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MAGNETIC RESONANCE

Cyclops lesions detected by MRI are frequent findings after ACL surgical reconstruction but do not impact clinical outcome over 2 years

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Abstract
Objectives To assess the impact of cyclops lesions with MRI in patients treated for anterior cruciate ligament (ACL) tears on clinical outcome.
Methods In 113 patients (age 29.8 ± 10.5y; 55 females; BMI 24.8 ± 3.7 kg/m^2) with complete ACL tear, 3 T-MRI scans were obtained before, 6-months, 1-year (n = 75) and 2-years (n = 33) after ACL reconstruction. Presence and volume of cyclops lesions were assessed. Clinical outcomes were measured using the Knee injury and Osteoarthritis Outcome Score (KOOS) and differences between time points (ΔKOOS) were calculated. Changes of KOOS subscales were compared between patients with and without cyclops lesion. KOOS was also correlated with lesion volume.
Results Cyclops lesions were found in 25% (28/113), 27% (20/75) and 33% (11/33) of patients after 6-months, 1- and 2-years, respectively. The lesion volume did not change significantly ($P > 0.05$) between time points, measuring 0.65 ± 0.59, 0.81 ± 0.70 and 0.72.9 ± 0.96 cm^3, respectively. Clinical outcomes based on KOOS subscales were not significantly different in patients with cyclops lesions compared to those without cyclops lesions (each comparison $P > 0.05$), and no significant associations of clinical outcomes with lesion volume were found ($P > 0.05$).

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Conclusions Neither presence nor size of cyclops lesions within the first 2-years after ACL surgery were associated with inferior clinical outcome.

Key Points

- *Cyclops lesions had a prevalence of 25% in patients after ACL reconstruction.*
- *Subjects with cyclops lesions did not have an inferior clinical outcome.*
- *Cyclops lesions developed within the first 6 months after surgery.*
- *The size of cyclops lesions did not significantly change over a period of 2 years.*

Keywords Cyclops lesions · Anterior cruciate ligament tear · KOOS score · MRI · Clinical outcome

Introduction

Anterior cruciate ligament (ACL) rupture is a common and serious knee injury. There are approximately 250,000 new ACL ruptures in the United States each year, which mostly occur in young people [1]. Arthroscopic reconstruction of the torn ACL using a graft is the treatment of choice [2]. A frequent complication is a clinical syndrome defined as loss of knee extension associated with pain at terminal extension, which usually occurs within the first 2 years after surgery [3–7]. Main causes of the mechanical block preventing full extension are graft impingement and cyclops lesions [5, 6, 8, 9]. Cyclops lesions are focal nodules of fibrous tissue located in the intercondylar notch, tightly connected with the reconstructed graft and mostly located anterior to it [10]. The name arose from the arthroscopic appearance of the ovoid-shaped soft tissue mass, with venous vessels resembling a focal “eye-like” area [8]. Although the origin of the fibrous tissue is uncertain, it has been suggested that the formation of the cyclops lesion is stimulated by debris from the drilling and preparation of the tibial tunnel [8, 11]. Even though this lesion was previously defined as localized arthrofibrosis [6, 12, 13], histologically the cyclops lesion is composed of disorganized fibrous connective tissue with a central region of granulation tissue and newly formed vessels [8, 10, 14, 15]. Repeated microtrauma may expose the graft collagen fibres, which can lead to productive inflammatory processes and to the formation of a cyclops nodule [14]. Arthroscopic studies have estimated the prevalence of symptomatic cyclops lesions after ACL surgery ranging between 1% and 9.8% [16, 17]. Symptomatic cyclops lesions, also referred as cyclops syndrome [8, 18], are treated by arthroscopic removal with eventually an additional notchplasty, regaining the full extension of the knee [19–22].

On MR images, the cyclops lesion appears as a well-circumscribed nodule with convex anterior border and low to intermediate signal intensity on T1-weighted images, varying signal intensities on T2-weighted and intermediate-weighted images [12, 23]. Previous studies have demonstrated a good sensitivity, specificity, and accuracy of MRI in revealing cyclops lesions (sensitivity 85.0%, specificity 84.6%, and accuracy 84.8%) [24, 25]. In all mentioned previous studies the prevalence and clinical relevance of cyclops lesions have only been assessed in subjects which presented with severe loss of knee extension at follow-up. The prevalence and clinical significance of cyclops lesions after ACL surgery has never been assessed with multiple MRI scans in a mixed cohort with and without symptoms, and consequently their clinical significance remains unknown.

The purpose of this prospective study, therefore, was to assess the prevalence and the evolution of cyclops lesions in patients who underwent ACL reconstruction after tear, and to analyze the association between the presence of cyclops lesions and clinical outcome 2 years after the surgery. We expected that the presence of cyclops lesions may lead to decrease clinical outcome, particularly in terms of pain and sport activity. We also aimed to identify morphological criteria that were characteristic for symptomatic cyclops lesions.

