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Spacer exchange in persistent periprosthetic joint infection: microbiological evaluation and survivorship analysis

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Abstract

Purpose The purposes of this study were to determine demographics and characteristics of patients who underwent spacer exchange for persistent infection in the setting of two-stage arthroplasty for periprosthetic joint infection, to describe the microbiology of pathogens involved, to analyze survivorship free from infection in these patients.

Methods The institutional prospectively collected database was reviewed to enroll patients with minimum 2 years follow-up. Patients who underwent two-stage procedure for septic arthritis were excluded, as were patients who had spacer fracture or dislocation.

Results A total of 34 patients (41 procedures) were included. Mean age was 65.0 ± 12.8 years. Mean follow-up was 53.4 ± 24.8 months. Mean number of previous procedures was 3.6 ± 1.2. A total of 27 (79.4%) patients underwent final reimplantation. The most frequently isolated pathogen in spacer exchange was *Staphylococcus epidermidis* (10 cases, 28.6%). Polymicrobial cultures were obtained from 9 (25.71%) patients, 10 (28.6%) presented culture-negative infections. A total of 11 (32.4%) resistant pathogens were isolated, and 16 (47.0%) difficult to treat pathogens were detected. Eradication rate was 78.8%. Overall survivorship of implants after final reimplantation was 72.8% at 51.8 months.

Conclusion Surgeons should be aware that subjects necessitating spacer exchange often present multiple comorbidities, previous staged revision failures, soft-tissue impairment and difficult to treat infection. In these patients, spacer exchange provides good clinical results and infection eradication, preventing arthrodesis or amputation.

Keywords Periprosthetic joint infection · Bone infection · Total knee revision · Total hip revision

Introduction

Periprosthetic joint infection (PJI) is among the most serious and frequent complications after total-joint arthroplasty and it is estimated to occur in between 0.3 and 1.7% of all total hip arthroplasties (THA) and 0.8% and 1.9% of all total knee arthroplasties (TKA) [1, 2]. As an existing challenging issue and considering the ongoing growth in arthroplasty volume, PJI is on track to become a disease of great burden [3, 4]. In addition, in recent decades, the number of multi-resistant organisms has progressively increased due to antibiotic inappropriate and extensive use, inadequate diagnostic, pathogens gene mutations and while the concurrent production of novel antibiotics has slowed, restricting the non-surgical options to treat PJI and increasing septic recurrence [5–8]. Several operative approaches are currently used to treat PJI, and [9] despite the encouraging data for the one-stage protocol, two-stage revision is performed most often worldwide

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and is the gold standard procedure for ensuring excellent clinical outcomes and eradication rates [10–12]. In a review of 687 patients treated with two stage is reported mean Knee Score Society (KSS) of 77.8 and and a eradication rate of 84.8% and a success rate ranged between 75 and 98% [10]. Although optimal results can be obtained through a two-stage exchange, PJI can still persist, compelling surgeons to perform irrigation and debridement, antibiotic suppression and second two stage or demolitive solution as arthrodesis or amputation [13, 14]. The outcomes of these treatments are poor in term of clinical result and septic eradication, and optimal treatment is still debated. The septic recurrence seems to be related to pathogens, as Staphylococcus Aureus, and local complication, as wound dehiscence and postoperative hematoma [15, 16].

The spacer exchange has been recently proposed to solve recalcitrant infection because the second irrigation, debridement and a new local delivered antibiotic may help the PJI eradication. In current literature only two studies had investigated the spacer exchange procedure. Currently there are no clear consensus or guidelines about spacer exchange reliability, which patients had maximum benefit and when PJI benefit most from this procedure.

The aim of the current study was to (1) determine the demographics and characteristics of patients with persistent PJI who have undergone a spacer exchange at a single high-volume total-joint revision arthroplasty center, (2) describe the microbiology and resistance of PJI-causative organisms and (3) analyze survivorship free from PJI recurrence.

Material and methods

The local ethics committee approved this single-center study. Informed consent was obtained from all individual participants included in the study.

Inclusion/exclusion

We retrospectively evaluated patients requiring a spacer exchange due to persistent infection during a two-stage revision protocol for prosthetic infection. A prospectively collected database was used for data analysis. All the procedures for the spacer implantation, spacer revision and prosthesis reimplantation were carried out by a single experienced surgeon between 1 January 2011 and 30 September 2018 at a tertiary care referral center. The authors set a minimum follow-up of 2 years from final prosthesis reimplantation. All revision procedures due to component failure or dislocation were excluded. Cases of spacer exchange in the two-stage revision after primitive septic arthritis were also excluded.

