

# Recommendations for the management of septic arthritis after ACL reconstruction

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## Abstract

**Purpose** To evaluate the current evidence for the management of septic arthritis after anterior cruciate ligament (ACL) reconstruction, the factors that affect the outcome after treatment and the retention of graft and implants.

**Methods** A systematic literature search of the PubMed database was performed on septic arthritis after ACL reconstruction. A total of 301 publications were initially identified, and 17 papers were found to fulfil the criteria to be included in the review.

**Results** There were 196 cases of septic arthritis after ACL reconstruction in over 30,000 ACL reconstructions, making the proportion of infection 0.6 %. Most patients (114/123, 92.6 %) had an acute or subacute infection at an average of  $16.8 \pm 10.5$  days after ACL reconstruction. Coagulase-negative Staphylococci (CNS) was the most common organism (67/147, 45.6 %) followed by *Staphylococcus aureus* (SA) (35/147, 23.8 %); 86.9 % underwent surgical treatment of which 92.8 % had an average of 1.54 (up to 4)

arthroscopic debridements. The group with SA infection had a higher graft removal rate (33.3 %,  $p = 0.019$ ), a longer antibiotic duration (35.4 days,  $p = 0.047$ ) and a worse range of flexion ( $111.5^\circ$ ,  $p = 0.036$ ) than the CNS group.

**Conclusions** CNS was the most common organism in septic arthritis after ACL reconstruction followed by SA. For most authors, arthroscopic debridement combined with intravenous antibiotic therapy was the initial treatment of choice. Antibiotic therapy with or without multiple irrigations of the joint is not recommended based on the high failure rates. Delayed diagnosis of more than 7 days or SA infection required a longer duration of antibiotic therapy and increased the likelihood for graft removal and restricted range of motion. Fungal infection and tubercular infection had a high prevalence of late diagnosis and open debridement.

**Level of evidence** Systematic review, Level IV.

**Keywords** Anterior cruciate ligament · Septic arthritis · Treatment · *Staphylococcus aureus*

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## Introduction

Septic arthritis after arthroscopic anterior cruciate ligament (ACL) reconstruction is a serious complication, with a reported incidence rate of 0.14–2.25 % [3–5, 7, 11–13, 15, 17–20, 23–26]. The presentation of septic arthritis after ACL reconstruction includes a painful knee joint with limited range of motion, persistent effusion, local erythema and fever usually over  $38^\circ\text{C}$  [3–5, 7, 11–13, 15–19, 23–26, 28].

A delay in treatment could lead to graft failure, articular cartilage damage and joint dysfunction. The low incidence and reports of post-ACL reconstruction septic arthritis

make it difficult to find a consensus on an optimum management protocol in the literature. Most authors recommended immediate operative treatment, but there have been different reports on the need for removal of the ACL graft and/or implant as well as the duration of intravenous antibiotics [3–5, 7, 11–13, 16–20, 23, 25, 26, 28]. In contrast, some authors recommended non-surgical treatment with joint irrigation and antibiotics [15, 24].

A systematic review of the literature to summarize the current evidence on the incidence, presentation and management of septic arthritis after ACL reconstruction was performed. The purpose of the study was to determine: (1) the best option for the treatment of septic arthritis after ACL reconstruction—non-surgical or operative treatment; (2) the factors that affect the outcome after treatment—organism type and timing of intervention; and (3) the factors determining the retention of graft and implants.