Material and methods

Subjects

Clinical data and images of 113 patients recruited for two ongoing prospective longitudinal studies were analyzed. One of these studies was a multi-centre study (AF-ACL study) conducted at three sites, the University of California in San Francisco (UCSF), the Hospital for Special Surgery (HSS, New York) and the Mayo Clinic (Rochester) (58 subjects). The other one was a single-centre study performed at University of California, San Francisco (NIH-P50-ACL study; 55 subjects). The two studies applied the same imaging protocols, inclusion and exclusion criteria were identical and studies had the same age range, sex distribution and BMI. Baseline characteristics of all patients are shown in Table 1. All patients gave written informed consent and both studies were approved by the Committees for Human Research/Institutional Review Boards at all participating institutions and carried out in accordance with their rules and regulations.

For both cohorts, the inclusion criteria were clinically diagnosed acute complete ACL rupture confirmed by MR imaging, willingness and capability to undergo ACL reconstruction as well as standard pre- and post-injury/operative rehabilitation. Further inclusion criteria included recorded orthopaedic knee evaluation as well as the surgical report of arthroscopic ACL reconstruction performed within 20 weeks (average was 8.6 ± 6.2 weeks) after injury. The grafts used for the arthroscopic ACL reconstruction were either a hamstring autograft, a patellar autograft or a posterior tibialis allograft. Even though the AF-ACL study was a multicentre study, the technique surgery was precisely standardized throughout the participating centres.

Table 1 Characteristic of the 113 patients enrolled at baseline

Sex (n = 113)*	
Male	58 (51.3%)
Female	55 (48.7%)
Age (years)+	29.8 ± 10.5
BMI (kg/m^2)+	24.8 ± 3.7
Injured side (*n* = 113)*	
Left	53 (46.9%)
Right	60 (53.1%)
Surgery delay after trauma (weeks) +	8.6 ± 6.2
Graft type (*n* = 113)*	
Hamstring/Patellar Autograft	75.2%
Posterior Tibialis Allograft	24.8%

*Data expressed as Count (Percentage %). + Data expressed as Mean ± Standard Deviation

Exclusion criteria were prior history of osteoarthritis, inflammatory arthritis, previous injury and surgery on either knee, and repeated injuries of either knee during the follow-up period. Additionally, patients who required surgical intervention for other ligamentous injuries aside from the ACL, e.g., collateral ligament and posterior cruciate ligament tears, were excluded. Since we were expecting cyclops lesions to be relatively rare, we decided not to exclude subjects with meniscal or chondral damage during our inclusion/exclusion process in order to not further decrease our cohort size as meniscal and chondral lesions are frequent after ACL injury.

Imaging protocol and analysis

All subjects (*n* = 113) were scanned prior to and 6 months after surgery. One-year follow-up MRIs were available for a subcohort of 75 (66%) patients, and two-year follow-up examinations for 33 (29%) patients (UCSF-P50-ACL study) (Fig. 1).

MR imaging was performed using 3 T MR scanners (GE Healthcare, Milwaukee, WI, USA) with an 8-channel phased array knee coil. The imaging protocols of both studies included a high-resolution 3D fast spin-echo sequence (Table 2): this sequence was used to assess the presence of cyclops lesions and additional findings. Furthermore, sagittal and coronal proton density (PD) weighted sequences were performed at baseline for both studies to confirm ACL injury and comorbidities. A cyclops lesion was defined as ovoid-shaped soft tissue mass located in the intercondylar notch and characterized by low to intermediate signal intensity on T1-weighted images, varying signal intensities on T2-weighted and intermediate-weighted images [12, 23]. A diameter of 0.5 cm in each plane was used as the minimum required size to avoid false-positive cases [24].

All exams were independently evaluated for the presence of cyclops lesions by two radiologists (a resident with three years of experience (LF), and a board-certified musculoskeletal radiologist with more than 5 years of experience in MSK Radiology (JBG)). Discordant cases were reviewed by a third board-certified musculoskeletal radiologist with more than 24 years of experience (TML). The volumes of the cyclops lesions (V_{CL}; cm^3) were measured by one radiologist (LF). Two perpendicular diameters of the lesion were measured on the sagittal 3-D fast spin-echo sequence and a third measurement was made on the axial reconstruction where the lesion was more conspicuous using the measurement tool on a picture archiving and communication system (Agfa IMPAX 6, Agfa Healthcare, Mortsel, Belgium), similar to a previous study [24] (Fig. 2). The V_{CL} was approximated to the volume of an ellipsoid, according to the following formula:

$$V = 4/3\pi \ a \ b \ c (V: \text{volume}; \ a, b, c: \text{semi-axis of the ellipsoid}).$$

The maximum axis of the cyclops lesions was noted too (A_{CL}; mm). The scans of the patients with cyclops lesions were evaluated for the presence of associated findings. In particular: 1) optimal positioning of the tibial tunnel parallel but posterior to the Blumensaat line on sagittal images, 2) optimal positioning of the femoral tunnel at less than 60° in the coronal images (1-2 o' clock) [2], 3) graft impingement, 4) screw migration, 5) presence of joint effusion and 6) structural abnormalities of the graft.

