MRI Findings of Early Osteoarthritis in Patients Who Sustained Septic Arthritis of the Knee After ACL Reconstruction

Uros Meglic,*† MD, Vladka Salapura,‡ MD, PhD, Prof, and Oskar Zupanc,† MD, PhD, Prof

Investigation performed at Department of Orthopaedic Surgery, University Medical Centre Ljubljana, Ljubljana, Slovenia

Background: Although a rare complication, septic arthritis (SA) after anterior cruciate ligament (ACL) reconstruction has potentially devastating consequences for the knee joint.

Purpose: To prospectively analyze, at a mean 4-year follow-up, subjective, clinical, radiographic, and magnetic resonance imaging (MRI) findings between patients with SA and those with no septic complication after ACL reconstruction.

Study Design: Cohort study; Level of evidence, 2.

Methods: Of 2006 ACL reconstructions performed between 2004 and 2014, a total of 20 patients experienced SA. All patients were treated with arthroscopic irrigation and graft-retaining debridement immediately after diagnosis and at least 6 weeks of antibiotic treatment. After the exclusion process, 18 patients were included in the SA group and 20 in the control group. At final follow-up at a mean 48 months, a physical examination, KT-1000 arthrometer laxity test, Lysholm knee score, Tegner activity score, and International Knee Documentation Committee radiographic score were completed and then compared with preoperative data. The Boston-Leeds Osteoarthritis Knee Score was used for MRI evaluation at final follow-up to note chondral changes.

Results: No significant differences between the SA and control groups were observed in pre- and perioperative variables that could indicate a higher incidence of early osteoarthritis (OA). Although range of motion and knee stability were not significantly different between the groups at final follow-up, the Lysholm score (mean ± SD, 79.8 ± 13.1 vs 90.9 ± 8.6; $P < .01$) and Tegner score (6.0 ± 1.1 vs 7.0 ± 1.4; $P = .03$) were significantly lower in the SA group as compared with the control group. MRI evaluation at final follow-up demonstrated a significantly higher degree of early knee OA in the SA group versus the control group. However, no differences in the degree of OA were seen on plain radiographs at final follow-up between the groups.

Conclusion: MRI evaluation provided signs of worsened chondral state in the SA group, which could be associated with reduced functional outcome and return to sports. In contrast to radiograph analyses, MRI was excellent at distinguishing damage to the cartilage and can be useful in early follow-up evaluation of patients with SA after ACL reconstruction.

Keywords: ACL; septic knee; cartilage; radiologic outcome; MRI; control group

Septic arthritis (SA) after anterior cruciate ligament (ACL) reconstruction is a relatively rare complication, with an incidence between 0.14% and 2.6%.[3,6,9,14] The surgeon needs to understand the risk factors and natural history of this complication, given its potentially devastating consequences for the knee joint. Persistent pain, dysfunction, diminished subjective outcomes, additional surgery, secondary graft failure, and development of early osteoarthritis (OA) have all been associated with this diagnosis.[19] Inferior functional outcomes have been reported as related to cartilage damage after infection.[24]

The goals of treatment are to protect the articular cartilage. Arthroscopic debridement with graft preservation and antibiotic therapy has been advocated as the treatment of choice.[10] There is no consensus about the best treatment

*Address correspondence to Uros Meglic, MD, Department of Orthopaedic Surgery, University Medical Centre Ljubljana, Zaloska cesta 9, 1000 Ljubljana, Slovenia (email: u_meglic@yahoo.com).

†Department of Orthopaedic Surgery, University Medical Centre Ljubljana, Ljubljana, Slovenia.

‡Institute of Radiology, University Medical Centre Ljubljana, Ljubljana, Slovenia.

Final revision submitted July 14, 2021; accepted July 26, 2021.

The authors have declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Slovenia National Medical Ethics Committee (No. 0120-49520173).

The Orthopaedic Journal of Sports Medicine, 9(11), 23259671211052519
DOI: 10.1177/23259671211052519

modality, especially regarding hardware removal and graft-retaining protocol.[10]

Several studies[14,19] have reported radiologic outcomes of OA in patients who sustained SA of the knee after ACL reconstruction. However, those studies focused primarily on osteoarthritic changes detected by plain radiographs. In contrast, radiologic outcomes assessed with magnetic resonance imaging (MRI) are a rarity. Yet, even those studies have a low level of evidence, with a lack of a control group and/or small study group.