## Materials and methods

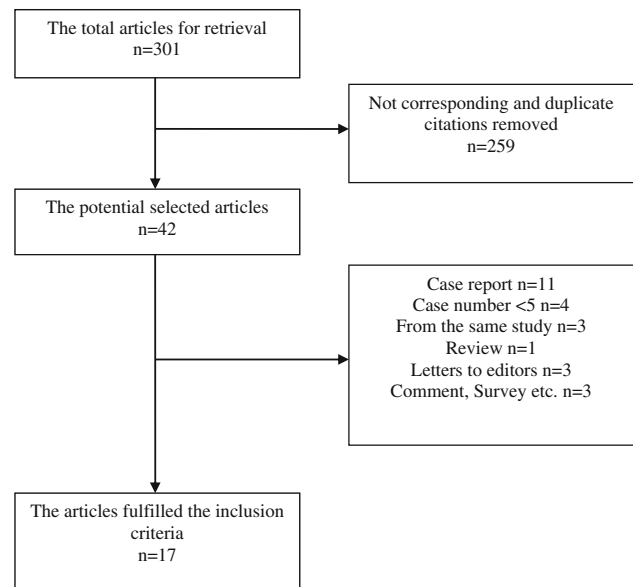
A systematic literature search of the PubMed database was performed concerning septic arthritis after anterior cruciate ligament (ACL) reconstruction. The search terms were [(anterior cruciate ligament) OR (ACL)] AND [(infection) OR (infected) OR (septic arthritis)]. The search restrictions were “Humans”, “English” and “1981–2012”.

A total of 301 articles were retrieved, and 42 of these were identified for potential selection. The references to these articles were reviewed for additional inclusion of articles in this study. After the review of these full-text articles, a total of 17 articles were found to fulfil the inclusion criteria and were included in this systematic review [3–5, 7, 11–13, 15–19, 23–26, 28].

There were four Level III retrospective cohort studies [3, 4, 13, 19], and 13 studies were Level IV case series included in this systematic review [5, 7, 11, 12, 15–18, 23–26, 28]. The process of how these articles were selected was summarized in Fig. 1.

Inclusion criteria were studies of all levels of evidence that had five or more reported cases of septic arthritis as it was difficult to summarize the diagnostic and treatment approaches of the authors for smaller series. This included randomized controlled trials, controlled clinical trials, prospective observational studies, retrospective observational studies and case series. Exclusion criteria were experimental studies involving animals, literature reviews, comments, letters to editors, superficial wound infection and case reports.

All the 17 publications were reviewed, and the patient data were extracted and entered into a separate database. The data collected (when available) were the following: (1) epidemiological information: patient’s age and gender, the



**Fig. 1** Study selection procedure

graft type; (2) diagnostic information: presentation and time to diagnosis, laboratory tests, culture results; (3) treatment information: timing of surgical intervention, treatment modality and success, graft and implant retention, antibiotic duration; and (4) subsequent outcome with IKDC, Lysholm score Tegner scale and instrumental KT-1000 arthrometer measurement.

## Statistical analysis

Statistical analysis was performed with Chi-square and independent-samples *t* test using the SPSS software package between organisms (SA and CNS) and diagnosis time (the duration from the onset of infection to diagnosis). Statistics could only be performed when all the necessary data were available for comparison [3, 5, 7, 11–13, 16–19, 23, 25, 26, 28]. Chi-square analysis was performed to determine whether the treatment methods and graft retention were statistically significant when comparing differences between cultured organisms or time of diagnosis. Between-group differences regarding presentation time, laboratory results, time of procedure, antibiotic duration, range of motion, Tegner scale, Lysholm score and KT-1000 arthrometer testing were analysed with an independent-samples *t* test. All tests were two tailed. Statistical significance was set at  $p < 0.05$ .

## Results

The review revealed 196 cases of septic arthritis after ACL reconstruction in 17 studies. There were 185 infected cases

out of 30,947 ACL reconstructions in 15 studies, giving a combined prevalence of 0.6 % (Table 1). There were additional 11 cases from another two studies that did not mention the actual number of ACL reconstructions performed. The mean age of the patients was 29.1 years (range 14–61).

Patients usually presented with a painful knee joint with limited range of motion, persistent effusion, local erythema and fever [3–5, 7, 11–13, 15–19, 23–26, 28]. The mean time to presentation infection after ACL reconstruction was  $23.5 \pm 46.8$  days (range 2–455). Post-operative infections were classified as acute (<2 weeks), subacute (between 2 weeks and 2 months) and late (>2 months) [3, 23, 25, 26]: 92.6 % had an acute (57/123, 46.3 %) or subacute (57/123, 46.3 %) intra-articular knee infection with an average of  $16.8 \pm 10.5$  days (range 2–56) after ACL reconstruction, and 7.3 % (9/123) patients had a late infection with an average of  $130.8 \pm 124.2$  days (range 61–455) after index surgery.

