Cranial cruciate ligament rupture is among the most common causes of hind limb lameness in dogs. Surgical treatment is recommended to stabilize the stifle joint, alleviate pain, treat concurrent meniscal tears, and delay the progression of osteoarthritis development. Surgical outcome after CCL repair has been evaluated through clinical examination, radiography, owner assessment, and force platform analysis. In many studies, owner assessment has consisted of simple questions regarding the surgical outcome and the owner's satisfaction with the surgical procedure. When reporting surgical results, excellent and good outcomes are often combined, and success rates are generally > 90%.

Recently, interest has grown in development and validation of more sophisticated owner-assessment tools for evaluating chronic pain in osteoarthritic dogs. Innes and Barr developed a visual analog score–based owner questionnaire, the Bristol Osteoarthritis in Dogs questionnaire, which has served in several studies of outcome after CCL surgery. Another validated visual analog score–based owner questionnaire, the Texas A&M Client Questionnaire, has been used to compare outcomes of TPLO and a novel extracapsular CCL repair technique. The Canine Brief Pain Inventory is a validated numeric rating scale–based questionnaire that has been used to evaluate response to treatment of chronic pain in osteoarthritic dogs. The HCPI provides yet another scale for owner evaluation of chronic orthopedic pain. Unlike the Bristol Osteoarthritis in Dogs questionnaire, Texas A&M Client Questionnaire, and Canine Brief Pain Inventory, the HCPI is based on 11 multifactorial descriptive scale questions of dog mood, behavior, and locomotion and also takes into account the emotional aspect of the pain. The HCPI has been used in the assessment of chronic pain in dogs with hip, elbow, and stifle joint osteoarthritis.

Studies have shown that in most dogs, osteoarthritic changes progress even after CCL surgery. Some have speculated that the clinical condition of dogs may deteriorate later in life as a result of the progression of degenerative joint disease. However, only few true long-
term (ie, > 2 years) surgical outcome studies have been reported, and most of them lack validated owner questionnaires. The primary purpose of the study reported here was to evaluate the general long-term surgical outcome after CCL repair by means of an owner questionnaire. As a part of the questionnaire, the validated HCPI served in the assessment of chronic pain and in specifying surgical outcome. The secondary purpose was, via owner assessment, to compare surgical techniques. We hypothesized that we would be able to define the general outcome by quantitatively differentiating excellent and good outcomes and that, on the basis of owner assessments, we would find no significant differences in long-term outcome between surgical techniques.

**Materials and Methods**

**Case selection**—This study was performed in cooperation with the Veterinary Teaching Hospital of the University of Helsinki and 5 private orthopedic referral clinics in Finland. Medical records were reviewed for cases of surgically treated CCL ruptures in dogs between January 2004 and December 2006. Patients with other concomitant stifle joint problems, such as patellar luxation, collateral ligament damage, and septic or immune-mediated arthritis, at the time of the initial CCL surgery were excluded. The study was performed in compliance with institutional guidelines for research on animals, and written consent from owners was obtained.

**Questionnaire**—A questionnaire was sent to the owners of dogs that fulfilled the inclusion criteria for the study. In addition to signalment information (age, breed, and body weight), the questionnaire inquired about the CCL surgery, dogs’ recovery and rehabilitation after surgery, current well-being, signs of chronic pain, and medications. If the dog underwent surgery bilaterally, the owner was asked to answer based on the cruciate surgery performed during this period, the owner was asked to answer based on the latter surgery.

Questions concerning the CCL surgery and the dog’s postoperative recovery inquired about the time of the operation or operations, the type of rupture (unilateral or bilateral), the duration of clinical signs before surgery (< 1 month, 1 to < 2 months, 2 to < 3 months, 3 to 4 months, or > 4 months), and the duration of postoperative lameness (< 1 month, 1 to < 2 months, 2 to < 3 months, 3 to 6 months, > 6 months, or the dog is still lame). Also, the owners were asked whether the dog had received postoperative physiotherapy (ie, range of motion or weight-bearing exercises, massage, swimming, or underwater treadmill).

