Magnetic Resonance Measurements of the Deviation of the Angle of Force Generated by Contraction of the Quadriceps Muscle in Dogs With Congenital Patellar Luxation

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Objective—To measure the quadriceps angle (Q-angle) in dogs with congenital patellar luxation using magnetic resonance (MR) methods.

Study Design—Prospective clinical study.

Animals—Thirty-eight client-owned dogs.

Methods—Thirty-eight dogs were examined and placed into the following groups based on the degree of patellar instability: normal, grade I, grade II, and grade III. MR images of 37 pelvic limbs without patellar instability, 33 pelvic limbs with patellar luxation, and 6 limbs with cranial cruciate ligament (CrCL) rupture were made. The Q-angle was calculated using trigonometric methods based on MR images. Limbs with patellar luxation were compared with normal stifles and stifle with other disorders.

Results—The average Q-angle of the normal group was 10.5° (24.9° to 2.0°). The grade I group had an average Q-angle of 12.2° (28.8° to 2°), the grade II group 24.3° (44.6° to 7.7°), and the grade III group 36.6° (51.4° to 15.6°). The average Q-angle of limbs with an isolated CrCL rupture was 19.3° (34.7° to 3.9°).

Conclusion—MR images can be used to make exact calculations of the Q-angle.

Clinical Relevance—MR images can be used to quantify the degree of patellar luxation.
normal to function correctly. Malalignment of one or more of these structures may lead to patellar luxation. Various bony and soft-tissue deformities of the pelvic limbs of animals with congenital patellar luxation cause a deviated direction of force of the quadriceps group.6-8

In human orthopedics, the deviation of the quadriceps direction of force is defined as the angle between the quadriceps resultant (direction of force of the quadriceps group), the patella, and the patellar ligament.9 Several points of measurement have been used to define the quadriceps resultant.9,10,11 This angle is referred to as the quadriceps angle (Q-angle) and can be determined with a goniometer. Goniometric measurements are performed by palpating the borders of the patella and placing an adhesive dot over the center of the patella; one arm of the goniometer is directed to the anterior superior iliac spine and the other to the tibial tuberosity.12

Using the anteroinferior iliac spine as a landmark provides a greater degree of accuracy when measuring the quadriceps resultant with computed tomography.12 During flexion, the sideways pull on the patella by the quadriceps group is dependent on the size of the Q-angle. An increase in the Q-angle can result in luxation or subluxation of the patella.13,14

**CLINICAL ASPECTS**

Patellar luxation is one of the most commonly diagnosed congenital disorders.15 The diagnosis of patellar luxation is generally made on clinical examination and graded based on the Singleton16 scale. The grading of patellar luxations is subjective and dependent on the examiner.17 Accurate grading is important for selective breeding, selecting a therapeutic modality, and for assessing prognosis after surgery. Successful surgical correction of patellar luxation requires an appropriate method of repair. Corrective procedures can be classified as osteoplastic or involving soft tissue. All methods have the common goal of neutralizing the abnormal luxating forces and stabilizing the position of the patella in the trochlear groove. Transposition of the tibial tuberosity is an established surgical correction of patellar luxations of grades II, III, and IV.18 This procedure corrects the pathologic malalignment of the extensor mechanism of the stifle joint. Generally, progression of degenerative joint disease cannot be arrested with surgery.19

The purpose of this study was to measure the quadriceps angle (Q-angle) in dogs with congenital patellar luxation using magnetic resonance (MR) methods, and to examine the relationship between the Q-angle and the degree of patellar luxation.

**MATERIALS AND METHODS**

Thirty-eight client-owned dogs of the following breeds: poodle (n = 6), West Highland white terrier (3), Maltese (3), German shepherd (2), Staffordshire terrier (2), Tibetan terrier (2), Yorkshire terrier (2), Rottweiler (1), Whippet (1), boxer (1), Golden retriever (1), Labrador retriever (1), Chow chow (1), Tibetan mastiff (1), Pitbull terrier (1), Chihuahua (1), and mixed-breed (9) were used in this study. The dogs were divided into groups based on clinical examination of their pelvic limbs. Both pelvic limbs were evaluated individually. The dogs were grouped as abnormal based on the clinical diagnosis of patellar or stifle instability. The pelvic limbs of the normal group had no detectable clinical signs of orthopedic disorders and were randomly selected. The dogs ranged in age from 8 months to 13 years.