The type of graft for ACL reconstruction was reported for 167 cases. There were 53 (31.7 %) patellar tendon autografts, 96 (57.5 %) hamstring tendon autografts and 18 (10.8 %) allografts. The infection proportion was 0.3 % (24/8,895), 0.9 % (38/4,194) and 0.3 % (13/4,175) for patellar tendon, hamstring tendon and allograft, respectively ( $p < 0.01$ ).

#### Laboratory and bacteriology

The white blood count (WBC) was elevated in 40 % ( $>10.0 \times 10^9/L$ ) of all cases. The erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) level were

markedly increased in 89 % of patients to  $>30$  mm/h and in 98 % of patients to  $>1.0$  mg/dL, respectively. The mean WBC, ESR and CRP values were  $9.6 \pm 0.6 \times 10^9/L$ ,  $62.5 \pm 6.5$  mm/h and  $18.3 \pm 4.8$  mg/dL, respectively (95 % confidence interval).

On hundred and forty-seven out of the 196 cases (75 %) had a positive organism cultured. The group of coagulase-negative Staphylococci (CNS) that includes *Staphylococcus epidermidis*, *Staphylococcus haemolyticus* and *Staphylococcus hominis* was the most common group of organisms isolated (Table 2). CNS was isolated in 67 (45.6 %) cases of positive cultures with septic arthritis following ACL reconstruction (out of 147 cases with a positive culture). The second most common organism isolated (35 cases, 23.8 %) was *Staphylococcus aureus* (SA). The other organisms (31 cases, 21.1 %) were Genus *Streptococcus* (including *Peptostreptococcus* and *Enterococcus*), *Enterobacter*, *Escherichia coli*, *Pseudomonas aeruginosa*, Propionibacteriaceae, *Corynebacterium* and *Klebsiella*. There were also eight cases (5.4 %) of tubercular infection and six cases (4.1 %) of fungal infection (*Rhizopus* and *Candida albicans*) (Table 2).

#### Management

The treatment modalities were clearly stated in 176 cases (89.8 %). Twenty-three cases had non-surgical treatment (intravenous antibiotic and/or repeated irrigation) [15, 24, 25], 142 cases an arthroscopic debridement [3–5, 7, 11–13, 15–19, 23–26, 28] and 11 an open surgical debridement [16, 28] (Table 3).

**Table 1** Incidence of septic arthritis after ACL reconstruction

	Published year	Level of evidence	Period (years)	No. of ACL reconstructions	No. of infections	Incidence (%)
Williams	1997	4	5	2,500	7	0.28
Viola	2000	4	6	1,794	14	0.78
Indelli	2002	4	6	3,500	6	0.14
Burks	2003	4	11	1,918	8	0.42
Schollin-Borg	2003	3	3	575	10	1.7
Fong	2004	4	3	472	7	1.48
Musso	2005	4	5	1,094	11	1.01
Judd	2006	4	8	1,615	11	0.68
Van Tongel	2007	4	15	1,736	15	0.51
Wang	2008	4	11	4,068	21	0.52
Katz	2008	3	5	801	6	0.75
Nag	2009	4	9	1,152	26	2.25
Barker	2010	3	5	3,126	18	0.58
Monaco	2010	4	8	1,232	12	0.97
Benner	2011	3	27	5,364	13	0.24
Total				30,947	185	0.60

