Comparison of three radiographic methods for diagnosis of hip dysplasia in eight-month-old dogs

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Hip dysplasia is often diagnosed by examination of a ventrodorsal radiographic projection of the pelvis obtained with the hip joints extended. Criteria for subjective grading of hip joint conformation and severity of osteoarthritis changes have been described, however, this test has limited application for diagnosis of hip dysplasia in juvenile dogs. Other radiographic methods for diagnosis of hip dysplasia have been proposed, including measurement of hip joint laxity as represented by the distraction index (DI) and measurement of the dorsolateral subluxation (DLS) of the femoral heads during simulated weight bearing as represented by the DLS score. A recent report suggested that DI and DLS scores, although associated, represent distinct features of hip joint structure and evaluate different components of hip joint stability. To our knowledge, studies comparing the clinical usefulness of DI and DLS scores to diagnose hip dysplasia in young dogs have not been published.

For obvious reasons, it is advantageous to diagnose hip dysplasia in dogs as early in life as possible. Currently available methods are inaccurate at 4 months of age, because the hip joints are not fully developed until dogs are at least 8 months old. Preliminary studies, however, have suggested that DI and DLS scores remain constant after 8 months of age. The purpose of the study reported here was to compare the accuracy of the extended-hip radiographic (EHR) score, the DI, and the DLS score for identifying hip dysplasia in dogs at 8 months of age.

Materials and Methods

Dogs—Overall, 129 dogs were used in the study; all dogs were from a colony maintained at the James A. Baker Institute for Animal Health. Fifty-four of the dogs were purebred Labrador Retrievers, and 2 were purebred Greyhounds. The remaining 73 were Labrador Retriever-Greyhound crossbreds; 14 were 75% Labrador Retriever and 25% Greyhound, 37 were 50% Labrador Retriever and 50% Greyhound, and 22 were 25% Labrador Retriever and 75% Greyhound. Genetic backgrounds of the dogs and additional details of the colony have been published.

Dogs were fed a commercial dog food and water ad libitum. The experimental protocol was reviewed and approved by the Institutional Animal Care and Use Committee of Cornell University.

Radiographic evaluations—Dogs were radiographed at 8 months of age. Extended-hip radiography, distraction radiography, and DLS radiography were performed, in that order, during a single episode of general anesthesia. Dogs were sedated with acepromazine (0.02 mg/kg [0.01 mg/lb] of body weight, IV) and glycopyrrolate (0.01 mg/kg IV).
Necropsy examination—Age at which dogs were euthanatized was determined on the basis of space limitations and the needs of other studies. Thus, age at the time of euthanasia ranged from 8 to 36 months. Dogs were euthanatized by IV administration of an overdose of barbiturate, and the hip joints and surrounding musculature were removed and placed in crushed ice. The hip joints were examined grossly within 2 hours after death, and a cartilage degeneration score from 0 to 2 was assigned to each joint. A score of 0 was given if the gross appearance of the articular cartilage was normal, a score of 1 was given if the articular cartilage contained an area of fibrillation or ulceration larger than 0.5 cm.

Cartilage degeneration scores were assigned by 1 of 3 individuals. To the extent possible, individuals who assigned scores were unaware of results of the radiographic evaluations. However, because some dogs with extreme DLS scores were intentionally selected for necropsy, the gross examination could not always be blinded.

Statistical analyses—The outcome variable was cartilage degeneration score at necropsy, because hip dysplasia has been associated with development of osteoarthritis. Because cartilage degeneration score was ordinal and distributions for continuous variables (eg, percentage Greyhound ancestry, age at necropsy) were asymmetric, nonparametric statistical methods were used. All analyses were done at the level of the individual dog. For each dog, the lower of the 2 DLS scores and the higher of the 2 EHR scores, DI, and cartilage degeneration scores were used, even if these values were not for the same hip joint.