Reproducibility

Inter-reader reproducibility for the evaluation of the presence or absence of cyclops lesions was assessed between the two radiologists in all 113 cases by using the Cohen's Kappa and 0.885 (95% confidence interval: 0.788- 0.983). For intra-reader reproducibility analysis, one reader repeated the readings in 40 randomly selected patients after at least 14 days. The Cohen's Kappa for intra-reader reproducibility was 0.882 (95% confidence interval: 0.723-1.000). To assess intra-reader reproducibility of volume measurements, the measurements were repeated by one reader at least one month after the first assessment in all the subjects with cyclops lesion. The mean differences was -22.7,

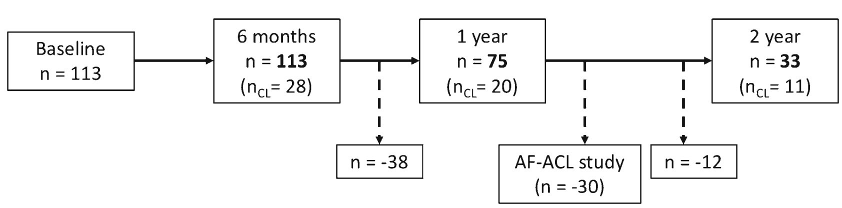

Fig. 1 Patients flow-chart. n: number of subject. n_{CL}: number of subject with cyclops lesions

Table 2 Sequence parameters

	TR (ms)	TE (ms)	BW (kHz)	ETL	NEX	FOV (cm)	Matrix	Slice/Gap (mm)	Add opt
Sagittal Fat Sat 3D FSE	1500	23	50	32	2	16	384x384	1/NA	Fat Sat
Sagittal 2D PD**	5100	30	62.5	13	1-2	16	512x480	3.5/0	TRF
Coronal 2D PD**	5100	30	62.50	13	1	14	512x416	3.5/0	TRF

TR (time to repeat); TE (time to echo); BW (bandwidth) ETL (echo train length); NEX (number of excitations); FOV (field of view); Add opt (additional option); Fat Sat (fat saturation); PD (proton density); TRF (tailored radio frequency pulse). ** available at baseline for both studies, and at 6 months and 1-year time points only for the AF-study

the lower limit of agreement -232.1 and the upper limit of agreement 186.7.

Clinical outcome

At each time point, all five subscales of the Knee injury and Osteoarthritis Outcome Score (KOOS) [26, 27] were assessed: pain, symptoms other than pain, activities of daily living (ADL), sport and recreational function, and knee-related quality of life (QOL). KOOS subscales range from 0 to 100 and the maximum value of KOOS achievable by a healthy patient is 100. For each subscale, the differences of the absolute values at follow-up and baseline examination were expressed as ΔKOOS, with negative values indicating clinical worsening. The presence of a Minimal Detectable Change (MDC) was assessed as previously defined [28].

Additionally, for all the UCSF-P50-ACL study patients ($n = 55$), clinical orthopedic reports at 6 and 12 months after surgery were reviewed: in particular data on range of motion (ROM), Lachman test, pivot shift test, subjective pain and sport activity were collected.

Statistical analysis

Statistical analysis was performed with SPSS (Version 22.0. Armonk, NY: IBM Corp.) using a two-sided 0.05 level of significance. Independent samples t-tests (for numerical and approximately normally distributed data) and Pearson's chi-square tests (for categorical variables) were used to evaluate differences in baseline characteristics between subjects with and without cyclops lesion. Paired samples *t*-tests were used to assess whether cyclops lesions volumes changed significantly between time points. Differences of absolute KOOS and ΔKOOS subscale scores were compared between patients with and without cyclops lesion using independent samples t-tests. Rates of subjects achieving a MDC were compared between the two groups using a chi-square test. Associations of KOOS or ΔKOOS subscales with cyclops lesion volume were assessed using linear regression models (adjusting for age, sex and BMI) (independent variables: volume of cyclops lesions; dependent variable: KOOS or ΔKOOS subscales). Regression models were checked for the following assumptions: normality of the dependent variables and the residuals (Shapiro-Wilk