To assess the dog’s current well-being at follow-up, the questionnaire asked the owners’ opinions of the surgical outcome (excellent, good, fair, or poor). Possible chronic pain was assessed with the HCPI, which contained 11 questions on the dog’s mood, lameness, and willingness to move, play, and jump. Owners were asked to mark only the answer that best described their dog on a 5-point descriptive scale. The answers were later tied to a value (0 to 4), and when summed, gave a total index minimum score of 0 and a maximum score of 44. The HCPI has previously been evaluated for healthy dogs and dogs with hip and elbow osteoarthritis and used to assess a dog that had undergone stifle joint arthroplasty. Individual scores of 0 and 1 on each question indicate normal mood, behavior, and locomotion, and scores of 2, 3, and 4 indicate pain in ascending severity. Healthy dogs usually have an HCPI between 0 and 6, whereas values between 7 and 35 have been measured in dogs with chronic pain. However, healthy dogs may have index values up to 11, assuming that an individual score of 1 is considered normal. Therefore, index values between 6 and 11 represent an ambiguous zone where the dog may be either pain free or painful.

In addition, the owner was asked to rate the frequency of lameness of the dog’s surgically treated limb (never, hardly ever, sometimes, often, or always) and the dog’s willingness to bear weight equally on the surgically treated and contralateral limb (always, very often, often, sometimes, or hardly ever).

The questionnaire also inquired about the need for long-term administration of NSAIDs (eg, carprofen and meloxicam) and the frequency (ie, daily, daily but at intervals as a regimen, a few times per week, a few times per month, or a few times per year) as well as whether the drug was administered for the surgically treated stifle joint. Similar questions asked about nutraceutical products (ie, glucosamine and chondroitin sulfate), pentosan polysulfate sodium injections, and special diets for dogs with degenerative joint disease.

**Medical records review**—With permission from the owners, the surgical records from the veterinary teaching hospital and 5 private clinics were reviewed to ascertain the surgical date, technique used, surgically treated limb, and information about the meniscal tear. Surgical records were also searched for, and owners were asked about possible revision surgery as a result of failure of the surgical technique.

**Statistical analysis**—Data analyses were performed with statistical software programs. Explanatory variables included age, body weight, duration of clinical signs before surgery, surgical technique (intracapsular, extracapsular, or osteotomy), unilateral or bilateral surgery, meniscal integrity (damaged vs intact), number of surgical procedures (1 vs ≥ 2), and follow-up time. The questionnaire outcome variables included HCPI, surgical outcome (excellent, good, fair, and poor), duration of postoperative lameness, frequency of lameness at follow-up, and willingness to bear weight equally on the surgically treated and contralateral limbs at follow-up. Results from nominal and ordinal data (breed, surgical technique, unilateral or bilateral surgery, meniscal integrity, number of surgical procedures, postoperative rehabilitation, duration of postoperative lameness, surgical outcome, frequency of lameness, willingness to bear weight equally on the surgically treated and contralateral limb at follow-up, and NSAID or nutraceutical treatment) are reported as frequencies and percentages. For continuous data, the results are summarized as mean ± SD (age, body weight, follow-up time, and HCPI), range (body weight, follow-up time, and HCPI), and 95% confidence interval (HCPI). Kolmogorov-Smirnov and Shapiro-Wilk tests as well as graphic rep-
resentations served to determine whether data were normally distributed. The Spearman rank test served to analyze the association between the HCPI and the explanatory variables (age, weight, duration of clinical signs before surgery, and follow-up time) as well as between the HCPI and other outcome variables (duration of postoperative lameness, frequency of lameness, and willingness to bear weight equally to surgically treated and contralateral limbs at follow-up). An unpaired $t$ test was used to compare differences in HCPI and age between the excellent and good outcome groups as well as between dogs with and without meniscal tear. The Mann-Whitney rank sum test served to compare differences in the ordinal outcome variables (duration of clinical signs before surgery, duration of postoperative lameness, frequency of lameness at follow-up, and willingness to bear weight equally on the surgically treated and contralateral limbs at follow-up) between the dogs that underwent surgery at least twice and dogs that underwent surgery only once. An unpaired $t$ test was used for similar analysis with continuous explanatory or outcome variables (age, weight, follow-up time, and HCPI). The Kruskal-Wallis statistic was used to compare differences for similar analysis with continuous explanatory or outcome variables (duration of postoperative lameness, frequency of lameness at follow-up, and willingness to bear weight equally on the surgically treated and contralateral limbs at follow-up). An ANOVA was used to compare differences for continuous variables (age, body weight, follow-up time, and HCPI) between the surgical techniques and the Bonferroni-Holm correction method served to further evaluate significant difference in duration of postoperative lameness between surgical techniques. An ANCOVA was used to compare differences for continuous variables (age, body weight, follow-up time, and HCPI) between the surgical techniques and Bonferroni and Tukey post hoc analyses served to further evaluate significant differences found between the techniques. For comparison of HCPI between surgical techniques, ANCOVA allowed removal of the variance arising from the age of the dog. Results were considered significant at $P < 0.05$.

