Asymmetrical lumbosacral transitional vertebrae in dogs may promote asymmetrical hip joint development

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Keywords

Lumbosacral transitional vertebrae, dog, developmental orthopaedic disorders, diagnostic radiology, hip dysplasia

Summary

Objectives: This study examines the relationship between the morphology of the lumbosacral transitional vertebra (LTV) and asymmetrical development of the hip joints in dogs.
Methods: A total of 4000 dogs which had been consecutively scored for canine hip dysplasia were checked for the presence of a LTV. A LTV was noted in 138 dogs and classified depending on the morphology of the transverse processes and the degree of contact with the ilium.
Results: In dogs with an asymmetrical LTV, the hip joint was significantly more predisposed to subluxation and malformation on the side of the intermediate or sacral-like transverse process ($p < 0.01$), on the side of the elevated pelvis ($p < 0.01$), or when an asymmetrical LTV resulted in pelvic rotation on its long axis ($p < 0.01$), whereas hip joint conformation was less affected on the side featuring a free transverse process ($p < 0.01$).
Clinical significance: The results support our hypothesis that an asymmetrical LTV favours pelvic rotation over its long axis, resulting in inadequate femoral head coverage by the acetabulum on one side. Inadequate coverage of the femoral head favours subluxation, malformation of the hip joint, and secondary osteoarthritis. Asymmetrical hip conformation may therefore be the sequela of a LTV and mask or aggravate genetically induced canine hip dysplasia.

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Introduction

This study investigated the relation between the morphology of a lumbosacral transitional vertebra (LTV) and the conformation of the hip joints in dogs. A LTV is an anomalously formed vertebra displaying the characteristics of both a lumbar and a sacral vertebra. It is located between the last anatomically regular lumbar vertebra and the sacrum (1–3). The prevalence of a LTV in dogs ranges from 0 to 40% depending on its morphology, the breed of the dog, and the sample population (1, 2, 4, 6, 9–13). The morphology of a LTV is highly variable (1, 2, 4–7). In the simplest, and by far most common form, the dorsal spinous processes of the first and second sacral vertebra are not fused (12, 13). Malformations of the transverse processes, vertebral arch, and vertebral body are less common (8). A LTV occurs in symmetrical or asymmetrical form (1, 9). A LTV can lead to rotation of the pelvis. When the acetabulum is higher or positioned more cranially on one side, a smaller area of the ipsilateral femoral head is covered by the acetabulum, which favours an abnormal development of the hip joint (10). A hereditary predisposition for a LTV has been suspected or confirmed (1, 11-14).

Canine hip dysplasia (CHD) is defined as an abnormal development of the hip joint due to multiple factors. The condition includes a hereditary component and usually results in coxarthrosis (15, 16). Laxity of the hip joint is considered to be the main contributing factor to the development of CHD in an individual animal (17, 18). Additional predisposing factors include rapid growth and weight gain as well as an excessive amount of calcium in food consumed during the growth phase (15, 19, 20). The exact pathogenesis is undetermined as of yet.

Unilateral CHD has been reported to occur in 10 to 34% of dogs. The potential association with a LTV is discussed in a few studies (12, 21–25, 28). In one study, asymmetrical conformation of the hip joints was observed in 19.3% of the dogs with asymmetrical LTV and in 14.2% with symmetrical LTV or normal lumbosacral anatomy respectively (12). Of the dogs presenting with unilateral pelvic contact of the LTV, 16 showed inferior hip conformation on the same side and six dogs on the opposite side, while no difference was noted in 92 dogs. No significant difference was found. In another study on 891 dogs, 16.7% showed unilateral CHD. Of these, 5.4% were also diagnosed with a LTV whereas only 3.1% of dogs with bilateral identical hip joints exhibited a LTV (25). Detailed differences in the conformation of the LTV and the hip joints were not taken into account. A third study found neither a correlation between the occurrence of LTV and all grades of CHD, nor between occurrence of asymmetric LTV and unilateral hip dysplasia, while occurrence of a LTV and severe CHD was strongly correlated (28).

The goal of the present study was to investigate the relationship between the morphology of LTV and the conformation of the hip joints in dogs. We hypothesized that asymmetrical hip malformation occurs more commonly in dogs with an asymmetrical LTV.