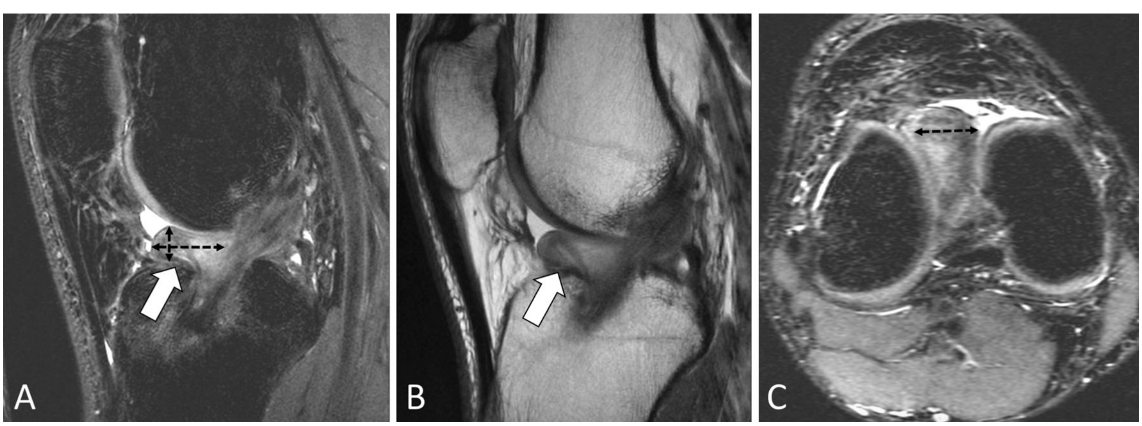

Fig. 2 Sagittal 3-D fast spin-echo (**a**), sagittal proton density- (PD-) (**b**) and axial 3-D fast spin-echo (**c**) weighted images of a 23-year-old female patient showing a well-defined mass (arrows) in the intercondylar notch, localized anteriorly to the anterior cruciate ligament graft and tibial tunnel. The nodule has a convex border, presents intermediate signal in both sequences and was therefore defined as a cyclops lesion. The dashed double arrows in A and C show how the 3 axis of the lesion were measured

test $p > 0.05$). There was not multicollinearity among the independent variables (none of predictor variable pairs showed correlation above 0.2). The absence of influential outliers in the data (max observed: Cook's distance is <1) as well as homogeneity of variances were also checked. The standard residual was between -3 and 3.

Results

Prevalence and volume of cyclops lesions

At 6 months, 28 (24.8%; C.I. 95%: 16.6-32.7) patients presented a cyclops lesion with a mean volume of 0.65 ± 0.59 cm^3 (0.06 cm^3 to 2.85 cm^3; A_{CL}: 5 mm to 21 mm; Table 3). Patients with a cyclops lesion had significantly lower BMI than patients without a cyclops lesion ($p = 0.002$). There were no significant differences between patients with or without cyclops lesions regarding age, sex, the side of the injured knee or the type of ACL graft ($p = 0.26$, 0.78, 0.35, 0.87, respectively). The average time between injury and surgery was 8.6 ± 6.2 weeks. Patients with cyclops lesions showed no difference in time between injury and surgery compared to patients without cyclops lesion ($p = 0.31$). At 1-year ($n = 75$), 20 patients (26.6%; C.I. 95%: 16.6-36.6) presented a cyclops lesion with a mean volume of 0.81 ± 0.70 cm^3 (0.06 cm^3 to 2.79 cm^3; A_{CL}: 5 mm to 27 mm). At 2-years ($n = 33$) 11 patients (33.3%; C.I. 95%: 17.2-49.4) presented a cyclops lesion with a mean volume of 0.72 ± 0.96 cm^3 (0.10 cm^3 to 3.49 cm^3; A_{CL}: 7 mm to 27 mm). There was not significant difference in the volume estimations found between the different time points; volume of cyclops lesions calculated at 6-month follow-up did not differ significantly from the measurements at 1-year ($p = 0.14$) and at 2-year ($p = 0.32$) follow-up, respectively (Fig. 3). In the subgroup of subjects with a cyclops lesion diagnosed on the 6-month MRI, all lesions persisted in the follow-up examinations in those patients in which follow-up MRI was available. None of the subjects without cyclops lesion on the 6-month MRI developed a cyclops lesion in the follow-up studies.

Associated findings in patients with cyclops lesions

All patients showed a correct tibial tunnel positioning parallel and posterior to the Blumensaat line. In five patients (17.8%) the femoral tunnel was positioned too horizontally, with an angle of 61-66°, corresponding to 2-to-3 o' clock in the coronal images. Graft impingement was noted in only one patient with a cyclops lesion of 0.87 cm^3 and a large septated popliteal cyst; two years after surgery the popliteal cyst completely resolved. In four patients (14.2%) arthrofibrosis was noted and one patient in particular showed extensive arthrofibrosis anterior and posterior to the graft, with the tibial screw prominent at the tibial tuberosity (Fig. 4). Mild joint effusion was noted in 2/12 patients at 2-years. Regarding the graft, two patients showed a partial tear, after 6 months and two years, respectively.