**Table 2** Laboratory data and organism

	WBC ( $\times 10^9/L$ )	ESR (mm/H)	CRP (mg/dL)	Organism (174 cases)
Williams	10.8	82	NA	4 SA, 1 CNS, 1 SA/CNS, 1 SA/PS
Viola	10.2	86.8	10	2 CNS, 9 NG
Indelli	NA	NA	NA	3 SA, 2 CNS, 1 STR
Burks	8.4	48	NA	3 SA, 1 PA
Schollin-Borg	8.4	62.3	9.2	1 SA, 6 CNS, 1 PB, 2 NG
Fong	11.7	72.1	12.3	3 SA, 2 PS, 1 SA/EB, 1 PS/ <i>Klebsiella</i>
Musso	9.41	50.33	5.50	5 CNS, 4 NG
Zalavras	NA	NA	NA	1 SA, 1 CNS, 2 CNS/PA, 1 <i>E. coli</i> /EC
Judd	9.8	66.9	13.7	1 SA, 8 CNS, 1 EB, 1 CB
Van Tongel	8.1	70.6	14.7	1 SA, 8 CNS, 1 STR, 1 EC, 1 EB, 1 CNS/SA, 1 CNS/CB, 1 NG
Wang	9.1	59.7	8.3	2 SA, 11 CNS, 1 EC, 1 CB, 1 CNS/SA, 5 NG
Katz	10.1	58.3	31.1	4 CNS, 1 CNS/SA, 1 CNS/CB
Nag	NA	45.1	59.5	10 SA, 4 CNS, 2 PS, 1 EB, 1 SA/TB, 8 TB
Muscolo	NA	NA	NA	5 <i>Rhizopus</i> , 1 <i>Candida albicans</i>
Barker	9.5	79.8	17.5	6 SA, 4 CNS, 2 CB, 6 NG
Monaco	8.6	76	7.4	11 CNS, 1 <i>E. coli</i>
Total				67 CNS, 35 SA, 8 TB, 6 Fungi, 31 others, 27 NG

WBC peripheral white blood cell count, ESR erythrocyte sedimentation rate, CRP C-reactive protein, NA not available, SA *Staphylococcus aureus*, CNS coagulase-negative Staphylococci, STR *Streptococcus* group, PS *Peptostreptococcus*, EC *Enterococcus*, EB *Enterobacter*, *E. coli* *Escherichia coli*, PA *Pseudomonas aeruginosa*, PB Propionibacteriaceae, CB *Corynebacterium*, TB tubercle bacillus, NG no growth

### Non-surgical treatment

Viola et al. [24] used antibiotic treatment as their modality of treatment where they administered ciprofloxacin and amoxicillin plus clavulanate from 15 to 90 days. They stopped antibiotics 3 days after achieving normal laboratory results. Two weeks after the onset of signs of infection, six of 14 patients (42.9 %) failed antibiotic treatment alone and required arthroscopic debridement because clinical symptoms and the laboratory tests remained unchanged. Monaco et al. [15] described the combined use of repeated joint irrigation and antibiotic therapy. The patients were all treated with knee irrigation with saline solution using inflow and outflow needles for 4 h per day for 2–3 days. Four (30 %) out of 12 patients failed this non-surgical treatment and required arthroscopic debridement. Wang et al. [25] reported six out of 21 patients (28.6 %) which were treated with joint irrigation and intravenous antibiotics with third-generation cephalosporin or vancomycin. Treatment was effective, and no patient had the ACL graft removed. However, non-surgical treatment required a longer time for fever and constitutional symptom resolution [9.2 vs 1.5 days ( $p = 0.059$ )] and a longer duration of intravenous antibiotic therapy than operatively treated patients [28 vs 19 days ( $p = 0.007$ )].

### Operative treatment

Out of 176 patients, 153 (86.9 %) underwent surgical treatment for septic arthritis; 142 of 153 patients (92.8 %) had arthroscopic debridement, and 11 patients (7.2 %) were treated with an open debridement after non-successful arthroscopic debridement. An average of 1.5 (range 1–4) arthroscopies were performed in the operative treatment group (Table 3).

Specific information on the number of arthroscopic debridements was only reported in 103 cases (Table 3). Sixty-two patients (60.2 %) had one, 29 patients (28.2 %) had two, nine patients (8.7 %) had three and three patients (2.9 %) had four arthroscopic debridements. Repeat debridement was done because of persistent fever, a hot and swollen knee and no ameliorative results of CRP and ESR [11, 23]. The number of arthroscopic debridements performed for each patient had no significant correlation with the type of organisms or time of diagnosis ( $p > 0.05$ ) (Table 4).

The duration of intravenous antibiotics was  $29.7 \pm 11.6$  days, until the CRP levels were near normal (Table 3). This was converted to oral antibiotics that were administered for another 2–4 weeks [7, 15, 19]. Oral antibiotics were stopped when the CRP normalized twice within an interval of a minimum of 14 days [23].

