give rise to accelerated intervertebral disc degeneration, i.e. adjacent segment disease, as found in dogs and humans after spinal fusion (Dekutoski et al., 1994; Eck et al., 1999; Park et al., 2004; Schendel et al., 1995).

In order to investigate the clinical relevance of DISH, it will be critical to conduct a prospective study and to promote awareness of DISH in dogs. As in humans, dogs with spinal stiffness and/or pain of the caudal lumbar spine as a result of DISH could benefit from conservative treatment with NSAIDs and weight loss (Belanger and Rowe, 2001; Utsinger, 1985). A randomized double-blind, placebo-controlled, clinical trial is needed to evaluate the effect of NSAIDs in dogs with DISH. Surgery may be necessary if conservative treatment does not provide adequate symptom relief or if neurological deficits or vertebral fractures are present.

Conclusions

Spondylosis and DISH were found alone or in combination in dogs and the prevalence of both disorders increased with increasing age. Veterinarians should be aware of the occurrence and the possible clinical relevance of DISH, which may cause stiffness and pain of the lumbar spine. A diagnosis can be made using radiographic examination, CT or MRI. On histology, DISH can be distinguished from spondylosis by the location (ventral longitudinal ligament) and extent of new bone formation.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

Acknowledgments

The authors would like to thank Ms. Elise Petersen, Ms. Monique Jacobs, Mr. Joop Fama and Ms. Anneke Jansen for technical support, Dr. Jane Sykes for language corrections and Dr. Bouvien Brocks for referring canine patients with DISH to our clinic. Special thanks to Dr. L. Anneloes Westerveld, MD, for discussions on diagnosing DISH.

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