Cyclops lesions and clinical outcome

On average, clinical symptoms of the majority of the patients improved, detected as higher KOOS scores, throughout the follow-ups at 6 months, 1-year and 2-years. Percentages of patients with clinical improvement, presenting MDC between follow-up and baseline for pain, symptoms, activities of daily living, sport/recreation activities and quality of life were the following: after 6-months (57.1%, 55.4%, 56.3%, 59.8%, 66.1%, respectively); after 1-year (68.9%, 74.3%, 59.5%,

Table 3 Group characteristics at different time points

	6 months			1-year			2-years		
	Patient with Cyclops	Patient without Cyclops	p-value	Patient with Cyclops	Patient without Cyclops	p-value	Patient with Cyclops	Patient without Cyclops	p-value
N (%)*	28/113 (24.8)	85/113 (75.2)		20/75 (26.6)	55/75 (73.4)		11/33 (33.3)	22/33 (66.6)	
AGE$^+$	28.0 ± 11.1	30.7 ± 10.4	0.26	30.9 ± 10.4	32.9 ± 8.2	0.39	30.5 ± 7.9	35.0 ± 7.8	0.18
BMI$^+$	23.4 ± 2.0	25.3 ± 4.1	0.002	23.0 ± 2.1	24.7 ± 3.6	0.052	22.9 ± 2.1	24.0 ± 2.6	0.22
Male/Female*	15/13	43/42	0.78	10/10	25/30	0.68	4/7	12/10	0.47
Left/Right injured side*	11/17	42/43	0.35	8/12	24/27	0.48	4/7	12/10	0.23
V_{CL} (mm^3)$^+$	0.65 ± 0.59			0.81 ± 0.70			0.72.9 ± 0.96		
A_{CL} (mm)$^+$	14.0 ± 4.0			15.6 ± 5.7			14.9 ± 6.8		

In addition to BMI at 6 months, there were no significant differences between the group of patient with cyclops lesions ($n = 28$ at 6 months, $n = 20$ at 1-year and $n = 11$ at 2-years) compared to patients without cyclops lesions, ($n = 85$ at 6 months, $n = 55$ at 1-year and $n = 22$ at 2-years) regarding age, sex of injured side. V_{CL}: volume of cyclops lesions. A_{CL}: maximum axis of cyclops lesions. *Data expressed as Count (Percentage %). $^+$ Data expressed as Mean ± Standard Deviation

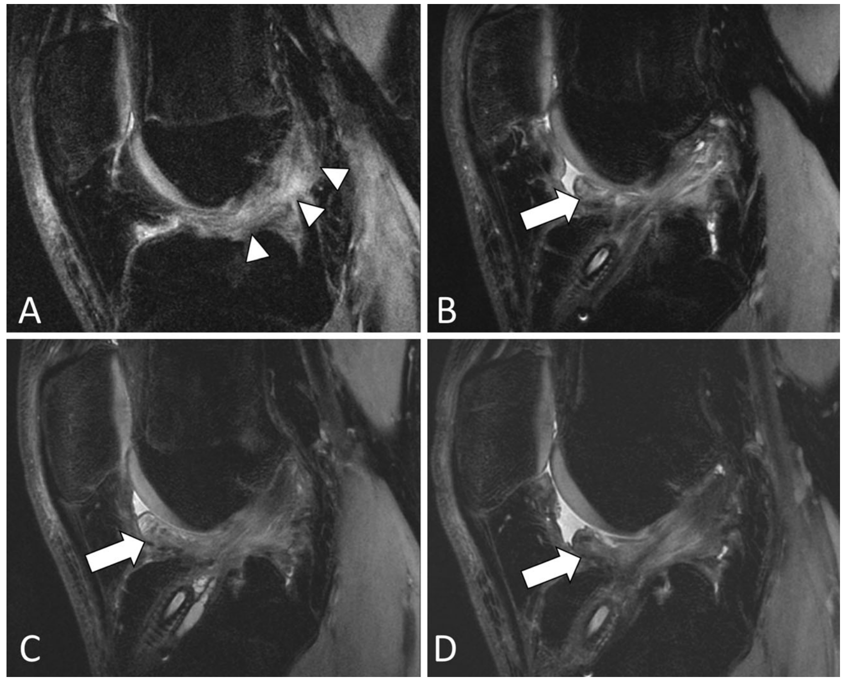

Fig. 3 Sagittal 3-D fast spin-echo images before surgery (**a**), 6 months (**b**), 1-year (**c**) and 2-years (**d**) after anterior cruciate ligament (ACL) surgery of a 19-year-old male patient. In A, the ACL is torn presenting high signal intensity (arrowheads). In B, C and D the ACL graft is present; the volume of the cyclops lesion (arrows) remains constant at the three different time points after the arthroscopic surgery

73.0%, 78.4%, respectively) and after 2-years (60.6%, 75.8%, 54.5%, 66.7%, 87.9%, respectively).