Simple associations between cartilage degeneration score (0, 1, 2) and other variables were tested by use of the Spearman rank correlation method. Logistic multiple regression was used to analyze the relationship between gross appearance of the cartilage (normal [cartilage degeneration score, 0] vs osteoarthritic [cartilage degeneration score, 1 or 2]) and age at necropsy, percentage Greyhound ancestry, and EHR score, DI, or DLS score (a separate model was constructed for each radiographic method). Age at necropsy and percentage Greyhound ancestry were dichotomized to meet the assumptions of logistic regression at their approximate median values (age at necropsy < 12 months vs ≥ 12 months; percentage Greyhound ancestry < 50% vs ≥ 50%). Dorsolateral subluxation scores were classified as low (< 45%), intermediate (≥ 45% but ≤ 55%), or high (> 55%) on the basis of a priori cut points. Distraction indices were classified as low (< 0.4), intermediate (≥ 0.4 but ≤ 0.7), or high (> 0.7). Radiographic scores were classified as unaffected (≤ 3) or affected (> 3). Variables were deleted by use of a backwards elimination process based on the Wald test. However, variables were deleted only if the likelihood ratio χ² was not significant and none of the coefficients changed by more than approximately 1 SE. Odds ratios (OR) and 95% confidence intervals (CI) were calculated, but Hosmer-Lemeshow goodness-of-fit statistics were not calculated, because some deciles had values of zero. Simple associations between any variable deleted and the variables remaining in the model were tested by use of the rank correlation method.

Sensitivity (percentage of dogs with abnormal cartilage that were correctly identified [a sensitivity of 100% indicates that there were no false-negative results]), specificity (percentage of dogs with normal cartilage that were correctly identified [a specificity of 100% indicates that there were no false-positive results]), and their CI were calculated for EHR scores, DI, and DLS scores; cut points that were used were EHR score > 3, DI > 0.7, DLS score ≤ 55%, and DLS score < 45%.

All statistical calculations were performed with standard software. Values of P < 0.05 were considered significant.

Results

Overall, 98 dogs were assigned a cartilage degeneration score of 0 at necropsy; 19 dogs were assigned a score of 1, and 12 were assigned a score of 2. Visual examination of data distributions suggested that dogs with higher cartilage degeneration scores were older at necropsy and had lower percentages of Greyhound ancestry; higher EHR scores, higher DI, and lower DLS scores (Table 1). The EHR scores (r = 0.47; n = 124),
DI ($t = 0.49; n = 105$), and DLS scores ($t = -0.54; n = 106$) were all significantly ($P < 0.001$) correlated with cartilage degeneration score, but correlation coefficients were only moderate. Sensitivity and specificity of using EHR score, DI, and DLS score to diagnose hip dysplasia in 8-month-old dogs differed among radiographic methods, as indicated by the lack of overlap among CI (Table 2). Gross appearance of the cartilage (normal vs osteoarthritic) was significantly related to age at necropsy, percentage Greyhound ancestry, EHR score, DI, and DLS score. Final logistic regression models included factors for age at necropsy, percentage Greyhound ancestry, or both (Table 3). Risk factors that remained in the model had Wald $P$ values < 0.01; all final fully reduced model $P$ values were $\geq 0.85$, suggesting good fit.

**Discussion**

If the prevalence of hip dysplasia is to be reduced, dogs must be identified as affected or unaffected prior to breeding. Diagnostic methods, therefore, need to be evaluated in juvenile dogs. Preliminary evidence from several studies,9,10,15,19,20 has suggested that available tests were inaccurate when used in dogs at 4 months of age or earlier, partly because of ongoing enchondral ossification and the attendant difficulty of imaging cartilage. Diagnostic methods appear to be more accurate at 8 months of age,9,10,21 when the hip joints are fully mature11 and the period of rapid growth is complete.

Table 2—Sensitivity and specificity of 3 radiographic methods for diagnosis of hip dysplasia in 8-month-old dogs

<table>
<thead>
<tr>
<th>Radiographic method</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EHR score $&gt; 3$</td>
<td>36 (21–58)</td>
<td>96 (90–98)</td>
</tr>
<tr>
<td>DI $\geq 0.7$</td>
<td>50 (28–72)</td>
<td>89 (80–95)</td>
</tr>
<tr>
<td>DLS score $\leq 55%$</td>
<td>83 (63–95)</td>
<td>84 (74–91)</td>
</tr>
<tr>
<td>$&lt; 45%$</td>
<td>58 (37–78)</td>
<td>93 (85–97)</td>
</tr>
</tbody>
</table>

Dogs were determined to have or not have hip dysplasia on the basis of a gross examination of the articular cartilage of the hip joints for signs of osteoarthritis at the time of necropsy; dogs were euthanatized at 8 to 36 months of age. Values in parentheses represent 95% confidence intervals. See Table 1 for remainder of key.