To explore the cartilage damage related to joint infection, a prospective cohort study was performed, with the primary purpose of evaluating subjective, clinical, and radiologic MRI outcomes of SA after ACL reconstruction.

METHODS

All procedures described in this study were performed in accordance with ethical standards, and ethics committee approval was obtained from the Slovenia National Medical Ethics Committee. Informed consent was obtained from all patients in this study. Only adult patients (>18 years old) were included; it was a prospective cohort study.

Primary ACL Reconstruction

From January 2004 to December 2014, a total of 2006 ACL reconstruction procedures were performed by the same group of 3 experienced orthopaedic surgeons. As part of routine clinical care, all patients underwent a preoperative examination for manual range of motion (ROM), laxity measurements with Lachman and pivot-shift tests, preinjury and preoperative Tegner score, standard radiographs, and MRI of the injured knee.[21] All patients underwent the same surgical technique for primary ACL reconstruction, performed by the same surgical team, using bone–patellar tendon–bone or hamstring tendon single-bundle autograft. In all cases, EndoButton fixation (EndoButton CL Ultra; Smith & Nephew) was used on the femoral side and a bioabsorbable interference screw (Mega Fix CP; Karl Storz Se & Co) on the tibial side. All patients received preoperative antibiotic intravenous prophylaxis with cefazoline. No antibiotic protocol was used for preparing the graft. All patients underwent the same standardized postoperative rehabilitation protocol, with unrestricted weightbearing and ROM after the operation.

Study Group

All patients who sustained SA after ACL reconstruction during the study period composed the study group. The diagnosis of SA was confirmed by positive history and knee examination, elevated serum inflammatory markers (C-reactive protein >5 mg/L and erythrocyte sedimentation rate >28 mm/h), and joint aspiration with synovial white blood cell count >40,000 cells/mm^3 and positive Gram stain. Arthroscopic irrigation with saline solution and graft-retaining debridement was performed on the day of admission in all suspected cases of SA. Intraoperatively, at least 3 synovial biopsy specimens were collected for microbiological cultures. Postoperatively, empiric intravenous antibiotic therapy was started. Antibiotic treatment was reevaluated after microbiological testing and adjusted as needed. Weightbearing and ROM were unrestricted after the operation. If improvement in clinical and laboratory parameters could not be observed at least 3 days after treatment, arthroscopic irrigation and debridement were repeated. In cases of improvement for at least 14 consecutive days, antibiotic treatment was changed to oral administration, and the patient was discharged. Treatment was considered successful if the patient was asymptomatic and laboratory parameters were normal after 6 weeks of antibiotic treatment.

Control Group

As a control group, patients with no SA after ACL reconstruction were randomly recruited in a ratio of 1 infection to 1 control per year. No matching criteria were used. Control group patients were included at the time of the final estimated follow-up after finishing the rehabilitation protocol (>6 months postoperatively).

Exclusion Criteria

In the SA and control groups, all patient data were examined for exclusion purposes. Exclusion criteria were (1) any cartilage lesion present on MRI before the primary operation, as it might have evolved into degenerative changes regardless of the incident; (2) concomitant reconstructive procedures aside from meniscal repair at the time of ACL reconstruction, including osteotomies or additional ligament lesions/reconstructions; and (3) reinjury of the knee.

Baseline and Follow-up Testing Protocol

Data regarding clinical examination, ROM measurement, preoperative laxity measurement (Lachman and pivot-shift tests), and preinjury and preoperative Tegner score were obtained from the patients' preoperative reports at inclusion. Lachman and pivot-shift tests with a grade 2 or 3 (out of 3) were counted as positive. All postinjury radiographs and MRI scans were obtained from a computer archive. Radiographs were graded according to guidelines of the International Knee Documentation Committee (IKDC).[7] MRI scans were examined for exclusion purposes.