Materials and methods

The radiographs of 4000 dogs that had been evaluated consecutively for CHD by the Dysplasia Committee at the Vetsuisse faculty of the University of Zurich hip dysplasia committee were retrieved from the archive and checked for the presence of a LTV. Age of the dogs ranged from six months to eight years (median: 1.5 y), though 97.1% of them were less than two years of age. For all dogs, at least two ventrodorsal radiographs of the pelvis were available and evaluated: one radiograph with the pelvic limbs in extension (standard OFA/FCI[a] position I) and one with the stifles abducted and the femora oriented approximately 90° to the spine (FCI position II). The hip joints were assessed according to the Swiss scoring system using six parameters: 1) measurement of the Norberg angle, 2) degree of femoral head subluxation, 3) and 4) malformation of the acetabulum, and 5) and 6) secondary changes of the femoral head and neck. Each parameter scored between 0 (no changes) and 5 (severe changes) (26). The sum of the six scores defined the severity of malformation. An excellent hip joint scores 0, while a severely dysplastic and arthrotic joint may reach a score of 30. The total score for the left hip was subtracted from that for the right hip. Thus, a positive result indicated a worse hip conformation on the right, a negative result a worse hip conformation on the left, while a result of 0 indicated equal hip conformation.

As the morphology of a LTV is highly variable, a LTV was classified depending on the morphology of the transverse processes and their degree of contact with the ilium (►Figure 1): 1) A type 1 or lumbar type transverse processes does not contact the ilium. It is either a normal lumbar transverse process, or it is short and wide-based. Its tip may be deformed and point in a cranial, lateral or even slightly caudolateral direction. A type 2 or intermediate type transverse process appears to be partially attached to the ilium and often to the sacrum. Its base is wider than that of a type 1, while its tip is narrow and free. A type 3 or sacral type transverse process has the characteristics of a sacral wing process with broad attachment to the ilium and often to

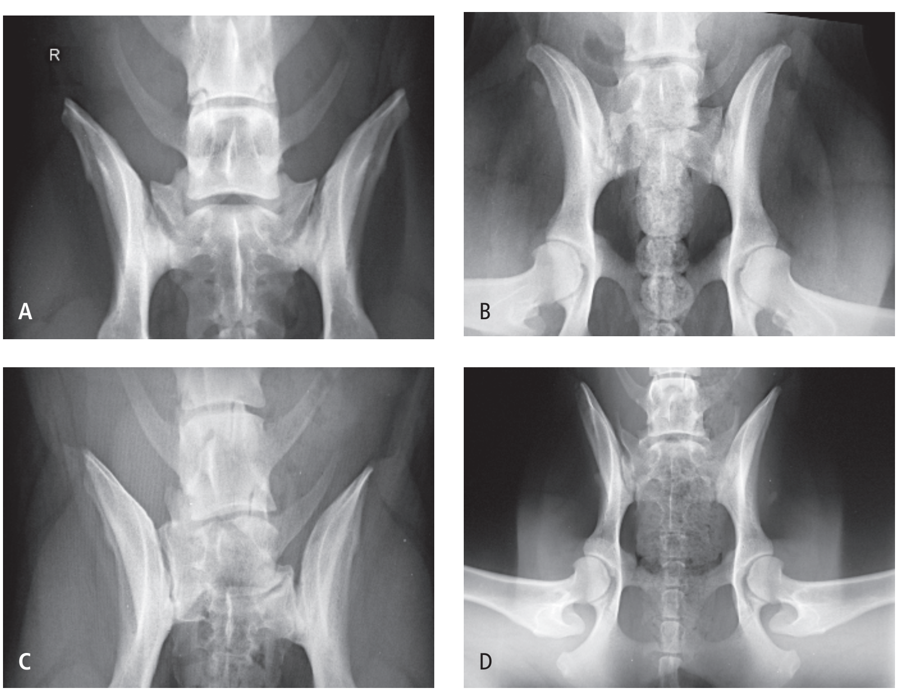

Figure 1 **A)** Normal lumbosacral anatomy. Both transverse processes of the last lumbar vertebra are identicallly formed, oriented in craniolateral direction and have no contact to the pelvis. The length and position of the sacroiliac joints are identical. **B)** Asymmetrical type 2/1 lumbosacral transitional vertebra (LTV). The right transverse process is broad based and in contact with the pelvis but retains a tip while the transverse process on the left is normal. The sacroiliac contact is slightly shorter on the right. **C)** Asymmetrical type 3/1 LTV. The transverse process on the right is completely fused with the sacrum while the one on the left is normal. Note the marked differences in length and position of the sacroiliac contact. **D)** Symmetrical type 2/2 LTV. Both transverse processes are broad based and seem to contact the pelvis. There is no difference in length and position of the sacroiliac contact.