**Clinical Examination**

After a history was taken and a general clinical examination performed, the gait of the dogs was evaluated for signs of lameness or abnormal angulation of the limb during the weight-bearing phase of motion. If lameness was detected, it was clinically graded and specifically evaluated to determine if it was intermittent or permanent. This was followed by visual inspection and palpation of the limb while the dogs were standing. Finally, the dogs were placed in lateral recumbency and the pelvic limbs were palpated. Special attention was given to axial deviation, muscle atrophy, and ability to displace the patella. The grading of patellar luxation (I-IV) was based on the clinical findings based on the Singleton16 scale.

**Positioning and Anesthesia**

General anesthetic was administered to the subjects before MR examination. A catheter placed in the cephalic vein was used for venous access during the examination. The animals were premedicated with 0.025 mg/kg intravenous (IV) atropine (Braun, Melsungen, Germany) and 0.5 mg/kg diazepam (Ratiopharm, Ulm/Donautal, Germany) IV. Xylazine (0.3 mg/kg) (Rompun, Bayer, Leverkusen, Germany) and 3 mg/kg IV ketamine (Essex, Munich, Germany) were given as induction agents. The animals were then intubated and put in dorsal recumbency in a semicircular foam-rubber support. The pelvic limbs were extended caudally until they were parallel to the examination table, which placed the hip joints and stifle joints in a position approaching maximal extension (limiting internal rotation...
secondary to flexion of the stifle). The pelvic limbs were internally rotated by the examiner to center the patella in the trochlear groove. A roll of foam rubber was taped between the stifles to keep the thighs parallel to each other. The animals were then placed into the magnetic resonance imager (MRI).

**MR Measurements**

A Magnetom Vision MR (Siemens AG, Erlangen, Germany) with a magnetic-field strength of 1.5 Tesla was used for the MR examination. A high-resolution linear polarized stifle-joint surface coil was used as the transmission and receiver coil.

A dorsal slice of the thigh and pelvic regions was used for base measurements. This scout was used to plan additional slices using a multislice, multiecho method. A T1-weighted turbo-spin sequence with a time of repetition (TR) of 500.0 ms and a time of echo (TE) of 15.0 ms was selected. The slice width was between 3 mm and 6 mm. The data were visualized on a 256 × 256-pixel matrix.

The course of the m. rectus femoris and the patellar ligament of the extended limb were used as base measurements for the Q-angle (Fig 1). The axis of the m. rectus femoris courses from its origin on the area musculi recti femoris to the middle of the trochlea ossis femoris. The course of the patellar ligament is a straight line from the middle of the trochlear groove to its insertion on the tibial tuberosity. The sideways deviation of the course of the patellar ligament, in relation to the axis of the m. rectus femoris, constitutes the size of the Q-angle. A lateral deviation is defined as a lateral Q-angle, and a medial deviation is defined as a medial Q-angle (Figs 2 and 3).

Based on the dorsal slice, parallel slices were taken through the cranial edge of the acetabulum, the patella in the trochlear groove, and through the tibial tuberosity (Fig 4). The transverse slices were projected on a grid, and the coordinates (x/y) of the following points were measured:

**Fig 1.** Reference lines for measurement of the Q-angle include the course of the m. rectus femoris (black line) and the patellar ligament (gray line), which are measured on the extended pelvic limb. A normal limb axis results in a neutral Q-angle.

**Fig 2.** The bone and soft-tissue deformities that occur in congenital patellar luxation cause a lateral deviation of the direction of force generated by contraction of the quadriceps group. A lateral Q-angle increase results in an increase in the lateral luxating force on the patella.