Final follow-up was performed at 4 years after the operation using clinical examination, manual ROM testing, laxity assessment (manual testing with Lachman and pivot-shift tests and maximum KT-1000 arthrometer measurements), and Lysholm and Tegner scores.[12,21] All clinical examinations were performed by the same author (U.M.). Lachman and pivot-shift tests with a grade 2 or 3 (out of 3) were counted as positive.

Final follow-up radiographs were graded according to the IKDC guidelines.[7] In addition, at final follow-up, an MRI evaluation of all operated knees was performed using 3-T magnetic resonance tomography (Magnetom Trio; Siemens) with a dedicated 8-channel transmit-receive knee

coil (Invivo) in a supine position, with the knee in approximately 30° of flexion and 10° to 15° of external rotation.

The MRI protocol was as follows:

- Proton density turbo spin echo sequence with fat saturation in the coronal and sagittal planes (repetition time [TR]/echo time [TE], 2400/32 ms; field of view [FOV], 15 cm; slice thickness/interslice gap, 3/1 mm; 384 × 384 matrix; 150° flip angle; 2 signals acquired) and axial plane (TR/TE, 2230/29 ms; FOV 15 cm; slice thickness / interslice gap, 3/1 mm; 512 × 512 matrix, 140° flip angle; 2 signals acquired)
- Proton density turbo spin echo sequence in the coronal and sagittal planes (TR/TE, 2000/30 ms; FOV, 15 cm; slice thickness/interslice gap, 3/1 mm; 384 × 384 matrix; 150° flip angle; 2 signals acquired)
- GRE FLASH sequence in the sagittal plane (TR/TE, 771/15 ms; FOV, 18 cm; slice thickness, 3 mm; 384 × 384 matrix; 30° flip angle; 1 signal acquired)

To score early signs of OA at final follow-up MRI evaluation, the Boston-Leeds Osteoarthritis Knee Score (BLOKS) was used.[8] Individual features of the BLOKS system that were counted include cartilage size and depth (0-3 points for each lesion), subchondral bone marrow lesions (0-3 points for each lesion), osteophytes (0-3 points for each osteophyte), synovitis (0 or 1 point), effusion (0-3 points), and meniscal alterations (0 or 1 point for each alteration). All MRI examinations were reviewed by a musculoskeletal radiologist with 15 years of experience at the time of analysis. All patient data and type of study group were hidden for reliable analysis.

Statistical Analysis

Student *t* tests were used for group comparisons when normality was accepted, and a Mann-Whitney *U* test was used when normality was rejected. The Fisher exact test was used for categorical data between groups. $P < .05$ was considered statistically significant. SPSS Version 21.0 (IBM) was used for all statistical analyses.

RESULTS

During the study period, 20 patients (1.0%) had a postoperative infection, and 20 were randomly recruited as a control group. Of the 40 patients in the study, 38 (95%) were included; 2 patients in the SA group were excluded because of a concomitant reconstructive procedure. In the first case, a subtotal meniscectomy was performed, and cartilage lesions were seen on postinjury MRI. In the second case, a lateral collateral ligament reconstruction was performed. No patients had a reinjury of the knee. All patients were comfortable with the postoperative rehabilitation protocol, and full ROM was achieved during the early postoperative rehabilitation period.

There were no significant differences between the groups regarding age, body mass index (BMI), laxity assessment, or activity level. No excessive valgus of the knee (>8°) was observed in any patient. All patients had minimum grade 2 on manual laxity assessment before initial ACL reconstruction. No statistical difference between the groups was found regarding associated meniscal injury, concomitant meniscal repair, and type of graft used at the initial reconstruction procedure. The baseline characteristics of the patients are presented in Table 1.