We defined as reoperation as any kind of surgery that involved the hip or knee joint after the final reimplantation procedure that did not involve removing the fixed component. Revision was considered as any surgical procedure that required implant removal for any reason. We defined septic recurrence as each re-infection or positive culture at reimplantation with the isolation of the original infecting organism, we defined "new infection" the isolation of a different pathogen [17].

Clinical and microbiological evaluation

Due to the lack of consensus on the criteria validated for the diagnosis of infection recurrence at reimplantation [18, 19], PJI persistence was investigated using several concurrent approaches. All the spacers were aspirated with synovial fluid analysis, although low sensitivity value, to obtain any possible PJI information. [20] Further, serological erythrosedimentation rate (30 mm/h), C-reactive protein level (10 mg/l), synovial white blood cell count, polymorphonuclear percentage and leukocyte esterase level were used to guide the clinical suspicious of PJI recurrence. In doubtful cases, synovial alpha-defensin point-of-care testing was used. The presence of fistula or spacer exposure was considered an indication for spacer exchange. In case of wound healed, infection was suspected in case of local cutaneous disease and altered serological exams. In unclear cases, final treatment decision was taken intraoperatively by considering evidence of periprosthetic purulence and fresh frozen tissue samples with polymorphonuclear (PMN) > 10% per high power field as a recurrence of infection.

The evaluation of persistence of PJI occurred in all the cases after the hospital discharge.

The PJI setting, antibiotic therapy and medical evaluation were performed along with an infectious disease specialist highly trained in musculoskeletal infection management. The antibiotic therapy was targeted on previous isolated microorganism until the final cultural result, than the antibiotic therapy was continued for 4 weeks to 8 with microorganism-direct specific antibiotic [21].

The clinical and radiographic evaluation were performed before and after surgery at 45 days, 3 and 6 months and subsequently once per year. The clinical assessments included physical examination, Harris Hip Score Scale (HHS) and Knee Society Score (KSS) to evaluate hip and knee function.

Microbiological data as well as antibiotic resistance were recorded at spacer revision stage and final reimplantation. We considered the PJI as caused by difficult to treat (DTT) pathogens for each infection caused by pathogens that were (1) resistant or (2) noted to be hard to diagnose or eradicate as defined by Zimmerli and Trampuz [22, 23]. Every possible minor and major related to the operated joint was

recorded. In multiple spacer exchanges, we considered the last microbiological data records.

Surgical technique

All hips were exposed with a posterolateral approach. All knees were exposed with a medial parapatellar approach. After accurate debridement and saline irrigation for the hip infections, the preformed femoral (Tecres, Sommacampagna, VR, Italy) and hand-made acetabular spacer with antibiotic-loaded cement (Palacos, Heraeus GmbH, Hanau, Germany) were placed. In the TKA revisions, the preformed spacers (Tecres, Sommacampagna, VR, Italy) were used in combination with hand-made reinforced stems according to the intraoperative bone loss. In the case of concurrent extensor mechanism disruption, a static spacer was used. Histopathological exams were performed in both the spacer exchange and reimplantation. In each procedure, 3–6 intraoperative samples were taken for microbiological analysis and 1 specimen for the frozen section and definitive histology.

During reimplantation and after the removal of the antibiotic-loaded spacer, a new accurate surgical debridement was performed. After evaluating the size and shape of the bone deficiency, the senior surgeon determined the best technique for addressing the bone defect. In Knee revision were always used uncemented stem in association with cone and wedge were used to fill meta-epiphyseal bone gap, while in hip revision were used acetabular revision cup with augment, trans-acetabular screws and cementless revision stems. Knee extensor mechanism disruption was managed with medial gastrocnemius flap.

Drainage was used and removed 48 h post-operatively. Partial weight bearing with crutches was begun on the second postoperative day after the removal of the surgical drain whenever possible. Passive and progressive hip or knee mobilization was begun on the first day after surgery and continued for the entire inter-stage period. In the case of extensor mechanism disruption, full extension with partial weight bearing was performed after surgery. Standard venous thromboembolism prophylaxis with enoxaparin and compression stockings was prescribed for at least for 45 days. In agreement with the infectious disease team, a specific intravenous antibiotic course was administered until intraoperative microbiological results were attained and continued with microorganism-directed antibiotic thereafter for 4–8 weeks.

Statistical analysis

Continuous variables were reported as mean ± standard deviation and compared between preoperative and final follow-up using a Student's *t*-test. Categorical variables were reported as the number of cases or a percentage. A two-tailed *p*-value of < 0.05 was set as statistically significant. Kaplan–Meier survival curves were created to analyze the final implant survivorship free from PJI recurrence.