**Fig 3.** The bone and soft-tissue deformities that occur in congenital patellar luxation cause a medial deviation of the direction of force generated by contraction of the quadriceps group. A medial Q-angle increase results in an increase of the medial luxating force on the patella.
1. Area musculi recti femoris (Fig 5; point 8);  
2. Deepest point of the trochlear groove (Fig 6; point 4);  
3. Insertion of the patellar ligament on the tibial tuberosity (Fig 7; point 1).

The Q-angle based on MR images (MR-Q) was calculated for each limb using trigonometry:

\[
\vec{a}_1 = \left( \frac{x_2 - x_1}{y_2 - y_1} \right) \\
\vec{a}_2 = \left( \frac{x_3 - x_2}{y_3 - y_2} \right)
\]

\[
\alpha = \arccos \left( \frac{\vec{a}_1 \cdot \vec{a}_2}{|\vec{a}_1| |\vec{a}_2|} \right)
\]

The difference between groups was examined with the aid of the Kruskal-Wallis test and then subjected to multiple Dunn comparisons. The Dunn tests were corrected according to Holm. A significance level of \( \alpha = 5\% \) was used for paired comparisons of parameters pertaining to the examination groups.

**RESULTS**

Of the 38 dogs examined, 13 had no orthopedic problems in either pelvic limb. In 25 animals, insta-
bility of the stifle or patella was diagnosed. A traumatic patellar luxation was not included in the group examined.

Of the 76 stifle joints examined, 33 had patellar instability. Rupture of the cranial cruciate ligament (CrCL) without signs of patellar instability was found in 6 limbs. In 37 limbs, neither patellar instability nor instability of the stifle joint was diagnosed (Fig 8).

Of the 19 dogs diagnosed with congenital patellar luxation, 14 (74%) were affected bilaterally and 5 (26%) were affected unilaterally. Of the 19 dogs with patellar instability, 17 (90%) were diagnosed with medial patellar luxation and 2 (10%) with lateral luxation.

Six dogs were diagnosed with a unilateral rupture of the CrCL without patellar instability. One dog suffered from bilateral CrCL rupture with a concurrent grade III patellar luxation.

Of the 33 limbs with patellar luxation, 30 luxated medially and 3 laterally. The 3 limbs with lateral patellar luxation were not a large-enough group to be statistically significant and were not included in the statistical evaluation.

Of the 30 pelvic limbs with a medial patellar luxation, 8 (27%) were grade I, 11 (37%) were grade II, and 11 (37%) grade III luxations. A grade IV patellar luxation was not detected in any dog.

The mean, median, maximal, and minimal values of the Q-angle increased with the grade of luxation (Table 1). The mean of the normal group was a medial angle of 10.5°. The group suffering from CrCL rupture had a mean Q-angle of 19.3°. The minimal Q-angle value of the normal group was 2° lateral.

In the normal group, the Q-angle in 90% of the limbs was $<17°$. Seventy-five percent of the limbs in the grade I group had Q-angle values $<16.5°$. A Q-angle $<16%$ was observed in only 25% of the limbs of the grade II patellar luxation group. In the group of dogs with grade III patellar luxations, only 5% of the limbs had a Q-angle of $<16°$. The median Q-angle was two times higher in the grade II group (20.6°) compared with the grade I group (10.1°). Fifty percent of the limbs in the CrCL rupture group exhibited a Q-angle of $>19.2°$.

The normal group had a Q-angle that was statistically significantly smaller than the Q-angle of the grade II and grade III groups. The Q-angle of the normal group did not differ significantly from that of the grade I group and the CrCL rupture group. A significant difference between neighboring groups could not be documented. Only the Q-angle of the grade I group was significantly different to the Q-angle of the grade III group.