The ΔKOOS scores of patients with or without cyclops lesion are summarized in Table 4. After 6 months, 1- or 2-years, KOOS and ΔKOOS values for all subscales were not significantly different when the two cohorts of patient with and without cyclops lesion were compared. Also the number of subjects reporting a MDC was not significantly different between the two cohorts ($p > 0.05$).

In patients with cyclops lesions, no significant correlations were found between lesion size (V_{CL}) and total KOOS at any time point (6 months, 1- and 2-years) or change of KOOS subscales (ΔKOOS) between the time points (each, $p > 0.05$).

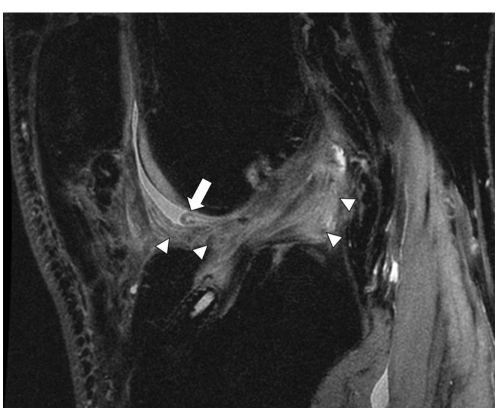

Fig. 4 Sagittal 3-D fast spin-echo images of a 43-year-old male patient 6 months after anterior cruciate ligament reconstruction with distal femoral and proximal tibia tunnel tracts. Extensive heterogeneous soft tissue representing arthrofibrosis is surrounding the graft posteriorly and anteriorly (arrowheads) as well as infiltrating the graft. A cyclops lesion (arrow) is partially visible. Postsurgical scar within Hoffa's fat pad

Even the patients with a volume greater than 2.0 cm^3 did not show significantly worse KOOS scores at any follow-up time point (each, $p > 0.05$). Also, no significant difference was seen in the V_{CL} between those patients with an absolute KOOS score for pain or quality of life lower than the mean scores and those with KOOS scores higher than the mean (each, $p > 0.05$).

In subjects from the P50-ACL study with physical examination data available for the 6- and 12-month follow-up time points ($n = 55$), no significant differences were found between subjects with and without cyclops lesion regarding the results of the range of motion, Lachman test, pivot shift test, subjective pain and sport activity at any time point ($P > 0.14$ for all; Fig. 5 and Table 5).

Discussion

Cyclops lesions detected with MR imaging had a prevalence of 25% 6 months after ACL reconstruction, with a lesion volume ranging between 0.06 cm^3 and 2.85 cm^3 (A_{CL}: 5-21 mm). Subjects with cyclops lesions did not have an inferior clinical outcome, as assessed with KOOS subscales, within the first 2 years after surgery. They regained the full range of motion of the knee within the first year and were able to practice sport activities without limitations.

In previous studies, the frequency of cyclops lesions was estimated to lie between 1 and 10%, based on arthroscopic findings in patients undergoing a second arthroscopy due to persistent loss of extension [9, 16, 20]. As of June 2016 (Pubmed search) we did not find a prospective study assessing

Table 4 Summary of KOOS (Knee-injury and Osteoarthritis Outcome Score) expressed as ΔKOOS and MDC at 6 months, 1-year and 2-years after anterior cruciate ligament surgery

	ΔKOOS*			MDC+		
6 months						
	Patient with Cyclops	Patient without Cyclops	p-value	Patient with Cyclops	Patient without Cyclops	p-value
Pain	16.2 ± 14.7	10.6 ± 17.6	0.13	19 (70.4)	45 (52.9)	0.11
Symptoms	12.0 ± 19.0	10.9 ± 20.5	0.80	17 (63.0)	45 (52.9)	0.36
ADL	17.8 ± 15.7	13.6 ± 18.4	0.29	17 (63.0)	46 (54.1)	0.42
Sport/rec	31.2 ± 30.3	21.1 ± 1.0	0.13	19 (70.4)	48 (56.5)	0.19
QOL	16.9 ± 19.0	19.1 ± 23.0	0.64	20 (74.1)	54 (63.5)	0.13
1-year						
	Patient with Cyclops	Patient without Cyclops	p-value	Patient with Cyclops	Patient without Cyclops	p-value
Pain	17.0 ± 13.6	14.8 ± 16.3	0.71	14.8 ± 16.3	14.8 ± 16.3	0.17
Symptoms	13.5 ± 15.8	16.4 ± 15.8	0.44	16.4 ± 15.8	16.4 ± 15.8	0.28
ADL	16.2 ± 16.1	15.6 ± 16.9	0.90	15.6 ± 16.9	15.6 ± 16.9	0.74
Sport/rec	37.5 ± 30.8	33.6 ± 29.5	0.76	33.6 ± 29.5	33.6 ± 29.5	0.37
QOL	25.6 ± 25.7	30.3 ± 27.7	0.52	30.3 ± 27.7	30.3 ± 27.7	0.82
2-years						
	Patient with Cyclops	Patient without Cyclops	p-value	Patient with Cyclops	Patient without Cyclops	p-value
Pain	14.8 ± 16.3	8.8 ± 11.7	0.12	7 (63.6)	13 (59.1)	0.80
Symptoms	16.4 ± 15.8	14.7 ± 13.4	0.73	7 (63.6)	18 (81.8)	0.25
ADL	15.6 ± 16.9	7.8 ± 7.2	0.06	7 (63.6)	11 (50.0)	0.45
Sport/rec	33.6 ± 29.5	24.5 ± 22.7	0.65	7 (63.6)	15 (68.2)	0.79
QOL	30.3 ± 27.7	27.8 ± 23.4	0.95	10 (90.9)	19 (86.4)	0.70