**Table 3** Management of septic arthritis after ACL reconstruction

	No. of cases	Treatment protocol (no. of case)	No. of procedures	Graft removed	Second reconstruction (duration after infection)	Duration of antibiotic
Williams	7	OP	1.5 (1–2)	3	1 (NA)	IV: 4–6 weeks
Viola	14	IV (8)/OP (6)	1	0		IV: 15–90 days
Indelli	6	OP	1.3 (1–3)	2	1 (1 year)	IV: >6 weeks
Burks	8	OP	2	7	4 (3 weeks, 1–6)	IV: 6 weeks
Schollin-Borg	10	OP		0		IV + oral: 4–12 weeks
Fong	7	OP	1.4	0		17.7 days (8–31, IV) + 4 weeks (oral)
Musso	9/11	IV (1)/OP (8)	1.3 (1–2)	0		6.5 weeks (4–10)
Zalavras	5	ROD		5	1 (14 months)	6 weeks
Judd	11	OP	2.4 (1–4)	1		IV: 28 days (14–42)
Van Tongel	15	OP	1.9 (1–4)	1		IV: 24.6 days (12–46)
Wang	21	IV and AC (6)/OP (15)	1	0		IV: 21.8 days (13–38)
Katz	6	OP		1		IV: 4–6 weeks
Nag	8/26	OP	1.3 (1–2)	0		Antitubercular chemotherapy (12 months)
Muscicolo	6	ROD		6		Amphotericin B/liposomal amphotericin (6 weeks)
Barker	18	OP	1.5 (1–3)	5		IV: 6 weeks
Monaco	12	IR (8)/OP (4)		0		Intramuscular + oral: 7 (6–8) weeks
Benner	13	OP		2		NA
Total	176/196	No-OP 23/OP 142/ROD 11	1.5 (1–4)	33		IV: 29.67 days

OP arthroscopic debridement, IV intravenous antibiotic, AC arthrocentesis, ROD radical open debridement, IR ambulatory irrigation, NA not available

Thirty-three of 176 (18.8 %) ACL grafts were removed because they were found to be insufficient on probing or were covered with a purulent exudate (Table 3). In 16 patients, seven grafts were removed during the first, in six patients during the second, in two patients during the third and in one patient during the fourth debridement.

The graft removal proportion (with arthroscopic debridement and open surgery) was 33.3 % (4/12), 39.1 % (9/23) and 50.0 % (5/10) for patellar tendon, hamstring tendon and allograft, respectively ( $p = 0.7$ ) [3, 5, 12, 26, 28].

Timing of ACL revision surgery varied significantly. Two authors performed the revision surgery 12 months or later after the infection had resolved [11, 26, 28]. Another author performed the revision ACL reconstruction within 6 weeks after the completion of the antibiotic therapy and after the laboratory values had returned to normal [5].

Eleven patients (7.2 %) required an open surgical approach following non-successful arthroscopic debridement [16, 28]. This consisted of an arthrotomy, washout, synovectomy, removal of graft and implants and curettage of the femoral and tibial tunnels. The reason for the open

debridement was persistent bacterial infection or fungal infection [16, 28]. An average of five prior arthroscopic debridements (range 2–8) were performed for fungal infection [16] and an average of 1.6 (1–3) arthroscopic debridements for persistent bacterial infection [28]. Antibiotic therapy was given for a minimum of 6 weeks [28].

#### Special treatment

For *fungal infection*, as a result of persistent symptoms after an average of five arthroscopic debridements (range 2–8), the patients (6 cases) were treated with open debridement and bone resection with the joint space filled with an antibiotic cement spacer [16]. After debridement, the patients were treated with intravenous antifungal therapy (amphotericin) before final reconstruction [16]. For tubercular infection, arthroscopic debridement combined with antitubercular chemotherapy (ATT) was the mainstay of treatment [18]. Arthroscopic debridement averaged 1.25 times (range 1–2) for the eight patients treated for tubercular infection. The graft was retained in all cases. ATT was started with four drugs—isoniazid (5 mg/kg),