Results

Signalment—Within the study inclusion time frame, 507 dogs with CCL ruptures underwent surgery, and the owners of 272 of 507 (53.6%) dogs answered the questionnaire. Of the 272 returned questionnaires, 19 were removed because of incomplete answers, leaving 253 dogs eligible for evaluation. The mean ± SD age at the time of surgery was 3.9 ± 3.3 years, and the body weight of the dogs was 30.0 ± 17.9 kg (66.1 ± 39.5 lb). The most common breeds were Labrador Retriever (36/253 [14.2%]), Rottweiler (21/253 [8.3%]), Bichon Frisé (16/253 [6.3%]), German Shepherd Dog (8/253 [3.2%]), Golden Retriever (7/253 [2.8%]), Newfoundland Dog (7/253 [2.8%]), Bernese Mountain Dog (6/253 [2.4%]), and Staffordshire Bull Terrier (6/253 [2.4%]); 25 mixed-breed dogs (25/253 [9.9%]) were included. The CCL was ruptured unilaterally in 164 of the 253 dogs (64.8%) and bilaterally in 89 (35.2%). At the time of the questionnaire, 220 of the 253 (87%) dogs were alive. Of the 33 dogs that had died, 5 were euthanized because of problems related to CCL disease, such as osteoarthritis or contralateral stifle joint CCL rupture.

CCL surgery—A modification of the original intracapsular technique was used in 88 of the 253 (34.8%) dogs. Two variations of an original modification of the extracapsular technique with a nylon leader line or polyester sutures were used in 87 of 253 (34.4%) dogs. Osteotomy techniques were used in 63 of the 253 (24.9%) dogs, including TPLOs (34/253 [13.4%]) and TTAs (29/253 [11.5%]), both performed as described. In addition, in 15 of the 253 (5.9%) dogs, the limb underwent surgery ≥ 2 times with a single or multiple techniques. The diagnosis was confirmed and joint visually inspected via arthroscopy in all the dogs. In only 126 of 253 (49.8%) dogs was the condition of the meniscus reported, with damage in 53 (20.9%) and the meniscus intact in 73 (28.9%).

Recovery and rehabilitation after CCL surgery—Six and 5 owners did not report the duration of postoperative lameness and whether the postoperative physiotherapy was used, respectively. Most owners reported that the duration of postoperative lameness was < 3 months. The duration of postoperative lameness was < 1 month for 81 of 247 (32.8%) dogs, 1 to < 2 months for 74 (29.9%), 2 to < 3 months for 37 (15%), 3 to 6 months for 24 (9.7%), or > 6 months for 16 (6.5%). Postoperative lameness was still present for 15 of 247 (6.1%) dogs. Postoperative rehabilitation administered by a physiotherapist was used in 38 of 248 (15.3%) dogs, and aquatic therapy was used as a part of this rehabilitation in 27 of 38 (71.1%) dogs.

Current well-being and signs of chronic pain—The follow-up time (interval between surgery and the questionnaire) was 2.7 ± 0.8 years (range, 1.3 to 4.5 years). Owners reported the surgical outcome in 226 dogs and felt it was excellent in 122 (54.0%), good in 97 (42.9%), fair in 0 (0%), and poor in 7 (3.1%). Owner long-term assessments of frequency of lameness in the surgically treated limb was available for 215 dogs and was described as never (97 [45.1%]), hardly ever (70 [32.6%]), sometimes (29 [13.5%]), often (11 [5.1%]), or always (8 [3.7%]). Owner long-term assessments of willingness to bear weight equally to surgically treated and contralateral limb was available for 212 dogs and was described as always (108 [50.9%]), very often (54 [25.5%]), often (19 [9.0%]), sometimes (13 [6.1%]), or hardly ever (18 [8.3%]).