The clinical outcomes, based on KOOS, were not inferior ($p > 0.05$) for patients with cyclops lesion compare to patient without cyclops lesions. MDC (minimal detectable changes); ADL (activity of daily living); Sport/rec (sport and recreation function); QOL (knee-related quality of life). *Data expressed as Count (Percentage %). + Data expressed as Mean ± Standard Deviation

the MRI prevalence of cyclops lesions in asymptomatic patients who underwent arthroscopic ACL reconstruction. Sanders et al. [22] enrolled 1841 patients retrospectively and reviewed their medical records, in particular the knee range of motion. They found that in 2% of the patients a second surgery was needed in order to treat cyclops lesions, however, the

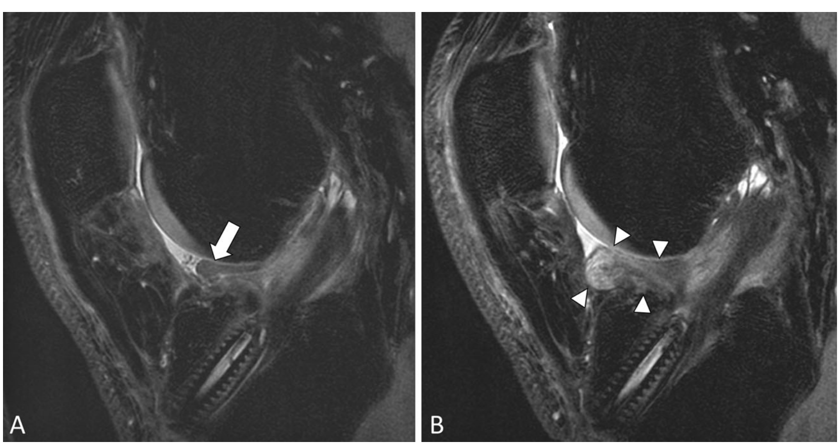

Fig. 5 Sagittal 3-D fast spin-echo images of a 32-year-old male patient 6 months (**a**) and 1-year (**b**) after anterior cruciate ligament reconstruction. At 6 months the patient presented a cyclops lesion (arrow) with volume (V_{CL}) of 0.98 cm^3 and maximum axis (A_{CL}) of 18 mm, moderate pain and quality of life KOOS very low. At 1-year, the V_{CL} of the lesion increased to 2.80 cm^3 (A_{CL} = 27 mm) (arrowheads), the pain disappeared and all KOOS scores improved. Even if the cyclops lesion had a volume more than 2 cm^3, the range of motion of the knee joint was not limited

Table 5 Clinical findings at different time points

	6 months			1-year		
	Patients with Cyclops	Patients without Cyclops	p-value	Patients with Cyclops	Patients without Cyclops	p-value
N (%)*	12/55 (21.8)	43/55 (78.2)		12/55 (21.8)	43/55 (78.2)	
Decreased ROM*	3 (25)	4 (9)	0.14	2 (16)	2 (5)	0.15
Lachman test*	0 (0)	2 (5)	0.44	0 (0)	1 (2)	0.59
Pivot shift test*	0 (0)	1 (2)	0.59	0 (0)	0 (0)	--
Subjective pain*	2 (16)	10 (23)	0.62	1 (8)	6 (14)	0.60
Sport activity*	5 (41)	10 (23)	0.20	10 (83)	37 (86)	0.81

There were no significant differences between the group of patient with cyclops lesions ($n = 12$) compared to patients without cyclops lesions, ($n = 43$) regarding decreased range of motion, Lachman test, pivot shift test, subjective pain or sport activity. ROM: range of motion. *Data expressed as Count (Percentage %)

prevalence of cyclops lesions in patients without severe loss of knee extension was not assessed. Previous studies based on second-look arthroscopy found an incidence of cyclops lesions between 14% and 21.5% [10, 15, 29]. Nevertheless, in these studies follow-up was only performed once, with inhomogeneous follow-up time points ranging from 8 and 36 months [10] and 14 to 70 months [29] after the ACL reconstruction. In contrast, in our longitudinal study the MR imaging follow-ups were performed for several patients at multiple set time points, therefore the evolution of cyclops could be evaluated.