Results

A total of 41 patients (48 spacer revision procedures) were identified. Five patients underwent a spacer revision due to mechanical failure and were then excluded. Other two cases were excluded because the primary spacer was used as a treatment for septic arthritis. The remaining 41 procedures in 34 patients (1 patient underwent bilateral knee revision surgery, 2 cases necessitated 2 interim spacer exchanges and an additional 2 cases required 3 exchanges) were performed to eradicate PJI and were included in the final analysis. In 23 (65.7%) of the cases, the knee was involved in the spacer exchange, while 12 (34.3%) of the cases were hip revisions. Among the patients, 18 (51.4%) were male and 17 (48.6%) were female. The mean age at spacer exchange was 65.0 ± 12.8 years. The mean BMI was 28.2 ± 4.9 kg/m^2. The mean follow-up from spacer exchange was 53.4 ± 24.8 months (range 24–108). The mean surgical time of the spacer exchange procedure was 120.3 ± 22.5 min. The mean number of previous surgeries in the involved joint were 3.6 ± 1.2 (range 2–7). Three patients were lost to follow-up: 1 before reimplantation and the 2 others died during follow-up. Multiple medical comorbidities were commonly detected in the included cohort of patients, with a mean Charlson Comorbidity Index (CCI) of 4.2 ± 2.4. Our series also included previous orthopedic comorbidities. Table 1 summarize the demographic data and relevant comorbidities.

A total of 27 (79.4%) patients underwent final reimplantation. Among patients who had not received reimplantation, six presented recurrence of infection and one died after spacer exchange.

The mean HHS improved from 22.4 ± 17.8 (Confindence Interval CI 95% 10.2–32.6; range 0–51.3) preoperatively to 68.3 ± 20.9 (CI 95% 45.7–82.7; range 44–92) at the final follow-up ($p < 0.0001$). The mean KSS improved from 23.1 ± 12.7 (CI 95% 17.6–28.4) preoperatively to 66.2 ± 15.6 (CI 95% 59.3–72.9) at the final follow-up ($p < 0.0001$).

The organisms identified during the spacer exchange procedure were *Staphylococcus epidermidis* in ten cases (28.6%, 8 out of 10 methicillin-resistant *Staphylococcus epidermidis* [MRSE]), coagulase-negative *Staphylococci* in 5 (14.3%) cases, *Enterobacter* in 5 cases (14.3%, 3 *Enterococcus*, 2 *Escherichia coli*), *Staphylococcus aureus* in 4 cases (11.4%, 2 out of 4 cases methicillin-resistant *Staphylococcus aureus* [MRSA]). Polymicrobial cultures were obtained from 9 (25.71%) patients (4 out of the 9 presented with at least 1 resistant pathogen). In total, 11 (32.4%)

Table 1 Demographic data

Patient Id	Joint (H/K)	Laterality (L/R)	Age (years)	BMI (kg/m^2)	Charlson Comorbidity Index	Orthopedic comorbidities	Previous surgery (*n*)*	Follow-up (months)
1	H	L	71.8	28	5	THA multiple dislocation	4	45[†]
2	H	L	67.7	30	4	/	2	35
3	K	R	67.4	26.6	7	/	4	74
4	H	L	67	31	4	Femural fracture	3	87
5	K	L	59.5	23	3	/	2	80
6	K	L	83	25	6	Controlateral Meniscectomy, Controlateral TKA, EMR (Patellar Tendon Rupture)	1	36
7	H	L	57.8	32	6	AVN femural head	3	36
8	K	L	44.9	28	1	/	1	103
9	K	R	82.2	23	9	Femural fracture, Controlateral PJI Controlateral Knee Arthrodesis	5	108
10	K	L	76.6	33	10	Controlateral PJI	5	57
11	H	L	35.7	19.6	0	Polytrauma, 2 previous Spacer Exchange	0	65
12	K	R	82.5	28	7	/	2	31[†]
13	K	R	74.2	31	5	/	5	106
14	H	L	62.2	28	2	/	3	–[‡]
15	H	R	62.2	30	6	/	3	44
16	H	L	71	29	5	Discectomy, Wohund dehiscence	3	90
17	K	R	66,9	29	6	HTO	5	88
18	H	L	65,2	30	2	Femural fracture, whound dehiscence	1	45
19	H	L	64,6	28	6	AVN Femural Head, THA Dislocation, Acscessuss	5	43
20	K	L	53,5	43	3	Tibial Plateau fracture and Exposition, PPF	4	28
21	H	L	83,4	27	4	THA Dislocation, Controlateral THA	1	75
22	K	R	72,6	24	4	TKA controlat	3	27
23[±]	K[±]	L[±]	58,3[±]	30[±]	2	/	4[±]	43[±]
23[±]	K[±]	R[±]	58,4[±]	30[±]	2	EMD, Patellectomy	4[±]	43[±]
24	K	L	71.3	21	7	Bilateral HTO, Whound Dehiscence	4	32
25	K	R	84.6	27	5	Femural Fracture, Polytrauma	4	46
26	K	L	61.4	28	6	/	6	44
27	K	L	59	31	3	/	2	57
28	K	L	79.3	23.8	5	/	4	41
29	H	L	52,2	22	2	/	3	34
30	K	L	28.9	21	0	Fistula	2	35
31	K	R	65.3	35	4	/	5	40
32	K	L	55.5	25.6	1	/	6	39
33	K	L	73.7	26	4	2 previous spacer exchange, fistula, external fixation on spacer	1	35
34	K	L	57.3	40	1	Fistola 1 previous spacer exchange	3	24