TABLE 1
Baseline Characteristics of the Study Patients[a]

	SA Group (n = 18)	Control Group (n = 20)	*P*
Age, y	31 ± 7	33 ± 6	.46
Male sex	11 (61)	12 (60)	≥.99
Body mass index, kg/m^2	25.9 ± 3.2	25.7 ± 3.4	.81
Concomitant meniscal injury	8 (44)	9 (45)	≥.99
Meniscal repair	2 (25)	2 (22)	≥.99
Bone–patellar tendon–bone graft	11 (61)	12 (60)	≥.99
Positive result			
Lachman test	18 (100)	20 (100)	≥.99
Pivot-shift test	18 (100)	20 (100)	≥.99
Follow-up period, mo	48 ± 4	48 ± 4	.99
Time from, d			
Initial operation to infection symptoms	11.7 ± 2.4	—	—
Infection symptoms to treatment	1.4 ± 0.7	—	—
Graft retention	18 (100)	—	—

[a]Data are reported as mean ± SD or No. (%) of patients. Dashes indicate data not applicable. SA, septic arthritis.

All 38 patients were available at follow-up. The mean follow-up was 48 months in both groups (range, 42-56 months). In the SA group, all patients were treated with at least 1 arthroscopic irrigation. The mean interval between the presentation of symptoms and joint irrigation was 1.4 days (range, 1-3 days). In no cases was the removal of the graft or fixation devices needed. The number of irrigation procedures needed was 1 to 3 (mean, 1.2). All patients had well-healed wounds; no reinfection occurred up to the time of final follow-up. Microorganisms were observed in 18 patients: coagulase-negative *Staphylococcus* in 12 (66.7%), methicillin-sensitive *Staphylococcus aureus* in 3, *Streptococcus* in 1, *Corynebacterium* in 1, and *Propionibacterium acnes* in 1.

Follow-up Clinical Results

Follow-up clinical examination showed no deficit in flexion ROM and no retears in any patient. At final follow-up, there was no statistically significant difference between the groups in the laxity assessment. All participants with positive manual laxity assessment at final follow-up had no more than grade 1. There was a statistically significant difference between groups concerning the Lysholm score, with lower scores seen in the SA group (mean ± SD, 79.8 ± 13.1 vs 90.9 ± 8.6 for controls; $P < .01$) (Table 2).

Preoperative versus follow-up Tegner scores showed a significant improvement in both groups (Table 3). Although the preinjury Tegner scores were not significantly different between groups, the final postoperative Tegner score in the

TABLE 2
Clinical Results at Final Follow-up[a]

	SA Group (n = 18)	Control Group (n = 20)	*P*
Flexion ROM, deg	134 ± 4.5	134 ± 5.5	.79
Positive test result			
Lachman	2 (11)	2 (10)	≥.99
Pivot shift	2 (11)	2 (10)	≥.99
KT-1000 side-to-side difference, mm	2.3 ± 1.0	2.1 ± 0.9	.63
Return to prior level of sport	7 (39)	18 (90)	**<.01**
Lysholm score	79.8 ± 13.1	90.9 ± 8.6	**<.01**

[a]Data are mean ± SD or No. (%) of patients. Bold *P* values indicate statistically significant between-group difference ($P < .05$). ROM, range of motion; SA, septic arthritis.

TABLE 3
Preinjury and Final Follow-up Tegner Scores[a]

	SA Group (n = 18)	Control Group (n = 20)	*P*
Preinjury	7.0 ± 1.7	7.1 ± 1.6	.93
Preoperative	5.0 ± 1.0	5.4 ± 1.4	.33
Final follow-up	6.0 ± 1.1	7.0 ± 1.4	**.03**
P value (vs final follow-up)			
Preinjury	**< .01**	.84	
Preoperative	**<.01**	**<.001**	

[a] Data are mean ± SD. Bold *P* values indicate statistically significant between-group difference ($P < .05$). SA, septic arthritis.

TABLE 4
Radiographic Signs of Osteoarthritis Preoperatively and at Final Follow-up[a]

IKDC	SA Group (n = 18)	Control Group (n = 20)
Preoperative		
Normal	18 (100)	20 (100)
Mild	0 (0)	0 (0)
Moderate	0 (0)	0 (0)
Severe	0 (0)	0 (0)
Final follow-up		
Normal	16 (89)	18 (90)
Mild	1 (5.5)	1 (5)
Moderate	1 (5.5)	1 (5)
Severe	0 (0)	0 (0)

[a]Data are presented as No. (%) of patients. IKDC, International Knee Documentation Committee; SA, septic arthritis.