In our cohort, all patients that showed a cyclops lesion had already developed it within the first 6 months after surgery. Moreover, the volume of the lesions did not show a significant change within the first 2 years. Also, no correlation was demonstrated between age, sex, injured side, time between injury and surgery or type of graft and the formation of cyclops lesions. Interestingly, patients with a cyclops lesion presented with significantly lower BMIs than patients without a cyclops lesion. This could potentially suggest that higher BMI and thus increased loads in the knee joints may cause less proliferation of fibrous tissues. A broad spectrum of associate findings was shown in patients with cyclops lesions, but none of them were able to explain the formation or symptoms of cyclops lesions. Most of the patients of our cohort showed a clinical improvement represented by increasing KOOS scores: as expected the scores increased after 6 months and each following year post-surgically. Two years after surgery the benefit of the physical rehabilitation is more evident and more patients resumed sport activities. Furthermore, most of the patients regained full extent of motion and practiced sport activity within the first year after surgery, even those patients with a cyclops lesion larger than 2.0 cm^3.

Our data demonstrated that the clinical outcomes in patients with cyclops lesion are not inferior compared to those of patients without a cyclops lesion, based on KOOS scores of the first 2 years after surgery. Additionally, there were no correlations between the size of cyclops lesions and pain or symptoms other than pain. The reason why cyclops lesions can cause loss of extension needs further investigation: a wide variety of tissue may contribute to the formation of cyclops lesions, including fibrous tissue, fibrocartilage, bone and fat. One possible explanation may be that "harder" variants of lesions could represent a mechanical obstacle at the end of the knee extension, whereas "softer" variants, such as cyclopoid scars, do not affect the range of motion, as shown by Muellner et al. [15]. However, other studies did not find any cartilage or bone tissue in cyclops lesions causing limited knee extension [10, 14]. Therefore, when evaluating a patient with clinical symptoms and decreased range of motion, the radiologist should be aware that the presence of a cyclops lesion could be both, a main finding or a finding without further clinical relevance. Nevertheless, in patients without clinical symptoms and without decrease in range of motion, the presence and size of cyclops lesions are not necessarily correlated with pain or reduced sport and daily life activities.

Our findings are clinically relevant, since the pathophysiological effect of the presence of a cyclops lesion is not fully understood to date. Our results suggest that, probably, even in the setting of a conspicuous scarring and fibrotic tissue in the intercondylar notch of the knee, the motion of the joint is not limited and the pain does not affect the physical activities. No revision surgeries were performed in the period evaluated by our study. The "cyclops syndrome" [8, 18] has been described as very rare (0-2%) and most of the symptomatic cases with extension loss are reported in the literature within the first two years after surgery. Therefore, we were not surprised that there was no patient in our cohort that had to undergo surgery because of a cyclops lesion. Also, none of the patients reported a severe loss in range of motion. We believe this underlines our central finding, that the incidental MR imaging finding of a cyclops lesion is not necessarily associated with clinical symptoms.

Our study has several limitations. Firstly, a second arthroscopy or surgery was not performed; therefore, the results are limited by the sensitivity and specificity of the MRI technique, even if MR imaging has previously shown a high sensitivity and specificity when compared to arthroscopy [24, 25]. Some of the smaller lesions could represent exuberant fibrotic response of the anterior synovial reflection of the graft in the intercondylar region, but our findings are supported by other studies based on second-look arthroscopy [10, 29]. Secondly, the clinical reports including range of motion were available only for the patients of the UCSF-P50-ACL study. Finally, the follow-up period was reasonably short (AF-ACL is limited to 1-year and UCSF-P50-ACL is limited to 2-years) and there were several dropouts especially at the 2-year time point. Yet, while we believe the prevalence and associations with clinical parameters at 6 months are accurate, being based on a larger number of subjects still available, it was our intention to report all available time points, since most of the symptomatic cases with extension loss are reported within the first two years after surgery and the two-year time point may be relevant in this context. Nevertheless, it needs to be pointed out that due to the loss of patients in the follow-up time points, the confidence interval at 1 and 2 year were wider; therefore, further studies with larger cohorts or longer follow-up time are needed in the future to confirm these study results.

In summary, the prevalence of cyclops lesions detected by MRI is approximately 25% of the patients with ACL reconstruction, which is higher than previously estimated. Our study provides evidence that cyclops lesions develop within the first 6 months after surgery and that the presence of a cyclops lesion itself does not worsen the clinical outcome both in terms of function and overall clinical outcome of the patients after 2 years.

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