**Table 4** Laboratory results, treatment methods and follow-up outcomes for different organisms and diagnosis time

	Organisms		<i>p</i> value	Diagnosis time		<i>p</i> value
	SA	CNS		<7 days	>7 days	
No. of case	24	48		31	25	
Time to presentation	29.6 ± 31.1	13.5 ± 7.4	<b>0.02</b>	14.4 ± 10.7	31.4 ± 33.9	<b>0.022</b>
WBC	10.2 ± 3.2	8.9 ± 2.0	n.s.	8.95 ± 2.37	8.19 ± 0.35	n.s.
ESR	65.4 ± 32.1	54.9 ± 28.5	n.s.	58.08 ± 28.54	54.10 ± 21.43	n.s.
CRP	13.3 ± 6.8	10.6 ± 8.2	n.s.	11.98 ± 16.39	41.58 ± 25.44	<b>0.005</b>
Management (IV)	7/24	7/48	n.s.	5/31	1/25	n.s.
No. of procedure	1.7 ± 0.9	1.7 ± 0.9	n.s.	1.2 ± 0.5	1.5 ± 0.9	n.s.
Graft removed	8/24 (33.3 %)	4/48 (8.3 %)	<b>0.019</b>	0/31	7/25	<b>0.002</b>
Antibiotic duration	35.4 ± 11.4	27.8 ± 10.6	<b>0.047</b>	21.3 ± 6.4	32.0 ± 0.00	n.s.
Extension	0.0 ± 0.0	2.8 ± 3.6	n.s.	0.0 ± 0.0	0.0 ± 0.0	n.s.
Flexion	111.5 ± 23.8	130.6 ± 8.1	<b>0.036</b>	133.3 ± 2.9	126.8 ± 13.3	n.s.
Tegner	6.0 ± 4.2	5.5 ± 1.7	n.s.	5.6 ± 2.0	4.0 ± 1.4	n.s.
Lysholm	80.4 ± 25.9	72.7 ± 24.8	n.s.	80.7 ± 24.2	73.9 ± 15.5	n.s.
KT-1000 <sup>a</sup>	1.7 ± 2.6	0.5 ± 1.8	n.s.	1.8 ± 2.0	1.1 ± 2.9	n.s.

Bold values indicate  $p < 0.05$

<sup>a</sup> Patients with ACL graft

rifampin (10 mg/kg), ethambutol (15 mg/kg) and pyrazinamide (25 mg/kg)—daily for 4 months, followed by isoniazid and rifampin for 8 months [18].

#### Clinical outcomes

The SA group (24 cases) had a later presentation of septic arthritis from time of ACL reconstruction than the CNS group (48 cases) (29.6 and 13.5 days,  $p = 0.02$ ) (Table 4). The SA group also had a higher graft removal rate (33.3 and 8.3 %,  $p = 0.019$ ) and a longer intravenous antibiotic duration (35.4 and 27.8 days,  $p = 0.047$ ). The laboratory results (WBC, ESR and CRP) were higher in the SA group. However, this difference was not statistically significant ( $p > 0.05$ ). The CNS group had a better range of flexion at follow-up than the SA group (111.5° and 130.6°,  $p = 0.04$ ). The outcomes are displayed in Table 4.

We divided the diagnosis time (the duration from the suspected onset of infection to the diagnosis) into two groups, less than 7 days (31 cases) and more than 7 days (25 cases). The latter had a significant high graft removal rate ( $p = 0.02$ ). There was no case with graft removal in the patients diagnosed within 7 days. The reason for later presentation time and higher CRP level in the latter group may be caused by the fact that there were seven cases of tubercular infection in this group.

#### Discussion

The most important finding of this study was that arthroscopic debridement combined with intravenous antibiotic

therapy was the treatment of choice for the majority of authors. Delayed diagnosis of more than 7 days or SA infection required a longer duration of antibiotic therapy and increased the likelihood for graft removal and restricted range of motion. Fungal infection had a high prevalence of late diagnosis (84 days, range 38–150) followed by open debridement.