Table 3—Logistic multiple regression models of the relationship between 3 radiographic methods of diagnosing hip dysplasia in 8-month-old dogs and the gross appearance of the articular cartilage of the hip joints at the time of necropsy

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>SE (coefficient)</th>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>EHR score (High ($&gt; 3$))</td>
<td>1.7</td>
<td>0.70</td>
<td>0.01</td>
<td>5.6</td>
</tr>
<tr>
<td>DI (High ($&gt; 0.7$))</td>
<td>1.7</td>
<td>0.58</td>
<td>0.005</td>
<td>5.2</td>
</tr>
<tr>
<td>DLS score (Intermediate ($\geq 0.4$ but $\leq 0.7$))</td>
<td>5.8</td>
<td>13.2</td>
<td>0.66</td>
<td>333.3</td>
</tr>
<tr>
<td>Low ($\leq 45%$)</td>
<td>2.3</td>
<td>0.78</td>
<td>&lt; 0.001</td>
<td>41.2</td>
</tr>
</tbody>
</table>

*Versus a score $\leq 3$, values were adjusted for percentage Greyhound ancestry ($< 50\%$ vs $\geq 50\%$) and age at the time of necropsy ($< 12$ months vs $\geq 12$ months). †Versus a DI $< 0.4$, values were adjusted for percentage Greyhound ancestry, and values classified as "high" were from the model excluding values classified as "intermediate." ‡Versus a DLS score $> 55\%$, values were adjusted for age at the time of necropsy. CI = Confidence interval. See Table 1 for remainder of key.

Therefore, we elected to compare the 3 diagnostic methods in the present study in dogs that were 8 months of age. Until reliable molecular genetic markers for hip dysplasia are identified, the use of methods that assess hip joint stability and conformation to diagnose hip dysplasia will remain important to practicing veterinarians, dog owners, and breeders.

The method used for the diagnosis of hip dysplasia should be the most accurate available and should be applied with rigor. The EHR score after 2 years of age has been used as the standard method for diagnosis of hip dysplasia in North America for > 35 years. With this method, not only is hip conformation evaluated, but the presence of osteoarthritis is also assessed. Evaluations performed before 2 years of age are considered preliminary, because younger dogs with hip dysplasia may not have evidence of subluxation when radiographed in the extended hip position,10,20 and radiographic signs of osteoarthritis may not yet be evident. We concede that EHR scores reported in the present study were obtained at 8 months of age, which is younger than the recommended age for use of this method.9,20

Because of the long-held view that laxity is an important component of the pathogenesis of hip dysplasia,22 the DI9,30 and a laxity-subluxation index21,24 were developed to measure passive laxity and subluxation of the hip, respectively, that may otherwise be masked with the EHR method. We also sought to develop a radiographic method that would allow the hips to be imaged in a neutral passively loaded position to reveal subluxation of the femoral heads, and these efforts led to the development of the DLS method.11,12

The DLS method is similar to the laxity-subluxation method described by Flückiger et al.23,24 but dogs are placed in dorsal recumbency with the laxity-subluxation method, and a dorsally directed load is applied actively to the hind limbs by the holder.

The DI explains $< 40\%$ ($r_{sp} = -0.61$) of the variation in the DLS score. In addition, the DI can be artificially increased by increasing intra-articular volume without affecting the DLS score,21 and the genetic loci that contribute to subluxation, as measured by the DLS score, appear to be different from those controlling...
passive laxity, as measured by the DI.\textsuperscript{15,16} Thus, we believe that the DLS score represents a component of hip joint conformation that is independent of passive laxity yet is important to the subsequent development of osteoarthritis. For this reason, we wanted to determine in the present study whether the DLS method held more promise for diagnosis of hip dysplasia, compared with the EHR and DI methods.

Comparison of diagnostic methods requires identification of a reliable standard to determine the true status of dogs (affected vs unaffected). In the present study, we used the gross appearance of the articular cartilage at necropsy as the standard for determining which dogs had hip dysplasia. Joint tissue changes characteristic of osteoarthritis in dysplastic hip joints have been described well.\textsuperscript{1,5} In previous studies,\textsuperscript{5,10,16,17} radiographic or necropsy evidence of osteoarthritis was used as strong support for a diagnosis of hip dysplasia. In the present study, we elected to use cartilage degeneration scores, because gross examination is a more sensitive method of detecting osteoarthritis in juvenile dogs than is radiography, as dysplastic dogs at 8 to 18 months of age can have grossly detectable cartilage lesions that are not sufficiently advanced to be evident radiographically. On the other hand, it is possible that 8 months of age is too early to see cartilage changes in dogs that are only mildly dysplastic. Therefore, some mildly dysplastic dogs may have been misclassified as unaffected, so that the true prevalence of hip dysplasia in the study population was underestimated.