SA group was significantly lower when compared with the control group ($P = .03$).

Follow-up Imaging Results

Radiographic evaluation at final follow-up demonstrated moderate joint narrowing in 1 patient in the SA group and 1 in the control group as well as mild joint narrowing in 1 in the SA group and 1 in the control group. Preoperative and final follow-up radiographic IKDC grading scores are presented in Table 4.

TABLE 5
BLOKS Results and Lesion Locations at Final Follow-up MRI Evaluation[a]

	SA Group (n = 18)	Control Group (n = 20)	*P*
BLOKS	14.2 ± 10.7	7.3 ± 4.8	**.01**
Cartilage lesion	7.4 ± 7	2.5 ± 2	**.01**
Medial patella	33	20	.34
Lateral patella	22	0	**.02**
Medial weightbearing femur	33	25	.41
Lateral weightbearing femur	22	25	.87
Medial tibia	44	5	**<.01**
Subspinous region	22	0	**.02**
Lateral tibia	0	0	>.99
Bone marrow lesion	1.7 ± 1	0.2 ± 0.2	**.01**
Medial patella	11	0	.13
Lateral patella	0	0	>.99
Medial weightbearing femur	11	0	.13
Lateral weightbearing femur	0	0	>.99
Medial tibia	33	5	**.02**
Subspinous region	11	0	.13
Lateral tibia	11	10	.45
Osteophytes	2.4 ± 1.3	1.7 ± 1.6	.16
Synovitis	0.6 ± 0.4	0.7 ± 0.3	.62
Effusion	0.7 ± 0.7	0.7 ± 0.6	.73
Meniscal alterations	1.4 ± 1.1	1.3 ± 1.5	.75

[a]Data are reported as mean ± SD score or percentage of group. Bold *P* values indicate statistically significant between-group difference ($P < .05$). BLOKS, Boston-Leeds Osteoarthritis Knee Score; MRI, magnetic resonance imaging; SA, septic arthritis.

The BLOKS outcome was significantly higher in the SA group (14.2 ± 10.7) than the control group (7.3 ± 4.8; $P = .01$) (Table 5). No significant differences between groups were found in the osteophyte, synovitis, effusion, and meniscal extrusion/alteration parts of the BLOKS system.

DISCUSSION

Our study has several important findings. First, no significant differences between the septic and control groups were observed in pre- and perioperative variables, which could influence the higher incidence of early OA changes. Second, although clinical outcomes involving ROM and knee stability showed no differences between the groups at the final follow-up, the Lysholm and Tegner scores were significantly lower in the SA group than the control group. Third, MRI evaluation demonstrated a significantly higher degree of early OA changes of the knee in the SA group than the control group at final follow-up. However, no difference in the degree of OA was shown on plain radiographs at final follow-up between the groups.

Several factors have been reported to influence the development of knee OA in patients after ACL reconstruction.[11]

Age and BMI increase the risk of knee OA.[4] It has been shown that the risk of OA is higher in patients who sustained ACL rupture when older than 30 years.[11] In our study, we attempted to minimize the influence of those factors. There was no difference between the groups regarding age and BMI in our study, and no patients had BMI >30 kg/m^2.

Meniscal tears at the time of ACL rupture are reported with an incidence from 25% to 65% and are frequently associated with chondral deterioration.[11] In our case, 44% of the patients in the SA group and 45% in the control group had meniscal injuries at initial reconstruction, which is comparable to the levels noted in the literature. In addition, no differences between the groups were observed regarding associated meniscal injury and concomitant meniscal repair at the initial reconstruction procedure.

Associated ligamentous lesions and chondral lesions at the time of initial trauma have shown an increased risk of developing OA.[11,15,16] To decrease the influence of both factors, all patients with concomitant ligamentous lesions and/or chondral lesions before initial ACL reconstruction were excluded from our study. In our study, all patients had an initial ACL reconstruction procedure with the single-bundle technique; there was no significant difference in graft type between the groups, and no allografts were used.