a OFA = Orthopedic Foundation for Animals, FCI = Fédération Cynologique Internationale.

the lateral process of the sacrum as well. There is no free tip identified. Slight morphological differences within a given type were not subdivided any further. Consequently a LTV can appear in nine combinations of transverse processes: Type 1 transverse processes on both sides (1/1), type 1 on the right and type 2 on the left (1/2), then 1/3, 2/1, 2/2, 2/3, 3/1, 3/2, and 3/3 respectively. Lumbosacral transitional vertebrae of type 1/1, 2/2 and 3/3 are symmetrical, the other ones asymmetrical. For some of the analyses, LTV were arranged in two subgroups: LTV with a free transverse process on one side and a transverse process with pelvic contact on the opposite side (1/2, 2/1, 1/3 or 3/1) forming one subgroup, and LTV with identical transverse processes (1/1, 2/2, 3/3) or bilateral pelvic contact (2/3 or 3/2) forming the other subgroup. Differentiation between lumbarisation and sacralisation of the LTV was not feasible as only the caudal part of the lumbar spine can be evaluated on properly collimated hip radiographs. A sacrum with a separated dorsal process of the first sacral vertebra as the only variation was not counted as a LTV in this study.

We determined the relation between the difference in the scores between the right and left hip joint and the a) morphology of the LTV; b) length of the sacroiliac contact zone (while the length of contact between the transverse processes of the LTV and the ilium was not measured); c) angular offset of the LTV relative to the last true lumbar vertebra; and d) rotation of the pelvis over the long axis. With the pelvis rotated, one wing of the ilium appears wider and the ipsilateral obturator foramen smaller than the opposite (▶Figure 2). Finally the relation between the type of LTV and the rotation of the pelvis was evaluated.

The data were analysed using commercial software[b]. Normal distribution of data was tested using the Wilk-Shapiro test. As data were normally distributed, a one-way analysis of variance with Bonferroni post hoc test was used. All p-values less than 0.05 were considered significant.

Results

A LTV with an abnormally formed transverse process was noted in 138 of 4000 dogs. There were 66 male (48%) and 72 female dogs (52%) indicating no sex predilection for a LTV (p = 0.52). The breed distribution can be found in a previous study (1).

All nine combinations of transverse processes were seen (▶Table 1). The LTV was symmetrical in 68 (49%) dogs with type 2 transverse processes in 38 and type 3 in 21 dogs. The LTV was asymmetrical in 70 dogs (51%) with type 1 and 2 transverse processes (1/2 and 2/1) predominating in 33 of the 70 dogs.