The HCPI (mean ± SD, 8.9 ± 6.3; range, 0 to 24) could be calculated for 206 dogs, and 64 (31.1%) dogs had an HCPI ≥ 12. Dogs that either had died (n = 33), had recently (within 3 months) undergone surgery on the contralateral stifle joint (4), or had missing answers to HCPI questions (10) were excluded from HCPI determination. The dog’s age and HCPI at the time of the questionnaire were positively correlated ($r = 0.252; P < 0.001$). The HCPI in dogs with good outcomes (11.8 ± 5.4; 95% CI, 10.6 to 12.9) was significantly ($P < 0.001$) higher than in dogs with excellent outcomes ($6.1 ± 5.7; 95% CI, 5.1 to 7.2; Figure 1). No significant difference in age was found between surgical outcome groups. The body weight of the dog, duration of clinical signs before surgery, follow-up time, and presence of absence of a meniscal tear had no significant association with HCPI. Instead, duration of postoperative lameness and HCPI were positively correlated ($r = 0.210; P = 0.002$).
In 15 dogs, the cruciate ligament–deficient limb underwent surgery more than once. Length of postoperative lameness was significantly ($P = 0.018$) longer, and willingness to bear weight equally on the surgically treated and contralateral limb at the time of the questionnaire was significantly ($P = 0.009$) lower in dogs that underwent surgery twice or more than in dogs that underwent surgery only once. Signalment or other outcome variables did not differ significantly between dogs that underwent surgery more than once and dogs that underwent surgery only once.

Current medications and other treatments—Of 213 and 196 dogs, respectively, 26 (12.2%) were receiving medication for the surgically treated stifle joint with NSAIDs and 49 (25.0%) were treated with nutraceuticals (ie, glucosamine and chondroitin sulfate). Of 26 dogs treated with NSAIDs, the frequency of administration was daily for 3 (11.5%) dogs, daily but at intervals as a regimen for 2 (7.7%), a few times per week for 3 (11.5%), a few times per month for 7 (26.9%), or a few times per year for 11 (42.3%). Of 48 dogs treated with nutraceuticals, the frequency of administration was daily for 26 (54.2%) dogs, daily but at intervals as a regimen for 15 (31.3%), a few times per week for 3 (6.3%), a few times per month for 1 (2.1%), and a few times per year for 3 (6.3%).

Comparison of surgical techniques—When surgical outcome was compared with the surgical techniques used, the dogs that underwent surgery with ≥ 2 techniques on the same stifle joint were excluded (n = 11). Dogs that underwent surgery via extracapsular, intracapsular, and osteotomy techniques had a mean ± SD (range) body weight of 18.9 ± 13.6 kg (41.7 ± 30.0 lb; 3 to 65 kg [6.6 to 143.3 lb]), 31.4 ± 16.7 kg (69.2 ± 36.8 lb; 6 to 90 kg [13.2 to 198.4 lb]), and 42.5 ± 14.4 kg (93.7 ± 31.7 lb; 10 to 80 kg [22.0 to 176.4 lb]), respectively, with significant ($P < 0.001$) difference in body weight between dogs that underwent surgery via the different techniques. Dogs that underwent the extracapsular technique were older at the time of surgery (7.3 ± 3.3 years) than those that underwent the intracapsular (5.8 ± 3.0 years) and osteotomy (4.6 ± 2.9 years) techniques ($P < 0.005$). The follow-up time was shorter in dogs that underwent osteotomy techniques (2.2 ± 0.7 years) than in dogs that underwent extracapsular or intracapsular techniques (2.9 ± 0.8 years). Apart from the positive correlation of the dog’s age and HCPI, there was no association between other signalment variables or follow-up time and the outcome variables that were used to compare surgical techniques.

The owner’s assessment of duration of postoperative lameness in dogs that underwent the osteotomy technique was significantly ($P = 0.014$; Bonferroni-Holm test, significance set at $P < 0.016$) shorter than in dogs that underwent the intracapsular technique (Figure 2).