**DISCUSSION**

Diverse deformities of the pelvic limb attenuate the extensor mechanism of the stifle and result in a sideways pull on the patella. By calculating the

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**Table 1. Statistical Values of the Q-Angle in Degrees**

<table>
<thead>
<tr>
<th></th>
<th>Normal (n = 37)</th>
<th>Grade I (n = 8)</th>
<th>Grade II (n = 11)</th>
<th>Grade III (n = 11)</th>
<th>CrCL Rupture (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>10.5</td>
<td>12.2</td>
<td>24.3</td>
<td>36.6</td>
<td>19.3</td>
</tr>
<tr>
<td>Median</td>
<td>10.9</td>
<td>10.1</td>
<td>20.6</td>
<td>38.1</td>
<td>19.2</td>
</tr>
<tr>
<td>Maximum</td>
<td>24.9</td>
<td>28.8</td>
<td>44.6</td>
<td>51.4</td>
<td>34.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>-2</td>
<td>2</td>
<td>7.7</td>
<td>15.6</td>
<td>3.9</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>5.6</td>
<td>8.5</td>
<td>10.9</td>
<td>8.6</td>
<td>10.1</td>
</tr>
</tbody>
</table>

NOTE. Data are from 73 canine pelvic limbs.
Q-angle based on MR images, the malalignment of the extensor mechanism can be quantified. Exact points of measurement can be made by analyzing transverse slices of the trochlear groove and tibial tuberosity; measurement errors caused by subluxation and rotation can be eliminated. This agrees with the literature from human medicine, in which computed tomography was used to measure the Q-angle.12

The normal group demonstrated that the canine Q-angle physiologically has an angle of 10° medially. The tibia is slightly internally rotated during flexion of the stifles. This observation is in agreement with other authors, who have described an axial deviation of 10° medially of the direction of quadriceps pull.13

Animals with pathologic deviation of the femoral axis during extension and rotational instability show an increase in the Q-angle during flexion of the stifles. With an increase in the sideways pull of the quadriceps, the force that luxates the patella also increases. Consequently, Q-angle measurements increased in the medial direction with increasing grade of patellar luxation.

Human medicine considers patellar instability and chondromalacia of the patella to correlate with the value of the Q-angle.14,20-25 Reduced and increased Q-angles correlate with increased femoropatellar pressures and cartilage lesions.26

The medial Q-angle was 9° greater medially in 6 limbs with ruptured cruciate ligaments compared with the normal group, but this did not result in clinically diagnosable patellar luxation. This increase of the Q-angle is caused by failure of the restraints (CrCL) of internal rotation. Internal rotation of the tibia is increased by centering the patella during positioning of the patient, causing the Q-angle to increase in the medial direction.

Medial patellar luxation can also be a direct consequence of CrCL rupture.27-29 This is understandable because the medial increase of the Q-angle following CrCL rupture also increases the sideways pull on the medial aspect of the patella. This was the case in the only dog included in the study that suffered from bilateral grade III patellar instability (Q-angle: right 36.2°, left 32.2°) and bilateral rupture of the CrCL. The authors recommend that the stability of the CrCL always be examined to correctly interpret increases of the Q-angle.

Transposition of the tibial tuberosity is an established surgical correction of grade II, III, and IV patellar luxations. The clinical response to treatment correlates with transposition accuracy.18 A preoperative evaluation of the Q-angle offers the possibility for exact reconstruction with a physiologically aligned extensor mechanism.

According to Singleton,16 the sensitivity of measuring the Q-angle is not adequate to make distinctions between the clinical grades of patellar luxations. A statistically significant correlation between the magnitude of the Q-angle and clinical grade is only evident after grade II-III is reached, when compared with dogs without signs of patellar luxation.

The Singleton scale16 divides the tendency of the patella to luxate into grades I to IV. The degrees of quadriceps displacement are continuous, and as a result, no significant differences can be found between neighboring groups of the Singleton grading scale.

Further examination is necessary to determine if a new grading system can be developed based on the size of the Q-angle that also accommodates differences between breeds, sexes, and ages of dogs. Future possibilities include using the Q-angle as an objective parameter for preoperative planning of corrective procedures and for selective breeding.

REFERENCES

2. Perot F: Luxations de la rotule chez le chien II. Point Vet 16:557-573, 1984