In the SA group, the graft was preserved in all patients, and no patients had reinjury or reoperation of the knee by the time of final follow-up. All patients were treated a few days (range, 1-3 days) after the onset of SA symptoms. In our opinion, this is a possible explanation as to why graft preservation was possible in all cases, thus diminishing the risk of OA development. Knee laxity because of ACL graft removal or rerupture has been associated with increased OA. Pogorzelski et al[17] showed significant inferior subjective and objective outcome scores in the graft resection group as compared with the graft retention group. In their study, a higher graft resection rate than that in the literature was explained with delayed optimal SA management. In a case series with delayed SA management reported by Schulz et al,[20] graft retention was possible in only 37.5% of the cases.

Postoperative infection, including SA, has been shown as an important factor in OA development.[11,20] This can be explained by a biochemical effect of increased cytokine levels and a consequently increased catabolism of chondrocytes leading to the development of chondral lesions.[11]

It is important to emphasize the clinical and functional outcomes at the final follow-up. Normal ROM and no significant differences in knee laxity were observed in both groups. Loss of extension was not observed, as distinct from some studies in the literature.[13] Normal or nearly normal knee joint laxity (grades 0 and 1) was found in 89% in the SA group and 90% in the control group. These results correspond to the results of previous similar studies[13,16] or noncomplication ACL reconstruction studies. However, the Lysholm score obtained at final follow-up in the SA group was 79.8, which is inferior when compared with the control group (90.9). The pain and swelling parts of the score were the ones that most significantly contributed to the difference. These findings are similar to comparable studies in the literature (according to the number of cases and follow-up time), such as Abdel-Aziz et al,[1] Torres-Claramunt et al,[22] and Schulz et al.[20] We note a 90% rate of return to the prior level of sports activity in the control group, while only a 39% rate of return is observed in the SA group after a mean 48 months. For the SA group, the postoperative Tegner scores were significantly lower than the preoperative scores ($P < .01$) and the postoperative scores in the control group ($P = .03$). In light of there being no differences in the pre- and perioperative variables between groups, the diminished subjective outcomes and return-to-sport rate of the SA group were likely related to chondral lesions as a sequela of SA.

Evidence of new degenerative changes after SA complication of ACL reconstruction was observed in our study. Based on final follow-up radiographs taken, we found degenerative changes in 2 (11%) patients in the SA group. However, the results were similar to the control group, with 2 (10%) patients showing degenerative changes on plain radiographs. Our study coincides with the prevalence of degenerative changes after ACL reconstruction found on plain radiographs as described in the literature.[13] However, no differences were observed between the SA and control groups at 48 months regarding radiographs. From these findings, we can determine that radiographs at an early stage are insufficient to assess chondral deterioration and do not prompt a clinician to begin with the preventive chondral protection measures.

Studies comparable in follow-up time to ours have usually reported no radiographic deterioration of the knee.[2,5,25] However, Monaco et al[14] did show radiographic deterioration in 3 (21%) patients in their prospective study, and Schollin-Borg et al[18] presented 2 (20%) cases with joint space narrowing of the medial compartment at maximum 56-month follow-up. Nevertheless, those studies had a low level of evidence with a lack of a control group. Only Abdel-Aziz et al[1] included a comparison of radiographic changes with a control group (ACL reconstruction without SA complication), presenting joint narrowing in 7 (30%) cases in the SA group and 2 (10%) in the control group. But their follow-up time was up to 96 months, which is twice as long as in our study. Their longer follow-up could explain their higher rate of radiographic changes, as chondral defects tend to increase over time.[11]

In contrast to radiographic analyses in several studies, outcomes assessed by MRI are an extreme rarity. Van Ginckel et al[23] presented a chondral fragility seen on MRI 6 months after ACL reconstruction with no septic complication. This information strongly suggests the importance of the chondrolytic effect of SA after ACL reconstruction. Pogorzelski et al[17] and Lo Presti et al[10] reported MRI signs of chondral defect appearing in 69% and 63%, respectively, at final follow-up (103 and 101 months). However, as compared with our study design, their follow-up time was >2 times longer, and no control group was presented.