The owner’s assessment of duration of postoperative lameness in dogs that underwent the osteotomy technique was significantly ($P = 0.014$; Bonferroni-Holm test, significance set at $P < 0.016$) shorter than in dogs that underwent the intracapsular technique (Figure 2). No significant
We evaluated long-term surgical outcomes and signs of chronic pain in dogs with surgically treated CCL rupture on the basis of the validated pain index and found that, after a mean period of 2.7 years, almost one-third (n = 64) of the dogs had an HCPI ≥ 12, already indicating pain, and of these, 15 (23%) had an HCPI ≥ 20. The owners in our study reported that 19 of 215 (8.8%) dogs were often or always lame, and 31 of 212 (14.6%) dogs were only sometimes or hardly ever willing to bear weight equally on the surgically treated and contralateral limb. Our results are in accordance with the previous assumption that the progression of osteoarthritis in the cruciate ligament–deficient limb may compromise the limb’s function later in life. In a study by Innes et al, 26 dogs were evaluated by means of the Bristol Osteoarthritis in Dogs questionnaire 40 to 60 months after surgery, and the results were compared with earlier assessments 13 months after surgery. The owners reported that their dogs’ function deteriorated during this time. However, it was unclear whether this deterioration resulted from the progression of osteoarthritis in the affected stifle joint or concurrent problems in the contralateral limb.

At follow-up, only 8 of 213 (3.8%) dogs were receiving NSAIDs for their surgically treated limb on a daily to weekly basis, although, based on the HCPI results, 64 of 206 (31%) dogs still had signs of chronic pain. This result may have many causes, such as the waxing and waning of signs and flare-ups. However, a more probable reason for the low percentage of dogs receiving NSAIDs may be the failure of owners to recognize signs of pain in their dogs. Chronic pain may cause very subtle changes in demeanor, general mood, and willingness to move, which can be difficult to detect. In a previous study, 30 owners failed to recognize signs of pain after only seeing an amelioration after the treatment. Instead, a new deterioration of the condition was required before the owners realized that their dog was in pain. 30 So, although owners in our study described mood, demeanor, and lameness that indicated that their dog still was in pain, they probably did not recognize these as the signs of pain and therefore saw no reason to provide pain medication and also reported the surgical outcome as being good. This also emphasizes the benefits of life-long multimodal supportive treatment for the treatment of osteoarthritis.

Owner assessments in the present study indicated that with the mean of 2.7 years of follow-up, 122 of 226 (54.0%) dogs had excellent long-term outcomes and 97 (42.9%) had good long-term outcomes. In our data, the proportion of the excellent outcome group was similar or somewhat lower than that in earlier studies, 8,22,23 in which there was excellent outcomes in 53% to 75% of patients, with mean follow-up times ranging from 5 to 29 months. This may reflect differences in patient material or treatment methods or, on the other hand, may result from differences in follow-up time between studies. Interestingly, the HCPI in dogs with good outcomes was significantly higher than in dogs with excellent outcomes. In many studies evaluating the outcomes of CCL surgery, excellent and good outcomes are often combined, generally resulting in success rates > 90%. Based on our results, this seems to be a rather insensitive way of reporting an outcome and may give a false impression of a successful pain-free outcome. In our study, the mean HCPI of all dogs was in the ambiguous zone (HCPI between 6 and 11) where the dog may be either pain free or painful. When owner assessment of surgical outcome was evaluated, dogs with good outcomes had an HCPI indicative of chronic pain, whereas dogs with excellent outcomes had values at the level of healthy dogs.

Only a few previous reports, 20–23,31 have used validated owner questionnaires to evaluate surgical outcome or compare surgical techniques or treatment methods. Boyd et al 20 and Renwick et al 21 used the Bristol Osteoarthritis in Dogs questionnaire to evaluate surgical outcome after TPLO and triple tibial osteotomy surgery, and both reported significant improvement in limb function, compared with preoperative status. When the Bristol Osteoarthritis in Dogs questionnaire was used to compare the outcome of TPLO and cranial tibial wedge osteotomy than after the TPLO procedure, with the follow-up ranging from 7 months to 3.3 years, 22 Cook et al 23 used the Texas A&M client questionnaire to compare outcomes on the
basis of visual analog scores 6 months after TPLO and a novel extracapsular CCL repair technique and found that there was no significant difference between these techniques. Interestingly, on the basis of the modified Bristol Osteoarthritis in Dogs questionnaire, Tivers et al concluded that placement of the fabella-tibial suture, in addition to caudal pole meniscectomy for dogs with CCL ruptures and concurrent meniscal tear, may not improve the surgical outcome over that of meniscectomy alone without additional stabilization.