There was a significant association between the morphology of the LTV and the

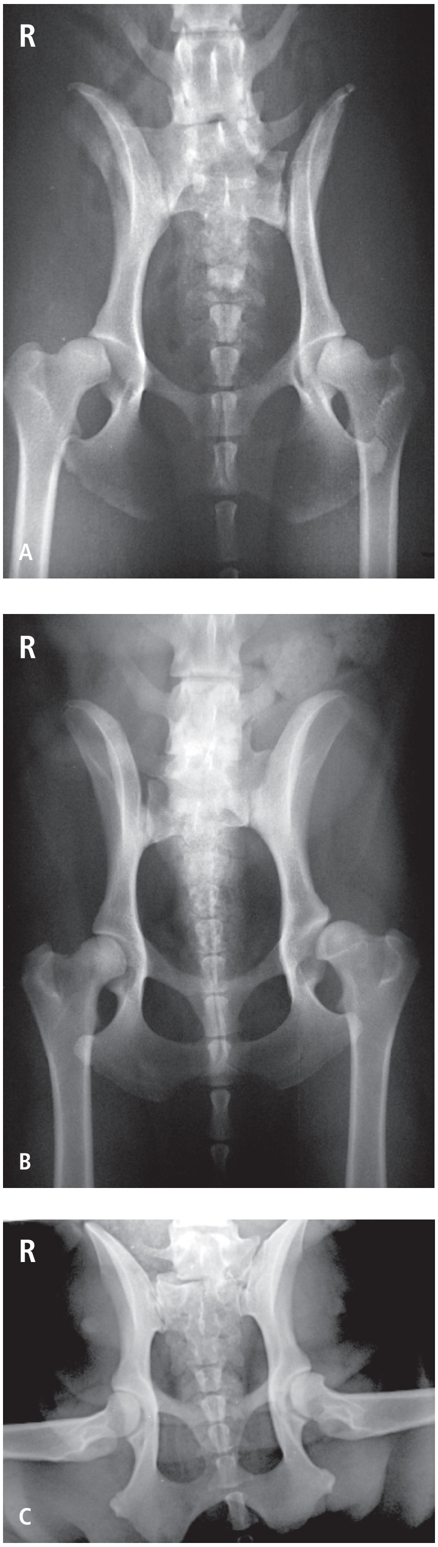

Figure 2 **A)** (020775, pelvic rotation over long axis, FCI-position I). Asymmetrical 1 lumbosacral transitional vertebra (LTV) of type 3/1. There is a sacral-like transverse process with a broad contact zone on the right, and a lumbar transverse process on the left. The LTV is angulated slightly relative to the lumbar spine and moderately relative to the pelvis. The pelvis is rotated over its long axis to the right, demonstrated by the wide iliac wing on the right and the deep acetabular fossa on the left. There is severe subluxation of the right femoral head and mild deformation of the craniolateral acetabular edge, while the left femoral head is moderately subluxating. Also note the difference in length and position of the sacroiliac joints. **B)** (070173, pelvic rotation over long axis, FCI-position I). Asymmetrical LTV of type 1/2. There is a lumbar-like transverse process on the right and an intermediate transverse process on the left. The last true lumbar vertebra is rotated to the right side, as indicated by the position of the articular processes and the dorsal spinous process. The LTV is misshapen. The pelvis is rotated counterclockwise over its vertical axis resulting in poor coverage of the left femoral head and severe coxarthrosis formation, while the right femoral head is properly seated in the acetabulum. Also note the difference in length and position of the sacroiliac joints. Parts **(A)** and **(B)** show extreme forms of hip joint asymmetry. In most dogs with asymmetric LTV, the difference is less pronounced. **C)** (981254, pelvic rotation over vertical axis, FCI-position II). Asymmetrical LTV of type 1/3. The last true lumbar vertebra is in a neutral position (cropped, note orientation of the caudal endplate). There is a LTV with a lumbar, but hypoplastic transverse process, on the right and a sacral transverse process on the left. The pelvis is rotated counterclockwise over its vertical axis. There is inadequate coverage of the left femoral head by the acetabulum and mild coxarthrosis formation, while the right femoral head is adequately seated.

b Stata®, Release 12.1, 2011: StataCorp., College Station, Texas, USA

Table 1 Combinations of types of lateral processes in 138 dogs with lumbosacral transitional vertebra.

Lateral process right/left (R/L)	n	n (%)
1/1	9	6.5
2/2	38	27.5
3/3	21	15.2
1/2, 2/1	33	23.9
1/3, 3/1	15	10.8
2/3, 3/2	22	15.9
Total	138	100.0

n = number.

Table 2 Correlation between type of lumbosacral transitional vertebra (LTV) based on lateral process morphology and mean score difference between the right and left hip joint ($p < 0.01$).

Lumbosacral transitional vertebra type[a]	n	Right & left hip joint score difference (mean ± SD)[b]
1/1, 2/2, 3/3, 2/3, 3/2	90	0.23 ± 3.88
1/2	17	-0.71 ± 3.24
2/1	16	2.56 ± 3.20
1/3	8	-4.00 ± 4.54
3/1	7	3.57 ± 3.10
No LTV	3862	0.01 ± 2.19

[a]Based on lateral processes (Right/Left); no LTV for comparison. [b]Score difference positive: right hip worse; score difference negative: left hip worse.

Table 3 Correlation between length of sacroilial contact (SIC) and mean score difference between the right and left hip joint ($p = 0.06$).

Sacroilial contact length	n	Right and left hip joint[a] mean score difference
SIC equal	91	0.5
SIC shorter on right	22	1.4
SIC shorter on left	25	-1.2

[a]Score difference positive: right hip worse; score difference negative: left hip worse. n = number

Table 4 Correlation between type of lumbosacral transitional vertebra (LTV) and angulation of the pelvis ($p < 0.01$).