In our study, we found MRI signs of chondral defect presenting in 12 (67%) patients in the SA group versus 5 (25%) in the control group at 48-month follow-up. Detailed analyses showed a major difference in chondral defects on the medial tibial plateau (44% of the SA group, 5% of the control

group), while on the lateral tibial plateau no, chondral defects were observed in either group. On the medial and lateral femoral condyle, a slightly higher rate of chondral defects was observed in the SA group, although this was not statistically significant. The differences observed in the patellofemoral part of the knee were also not statistically significant (33% in the SA group, 20% in the control group).

Significantly higher BLOKS results were observed in the SA group regarding cartilage lesions ($P = .01$) and bone marrow lesions ($P = .01$). Although increased chondral defects were seen in most compartments of the knees after SA, the highest difference was in the medial compartment. There were no differences in postoperative meniscal alterations, knee laxity, or knee alignment between groups and the graft was retained in all cases; as such, our study cannot provide an explanation why a higher rate of chondral damage was seen in certain locations. Further research is needed with longer follow-up and more patients.

In contrast to radiographs, MRIs in our study managed to express chondral deterioration to a higher extent in the SA group than the control group.

There are a few limitations of our study. It was conducted at a single institution, and given the low prevalence of this complication, the number of cases was relatively small. Nevertheless, it is comparable to similar studies with no control groups. Second, in both groups, there was a diversity in the level of sports activity, ranging from recreational sports (Tegner, 4) to the highest professional competitive sports (Tegner, 10). As mentioned in the literature,[11] the intensity of physical activity may play a role in the risk of further chondral injuries. Nevertheless, no significant differences were found between groups regarding Tegner scores before ACL reconstruction. Finally, the follow-up time in our study was relatively short. It is reasonable to think that the time may affect MRI findings, particularly cartilage status, so it would be useful to obtain data at a later date to validate additional chondral changes and determine the final outcome of the infected knees.

CONCLUSION

SA after ACL reconstruction is associated with reduced functional outcome and return to prior levels of sports activity. Our control group study reports signs of worse chondral state in the SA group than the control group. Although no differences in OA could be obtained from plain radiographs at 48 months, MRI proved to be excellent at distinguishing damage to the cartilage and can be useful even in early follow-up evaluation of these patients. Although the graft was preserved in all patients in our study group, MRI still showed chondral deterioration. Our study thus provides insight into the consequences of SA to a knee joint showing early signs of chondral deterioration. A quick start of combined surgical and pharmacologic treatment early in the disease is essential to minimize symptoms. Early recognition of chondral deterioration with MRI enables a clinician to begin with preventive chondral-protection measures and provides the patient with a good knee–related quality of life, even after such a devastating complication as SA after ACL reconstruction.