From our review, most authors recommend arthroscopic debridement when the diagnosis of infection is established [3–5, 7, 11–13, 15–20, 23–26, 28]. Some authors have shown reasonable success with non-operative treatment such as joint irrigation and antibiotic treatment [15, 24, 25]. However, not every case of conservative treatment can be successful; 33.8 % of patients were converted to arthroscopic debridement after non-successful conservative treatment. Monaco et al. [15] had a failure rate of 30 % with joint irrigation and antibiotics, Viola et al. [24] had a failure rate of 43 % with the treatment of antibiotics alone, and Wang et al. [25] showed that the recovery time and intravenous antibiotic duration are decreased with arthroscopic debridement representing a higher risk of articular cartilage damage and greater hospitalization costs for patients with conservative treatment. Therefore, antibiotic therapy with or without multiple irrigations of the joint is not recommended based on the high failure rates reported by three investigators who used this methodology.

Immediate onset of therapy seems to be very important in septic arthritis. Wirtz et al. [27] reported that an early arthroscopic debridement within 5 days in case of septic arthritis without osseous led to an effective resolution of infection with better functional results than an arthrotomy.

An animal study showed that the cartilage would have lost more than half of its glycosaminoglycan and collagen if treatment had not begun within 7 days from the onset of infection [21]. In this study we found that an early diagnosis was important for graft retention. Patients diagnosed after 7 days from the onset of infection had a significant higher graft removal rate ( $p = 0.02$ ). Patients diagnosed within 7 days also had a shorter intravenous antibiotic duration than the latter group (21.3 and 32.0 days,  $p = 0.120$ ) (Table 4). On the contrary, there was no case with graft removal in the group diagnosed within 7 days.

An average of 1.54 times (range 1–4) additional arthroscopic interventions had to be performed. Initial arthroscopic debridement had a 60 % success rate with the remaining 40 % requiring repeated arthroscopic debridement(s). The latter was performed in patients with persistent clinical signs after the first debridement. There was no correlation with the type of organisms or time of diagnosis and the numbers of arthroscopic debridements performed ( $p > 0.05$ ).

Stutz et al. [22] found that the number of arthroscopic debridements in septic arthritis and the efficacy of treatment depended on the initial stage of the infection. According to Gächter [8], stage I is defined by joint effusion, redness of the synovial membrane and possible petechial bleeding. Stage II shows a severe inflammation and fibrinous deposition, pus. In stage III patients present with a thickening of the synovial membrane and multiple pouches due to adhesions. Finally, stage IV is defined by aggressive pannus with infiltration into the cartilage, possibly undermining the cartilage, radiological signs of subchondral osteolysis and radiological signs with possible osseous erosions and cysts.

Using this staging system, Stutz et al. [22] reported that only one patient in the stage I group needed repeated arthroscopic debridement, but 52 and 75 % of patients in stage II and III groups. They concluded that an arthroscopic staging of the initial joint infection has prognostic and therapeutic consequences [22]. In another study, the authors suggested an arthroscopic debridement to be insufficient in stage IV septic arthritis and recommended an open debridement in such case [8].

Most authors choose to retain the graft and hardware in place when the graft was considered functional [3, 4, 7, 11–13, 15, 17–19, 23–26]. Others prefer to remove the graft and hardware immediately [5]. They believe this might minimize the risk of persistent infection. Their indications of immediate graft removal were the following: (1) elongated and non-functional graft during clinical examination and arthroscopic evaluation; (2) thick purulent exudation tightly adhered to the graft; and (3) persistence of knee infection after two to three debridements. Loosened femoral or tibial fixation devices were also removed at the same time [11, 20, 23].

Several authors recommended delaying ACL revision surgery after graft removal for at least 6–9 months [11, 14, 20, 28]. However, one author [5] performed revision ACL reconstruction within 6 weeks after completion of their antibiotic course. They showed that patients treated with early reimplantation of an ACL graft were satisfied with their outcomes without recurrent infection or abnormal laxity.