We used the HCPI to compare long-term outcomes of intracapsular, extracapsular, and osteotomy techniques, but significant differences between the techniques were not seen. The owners reported that the duration of postoperative lameness was significantly shorter in dogs that underwent osteotomy techniques than in dogs that underwent intracapsular technique. This supports the general subjective opinion and the results of a recent study that found early weight bearing in dogs that underwent osteotomy techniques. When lameness and weight bearing were evaluated at the follow-up, significant differences between surgical techniques were no longer evident.

The present study had several limitations. The population of dogs in this study was very heterogeneous, with many confounding factors. There were large variations in the age, body weight, and conformation of the dogs. Due to the retrospective nature of the study, the activity level, postoperative rehabilitation, and medications of the dogs as well as owner compliance to the treatment were not standardized, and this may have affected the results of the comparison of the surgical techniques. Naturally, it would have been ideal to perform a prospective, randomized, controlled clinical trial with the effect of confounding factors minimized. On the other hand, it could be considered that circumstances in our study mirror the real-life situation where the age, weight, conformation, and other health issues of the patient, owner compliance, and postoperative treatment may often vary in the patient material.

The study results are based on owner opinions of the postoperative recovery and current well-being of dogs and lack veterinary evaluation and force platform analysis. However, owners are able to evaluate their dogs in their own unstressful environment over time, and thus, an owner's opinion as a part of the outcome assessment should not be underestimated. In addition, the questionnaire included the validated HCPI as part of the evaluation of chronic pain.

The questionnaire was sent 1 to 4 years after CCL surgery, and owner recollection of the time relating to surgery and postoperative recovery can be questioned. Two questions concerning the duration of clinical signs before surgery and the interval between surgery and the resolution of lameness depended purely on owner recollection. Therefore, results of these questions must be interpreted cautiously. All other questions were related to the current well-being of the dog at the time of questioning, where no recollection was needed. The accuracy of the information related to the surgery was also checked from the surgical records.

We conclude that, based on several pain-related questions, many more dogs than expected were found to have signs of chronic pain a mean of 2.7 years after CCL surgery. The level of chronic pain differed significantly between the dogs with excellent and good outcomes. The owner assessments revealed no significant differences in long-term outcome between surgical techniques.

References

Qualitative and quantitative interpretation of computed tomography of the lungs in healthy neonatal foals

Kara M. Lascola et al

Objective—To qualitatively describe lung CT images obtained from sedated healthy equine neonates (≤ 14 days of age), use quantitative analysis of CT images to characterize attenuation and distribution of gas and tissue volumes within the lungs, and identify differences between lung characteristics of foals ≤ 7 days of age and foals > 7 days of age.

Animals—10 Standardbred foals between 2.5 and 13 days of age.

Procedures—Foals were sedated with butorphanol, midazolam, and propofol and positioned in sternal recumbency for thoracic CT. Image analysis software was used to exclude lung from nonlung structures. Lung attenuation was measured in Hounsfield units (HU) for analysis of whole lung and regional changes in attenuation and lung gas and tissue components. Degree of lung attenuation was classified as follows: hyperinflated or emphysema, −1,000 to −901 HU; well aerated, −900 to −501 HU; poorly aerated, −500 to −101 HU; and nonaerated, > −100 HU.

Results—Qualitative evidence of an increase in lung attenuation and patchy alveolar patterns in the ventral lung region were more pronounced in foals ≤ 7 days of age than in older foals. Quantitative analysis revealed that mean ± SD lung attenuation was greater in foals < 7 days of age (−442 ± 28 HU) than in foals > 7 days of age (−521 ± 24 HU). Lung aeration and gas volumes were lower than in other regions ventrally and mid lung caudal to the heart.

Conclusions and Clinical Relevance—Identified radiographic patterns and changes in attenuation were most consistent with atelectasis and appeared more severe in foals ≤ 7 days of age than in older neonatal foals. Recognition of these changes may have implications for accurate CT interpretation in sedated neonatal foals with pulmonary disease. (Am J Vet Res 2013;74:1239–1246)