REFERENCES

1. Abdel-Aziz A, Radwan YA, Rizk A. Multiple arthroscopic debridement and graft retention in septic knee arthritis after ACL reconstruction: a prospective case-control study. *Int Orthop*. 2014;38(1):73-82.
2. Burks RT, Friederichs MG, Fink B, Luker MG, West HS, Greis PE. Treatment of postoperative anterior cruciate ligament infections with graft removal and early reimplantation. *Am J Sports Med*. 2003;31(3): 414-418.
3. Cadet ER, Makhni EC, Mehran N, Schulz BM. Management of septic arthritis following anterior cruciate ligament reconstruction: a review of current practices and recommendations. *J Am Acad Orthop Surg*. 2013;21(11):647-656.
4. Casteleyn PP, Handelberg F. Non-operative management of anterior cruciate ligament injuries in the general population. *J Bone Joint Surg Br*. 1996;78(3):446-451.
5. Fong SY, Tan JL. Septic arthritis after arthroscopic anterior cruciate ligament reconstruction. *Ann Acad Med Singap*. 2004;33(2):228-234.
6. Gobbi A, Karnatzikos G, Chaurasia S, Abhishek M, Bulgherhoni E, Lane J. Postoperative infection after anterior cruciate ligament reconstruction. *Sports Health*. 2016;8(2):187-189.
7. Hefti F, Müller W, Jakob RP, Stäubli HU. Evaluation of knee ligament injuries with the IKDC form. *Knee Surg Sports Traumatol Arthrosc*. 1993;1(3-4):226-234.
8. Hunter DJ, Lo GH, Gale D, Grainger AJ, Guermazi A, Conaghan PG. The reliability of a new scoring system for knee osteoarthritis MRI and the validity of bone marrow lesion assessment: BLOKS (Boston Leeds Osteoarthritis Knee Score). *Ann Rheum Dis*. 2008;67(2):206-211.
9. Indelli PF, Dillingham M, Fanton G, Schurman DJ. Septic arthritis in postoperative anterior cruciate ligament reconstruction. *Clin Orthop Relat Res*. 2002;398:182-188.
10. Lo Presti M, Costa GG, Grassi A, et al. Graft-preserving arthroscopic debridement with hardware removal is effective for septic arthritis after anterior cruciate ligament reconstruction: a clinical, arthrometric, and magnetic resonance imaging evaluation. *Am J Sports Med*. 2020; 48(8):1907-1915.
11. Louboutin H, Debarge R, Richou J, et al. Osteoarthritis in patients with anterior cruciate ligament rupture: a review of risk factors. *Knee*. 2009;16(4):239-244.
12. Lysholm J, Gillquist J. Evaluation of the knee ligament surgery results with special emphasis on use of a scoring scale. *Am J Sports Med*. 1982;10:150-154.
13. Makhni EC, Steinhaus ME, Mehran N, Schulz BS, Ahmad CS. Functional outcome and graft retention in patients with septic arthritis after anterior cruciate ligament reconstruction: a systematic review. *Arthroscopy*. 2015;31(7):1392-1401.
14. Monaco E, Maestri B, Labianca L, et al. Clinical and radiological outcomes of postoperative septic arthritis after anterior cruciate ligament reconstruction. *J Orthop Sci*. 2010;15(2):198-203.
15. Noyes FR, Barber SD, Simon R. High tibial osteotomy and ligament reconstruction in varus angulated, anterior cruciate ligament–deficient knees: a two- to seven-year follow-up study. *Am J Sports Med*. 1993;21(1):2-12.
16. Oiestad BE, Holm I, Aune AK, et al. Knee function and prevalence of knee osteoarthritis after anterior cruciate ligament reconstruction: a prospective study with 10 to 15 years of follow-up. *Am J Sports Med*. 2010;38(11):2201-2210.
17. Pogorzelski J, Themessl A, Achtnich A, et al. Septic arthritis after anterior cruciate ligament reconstruction: how important is graft salvage? *Am J Sports Med*. 2018;46(10):2376-2383.
18. Schollin-Borg M, Michaëlsson K, Rahme H. Presentation, outcome, and cause of septic arthritis after anterior cruciate ligament reconstruction: a case control study. *Arthroscopy*. 2003;19(9):941-947.
19. Schub DL, Schmitz LM, Sakamoto FA, Winalski CS, Parker RD. Long-term outcomes of postoperative septic arthritis after anterior

cruciate ligament reconstruction. *Am J Sports Med*. 2012;40(12): 2764-2770.
20. Schulz AP, Götze S, Schmidt HG, Jürgens C, Faschingbauer M. Septic arthritis of the knee after anterior cruciate ligament surgery: a stage-adapted treatment regimen. *Am J Sports Med*. 2007;35(7):1064-1069.
21. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res*. 1985;198:43-49.
22. Torres-Claramunt R, Pelfort X, Erquicia J, et al. Knee joint infection after ACL reconstruction: prevalence, management and functional outcomes. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(12): 2844-2849.
23. Van Ginckel A, Verdonk P, Victor J, Witvrouw E. Cartilage status in relation to return to sports after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2013;41(3):550-559.
24. Van Tongel A, Stuyck J, Bellemans J, Vandenneucker H. Septic arthritis after arthroscopic anterior cruciate ligament reconstruction: a retrospective analysis of incidence, management and outcome. *Am J Sports Med*. 2007;35(7):1059-1063.
25. Viola R, Marzano N, Vianello R. An unusual epidemic of Staphylococcus-negative infections involving anterior cruciate ligament reconstruction with salvage of the graft and function. *Arthroscopy*. 2000;16(2):173-177.