#### Antibiotics

Adequate intravenous antibiotic therapy was shown to be essential. The parenteral administration of an antibiotic active against the most common organism (*Staphylococcus aureus* and coagulase-negative *Staphylococcus*) should be started as soon as a smear has been obtained (aspiration, arthroscopy). Based on the recommendation from the literature, a third-generation cephalosporin or vancomycin is recommended [3, 5, 7, 11–13, 15, 17, 19, 23–26, 28]. Therefore, we recommend the patients should be initially treated with intravenous cephalosporin or vancomycin after aspiration on admission and were changed according to the culture sensitivity studies.

In this review, intravenous antibiotics were continued for an average period of 29.7 days (Table 4). It was recommended that the patients remain on intravenous antibiotics for an average of 4–6 weeks, which might then be changed to oral antibiotics as soon as the CRP levels drop to nearly normal values ( $<1$  mg/mL) [13, 23, 25]. Then, oral antibiotics are administered for at least another 14 days, until the CRP was normal on two separate occasions.

#### *Staphylococcus aureus*

In this review, we found that *Staphylococcus aureus* was the second common organism to cause knee septic arthritis after ACL reconstruction, which is consistent with the cited literature. Balabaud et al. [2] reported in their series of knee septic arthritis that the most common organisms were *Staphylococcus aureus* and *S. epidermidis*. Stutz et al. [22] reconfirmed that *Staphylococcus aureus* was the most common organism (42 %) found in their series.

This review demonstrated that *Staphylococcus aureus* infections had a worse prognosis with a higher rate of graft removal, longer duration of antibiotic therapy and a greater flexion deficit. Patients with an SA infection usually present with higher WBC, ESR and CRP values than the most common organism group—the CNS. These findings suggest a higher level of virulence with a more severe picture of the septic arthritis in patients with SA, which might have several reasons. The biofilm that is formed by *Staphylococcus aureus* and *Staphylococcus epidermidis* is different

and characterized to be more adherent [6]. Gjertsson et al. [9] also reported the role of metalloproteinase-7 released by SA in the pathogenesis of cartilage destruction in septic arthritis. As an organism, SA is highly virulent [1, 10]. In an animal study,  $10^5$  *Staphylococcus aureus* organisms injected into the knee joint did result in septic arthritis, but injection of the same concentration of *S. epidermidis* organism did not do so [10]. Archer [1] showed that SA can be carried for several weeks to months in the mucosal surface with no presenting symptoms. These may explain our findings that the SA group had a later presentation time from ACL reconstruction (29.6 and 13.5 days,  $p = 0.02$ ), a higher graft removal rate (33.3 and 8.3 %,  $p = 0.019$ ) and a longer intravenous antibiotic duration (35.4 and 27.8 days,  $p = 0.047$ ) than the CNS group.

Therefore, our recommendation is to treat an SA infection with early intravenous antibiotics and repeated arthroscopic debridement as necessary. There should also be a lower threshold for graft removal and removal of all implants in SA infections.

The limitation is that there was no uniform definition of septic arthritis amongst the 17 papers. Some authors regarded a positive culture as a sign of septic arthritis [13, 18], but others found the clinical presentation was sufficient [17, 19, 24, 25]. Pooling data from different studies was also limited by the fact that the management of septic arthritis differed significantly between authors. Not all necessary data required for comparison between studies were reported. For example, there was only limited information provided on methicillin-resistant *Staphylococcus aureus* (MRSA) to enable us to study MRSA as a subgroup as it is known that these patients would have a poorer prognosis than for methicillin-sensitive *Staphylococcus aureus* (MSSA). Moreover, we recommend adapting the staging system for septic arthritis defined by Gächter [8]. This four-stage system has prognostic value and will allow comparison with other variables such as graft and fixation type.

## Conclusion

In conclusion, this is the first systematic review performed on septic arthritis after ACL reconstruction. CNS was the most common organism in septic arthritis after ACL reconstruction followed by SA. For most authors, arthroscopic debridement combined with intravenous antibiotic therapy was the treatment of choice. Antibiotic therapy with or without multiple irrigations of the joint is not recommended based on the high failure rates reported by three investigators who used this methodology. Delayed diagnosis of more than 7 days or SA infection required a longer duration of antibiotic therapy and increased the

likelihood for graft removal and restricted range of motion. Fungal infection and tubercular infection had a high rate of late diagnosis and open debridement.

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