Type of lumbosacral transitional vertebra	Angulation	No angulation
1/1, 2/2, 3/3	10	58
1/2, 1/3, 2/1, 3/1	27	21
2/3, 3/2	7	15

difference in the scores of the right and left hip joints ($p < 0.01$). In dogs with a symmetrical (1/1, 2/2, 3/3) or mildly asymmetrical (2/3 or 3/2) LTV morphology, the scores of the right and left hip joints were identical or differed minimally on average. Also in the 3862 dogs with normal lumbosacral anatomy, the hip score was equal on average. In contrast, in dogs with type 1/2 or 2/1 LTV, and particularly in dogs with type 1/3 or 3/1 LTV, the scores of the two hip joints differed more on average. The difference was highly significant for LTV of type 3/1, 1/3, and 2/1, while no difference was noted in dogs with a LTV of type 1/2. The average hip score difference was up to four points reflecting up to one degree difference based on FCI grading. Commonly, the worse hip joint was seen on the side of the intermediate or sacral transverse processes (▶Table 2). Hip joint abnormality consisted of a combination of reduced Norberg angle and reduced acetabular coverage of the femoral head, and in a lesser number of dogs, also modelling of the cranial (flattening) and dorsal (receding) acetabular edge, and occasionally osteophyte formation.

The length of the sacroiliac contact zone was different in 47 of the 138 dogs (34%): in 22 on the right and 25 on the left side. There was a tendency for an association between a shorter sacroiliac contact and a worse ipsilateral hip score ($p = 0.06$). Dogs with identical sacroiliac contact length had identical or similar scores for both hip joints (▶Table 3).

Angulation of the LTV was significantly associated with the difference in the hip scores ($p < 0.01$). In 20 dogs, the LTV was angulated to the right and the conformation of the right hip joint was, on average, better than that of the left hip joint. Conversely, in 24 dogs the LTV was angulated to the left and the conformation of the left hip joint was, on average, better than that of the right hip joint. Dogs with a normally positioned LTV had symmetrical hip joint development (▶Table 4).

Rotation of the pelvis over its long axis was significantly associated with the difference in the hip scores ($p < 0.05$). Elevation of the pelvis on the right was associated with a worse hip conformation on the right and vice versa, while the hip score was identical on average in dogs with no pelvic rotation.

The type of LTV and the rotation of the pelvis over its long axis was significantly associated ($p < 0.05$). The pelvic orientation was normal in 73% of the 90 dogs with symmetrical (1/1, 2/2, 3/3) or only mildly asymmetrical (2/3, 3/2) LTV, but in only 52% of the 48 dogs with markedly asymmetrical LTV (1/2, 2/1, 1/3, 3/1). Among the latter dogs, pelvic rotation was noted towards the side that was in contact with the transverse processes in 18, and away from that side in five, while no rotation was present in 25 (▶Table 5).

Discussion

The conformation of the hips is largely identical in normal and dysplastic dogs, as long as the lumbosacral morphology is symmetrical and the dog is not tilted during the radiographic examination (27). Thus, the total hip score should be identical for both hip joints or differ only slightly. In a previous study using the same population of dogs, a significant association between the morphology of the LTV and the length of the sacroiliac attachment was found (1). The length of the sacroiliac contact zones differed in only 18% of the dogs with a symmetrical LTV, but in 50% of the dogs with an asymmetrical LTV. A shorter sacroiliac contact was usually associated with a longer contact between lateral process and pelvis, and a worse hip joint conformation (1). However, the length of the sacroiliac contact does not seem to be the direct cause of asymmetrical hip joint conformation, as the association was rather weak. We hypothesize that it is the pelvic rotation associated with an asymmetrical LTV which causes different hip joint conformation, particularly in dogs with lax hip joints.

The difference in the hip joint scores was indeed larger in dogs with a free transverse process on one side of the LTV and a transverse process showing partial or complete pelvic contact on the other side (p <0.001). The largest difference was noted in dogs with a pronounced asymmetry (type 1/3 or 3/1). In general, the worse hip joint was seen on the side where the LTV contacted the pelvis. Our results contrast to those found by Wigger and colleagues (12). They defined a sacrum with correctly fused vertebral bodies but a separated dorsal process of the first sacral vertebra as LTV (78% of their total LTV). Moreover they misjudged a type 1/1 LTV as asymmetrical. Pelvic rotation over the long or vertical axis was not addressed. These differences in definition have contributed to their indistinct results and made comparison of results impossible. It also remains non-proven that separation of the spinal dorsal process of S1 is a mild form of a true LTV. Recent data suggest that this feature is over-read on plain radiographs (13). Our results do not contrast to those described by Citi and colleagues (25). They also found the highest proportion of unilateral hip malformation in dogs with LTV. However their statistical results are weak because they did not subgroup LTV according to their morphological variations (25). The age of their examined dogs varied from four months to 15 years which extends the list of possible causes of coxarthrosis. Our results differ from those of Komsta and colleagues who described a correlation only between occurrence of LTV and severe CHD (28). No explanation for this finding was given. An explanation may be the rather coarse graduation of hip conformation from A to E, concealing milder variations in hip joint conformation.