Unfortunately, a perfect diagnostic test for hip dysplasia in young (ie, 8-month-old) dogs is lacking. Although the proportions of affected and unaffected dogs in the study population would have significantly higher odds of having abnormal cartilage as did a dog with a high score. However, although a dog with a high DI (> 0.7) had 5.2 times the odds of having abnormal cartilage as did a dog with a low DI (< 0.4), a dog with an intermediate DI (≥ 0.4 but ≤ 0.7) did not have significantly higher odds of having abnormal cartilage than did a dog with a low DI. Therefore, we calculated sensitivity and specificity only for a DI cutoff of 0.7. Because the CI for sensitivity did not overlap, the sensitivity of DLS scores (sensitivity of 83%, using a value of 55% as the cutoff) was clearly better than that of the EHR scores (sensitivity of 38%, using a score of 3 as the cutoff). The point estimate of sensitivity of DLS scores was higher than that of DI (sensitivity of 50%, using a value of 0.7 as the cutoff), but the CI overlapped. Specificity was similar for the 3 methods, and using a lower cutoff for DLS score (45%) decreased sensitivity without increasing specificity to any great extent.

Our findings suggest that the strength of the EHR score at 8 months of age is its specificity (ie, a high percentage of dogs without hip dysplasia were correctly identified). However, the EHR score is subjective and subject to individual variations in radiographic assessment.\textsuperscript{10,16} Additionally, the Norberg angle, a measure of severity of subluxation that can be obtained from the EHR view, is not a significant risk factor for osteoarthritis.\textsuperscript{17}

Although the proportions of affected and unaffected dogs in the study population should have had no major effect on calculated sensitivities and specificities, the prevalence of hip dysplasia in a clinical or breeding population will affect the total number of dogs for which results of these tests are correct and the predictive values of the test results.\textsuperscript{18} If a test with moderately high sensitivity (eg, 83%) is used in a population with a low prevalence of hip dysplasia, a negative test result can be considered highly credible. Similarly, if a test with moderately high specificity (eg, 84%) is used in a population with a moderate or high prevalence of hip dysplasia, a positive test result can be considered highly credible.\textsuperscript{19} Explicitly, a DLS score > 55% in a population of dogs with a prevalence of hip dysplasia ≤ 35% would have ≥ 90% negative predictive value; a DLS score ≤ 55% in a population of dogs with a prevalence of hip dysplasia ≥ 64% would have ≥ 90% positive predictive value. In many medium to large dog breeds, prevalence of hip dysplasia is approximately 50%.\textsuperscript{20,21}

Added advantages of the DLS method are that the procedure is easy to perform, requires only a single radiograph, can be done with dogs anesthetized or sedated, and does not require an operator to hold the dog during radiography. In addition, the method and measurements are reproducible.\textsuperscript{21} We think that the essential features that result in passive subluxation in dysplastic hips, as reflected by the DLS score, are the same as those that contribute to osteoarthritis in other joints (eg, shoulder, elbow, stifle, and vertebral joints) in dogs with hip dysplasia. Further, we propose that passive subluxation, detected by use of the DLS method, be used as the defining characteristic of dysplastic hip joints.\textsuperscript{12,22,23} As we believe that this is the best method to date for mimicking the position of the hip joints in ambulating dogs. Thus, we
propose that a DLS score < 55% in an 8-month-old dog be considered an indication that the dog has the trait called hip dysplasia.

Clearly, the passive subluxation measured with the DLS method may not be identical to the dynamic subluxation that occurs as a dog ambulates. In addition, because sensitivity and specificity were not perfect, a DLS score < 55% in an 8-month-old dog should not be used to infer that the dog invariably will develop osteoarthritis. Environmental factors, such as a diet that contributes to rapid weight gain during growth, will also play an important role in determining which dogs will develop osteoarthritis. Equally important, radiographic evidence of osteoarthritis alone does not ensure that clinical signs of lameness will be observed. Finally, hip dysplasia probably is a polygenic trait in dogs, and a clinical signs of lameness will be observed. Furthermore, progeny of dogs with hip dysplasia may be born to parents with normal hip joints.11 In addition, the DLS method may not be identical to the dynamic subluxation of the femoral head and maximal passive laxity for evaluation of the coxofemoral joint in dogs.

References