Angulation and deformation of the LVT was seen more frequently in dogs with an asymmetrical LTV. Preferentially, the LTV was angulated towards the side of the worse hip joint.

Rotation of the pelvis over its long axis was seen in about one-third of the dogs with LTV. It was present almost twice as often in dogs with markedly asymmetrical LTV (type 2/1 and 1/3 or 3/1) when compared to those with no or only mild LTV asymmetry. The pelvis was usually elevated on the side where the transverse process was in contact with the pelvis. Similarly, rotation of the pelvis and hip score difference was associated as well and resulted in differences of up to one FCI grade. Unilateral elevation of the pelvis results in a reduced acetabular coverage of the femoral head, which may elicit malformation of the hip joint on the same side (2, 10). The abnormal position of the pelvis is associated with a shortened ilial attachment (2, 10).

Table 5 Correlation between type of lumbosacral transitional vertebra (LTV) and rotation of the pelvis over the long axis (p <0.05), chi-square test.

Lumbosacral transitional vertebra type based on lateral processes (R/L)	Pelvic orientation normal	Pelvis elevated on right	Pelvis elevated on left	Total dogs (n)
1/1, 2/2, 3/3, 2/3, 3/2	66	12	12	90
1/2	8	3	6	17
2/1	8	7	1	16
1/3	5	1	2	8
3/1	4	3	0	7
Total dogs (n)	91	26	21	138

n = number.

An asymmetrical LTV does not always elicit rotation of the pelvis, indicating that the causative factors of malalignment between the LTV and pelvis are complex and have not been fully revealed yet. Axial malpositioning of a normal dog during the radiographic examination results in apparent rotation of the pelvis and the caudal lumbar spine in the same direction. However if the direction or degree of the rotation, or both together, between pelvis and lumbar spine are different, an inherent malposition should be considered. Radiographs taken in lateral recumbency could help to discriminate the cause of rotation, but are not part of official FCI hip examination and were not available in the present study (13). Computed tomography imaging may help to identify the true cause of malalignment, but computed tomography is not an option for mass screening (13).

A pronounced asymmetrical LTV of type 1/3 or 3/1 is often associated with complex changes in the morphology and orientation of the LVT and the pelvis as well with the contact zone between spine and pelvis. The asymmetry of a LTV of type 2/1 or 1/2 is less pronounced and the effect on hip joint conformation is less consistent, documented by the inconsistent p-values. Occasionally, an asymmetrical LTV was deformed trapezoid-like and associated with pelvic rotation over the vertical axis. Rarely was a distortion of the pelvis itself noted. Rotation of the pelvis over its vertical axis may result in a reduced cranial coverage of the femoral head on one side. Both forms of pelvic rotation result in inadequate unilateral development or recession of the craniodorsal acetabular edge and increased risk of femoral head subluxation. The net effect is similar to subluxation commonly seen in dogs with CHD. Subluxation is currently considered to represent the major risk factor for CHD and subsequent coxarthrosis. While occurrence of LTV and genetically determined CHD are considered two independent entities, asymmetrical LTV seem to influence hip joint conformation.

Asymmetrical hip joint formation has been described in dogs with normal lumbosacral anatomy but explanations for this finding are rarely given (12, 21–25, 27, 28). Possible aetiologies are early trauma, axial distortion of the pelvis itself, hip joint laxity in combination with chronic or repetitive unilateral overload of one hip joint during training the dog, and – probably most important – incorrect positioning of the dog during radiographic examination. Moreover, laxity is reflected inconsistently on hip radiographs taken in standard FCI position I, and therefore cannot be quantified reliably (29). The true prevalence of conformational pelvic distortion in itself was not evaluated in this study. Three-dimensional analysis of the pelvic geometry using computed tomography would be needed to identify it (13).

The results of this study support our hypothesis that a pronounced asymmetrical LTV may favour asymmetrical hip joint development in dogs. Preliminary data on the heredity of LTV, differing incidence of LTV among breeds, and anecdotal information of entire litters showing LTV suggest a genetic disposition (1, 12, 13). We recommend that the occurrence of a LTV and its classification be an integral part of the mass screening of dogs for CHD. If future reports should confirm a hereditary component for LTV, it seems judicious that dogs with this abnormality be used cautiously for breeding.

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Conflict of interest

There are no conflicts of interest which exist.

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