AVN avascular necrosis, *EMD* extensor mechanism disruption, *H* hip, *HTO* high tibial osteotomy, *K* knee, *L* left, *PJI* periprosthetic joint infeciton, *PPF* periprosthetic fracure, *R* right, *THA* total hip arthroplsty, *TKA* total knee arthroplasty

*Previous surgery in same joint before first explant stage

[†]Decess after reimplantation

[‡]Decess before reimplantation

[±]Bilateral procedure

resistant pathogens were isolated in 11 different patients, and 16 (47.0%) DTT pathogens were detected (detailed report in Table 2).

At reimplantation, 20 (60.6%) patients had culture-negative results, and in 3 cases, only one sample was positive (different bacteria, considered contaminant)

Table 2 Microbiologic data isolated in different stage with reimplantation, septic survivorship and overall survivorship of the implant

Patient id	Isolation in explantation	Isolation in spacer exchange	Isolation in definitive treatment	Reimplatation (Y/N)	Reinfection (Y/N)	Overall survivorship (Y/N)
1	*E. faecalis* + A baumanii	*E. fecalis*, *A. baumanii*	Neg	Y	N	N
2	*E. faecalis* + *K. pneumoniae*	*E. fecalis*	Neg	Y	N	Y
3	Neg	MRSE	Neg	Y	N	Y
4	*E. coli*	*E. coli*	Neg	Y	N	Y
5	MSSA	*Klebsiella* spp.	Neg	Y	N	N
6	MRSE	Neg	Neg	Y	N	Y
7	MSSA + MRSE	MSSA + MRSE	Neg	Y	N	Y
8	*P. aeruginosa*	Neg	Neg	Y	N	Y
9	N/A	*Streptococcus* spp.	Neg	Y	N	Y
10	N/A	Corynebacterium*	MRSE*	Y	N	Y
11	MRSE, *Candida tropicalis*, *Klebsiella* spp.	MRSE, *Candida tropicalis*	MRSE	Y	N	Y
12	N/A	Neg	/	/	/	/
13	Neg	Neg	Neg	Y	N	N
14	MRSE + *Streptoccus* spp.	Neg	/	/	/	/
15	MRSA	MRSA + MRSE	MRSA	N	Y	N
16	CoNS	MRSE	MRSE	Yˆ	Yˆ	N
17	Neg	MRSE	Neg	Y	N	Y
18	Neg	Neg	*Streptococcus mitis*	N	Y	N
19	*Candida*	*E. coli*, *Enterococcus faecalis*	MRSA	N	Y	N
20	MRSA, *Peptostreptococcus* spp.	MRSE	Neg	Y	N	Y
21	ConS	CoNS	Staf coag neg (CoNS) + *Corynebacterium* spp	N	Y	N
22	Proteus ndd	CoNS	*S. epidermidis**	Y	N	Y
23	MSSA	*Serratia marcescens*	Neg	Y	N	Y
24	Neg	Neg	Neg	Y	N	Y
25	*Candida*	*Candida*	Neg	Y	N	Y
26	Neg	*S. haemo* MS, *C. acnes*, *Anaerococcus evotii*	/	/	/	/
27	Coryn. Argentoratense	*S. hominis* + *S. epidermidis*	*S. epidermidis**	Y	N	Y
28	N/A	Neg	Neg	Y	N	Y
29	ConS	CoNS	Neg	Y	N	Y
30	*S. aureus*	MRSA	*S. aureus*	N	Y	N
31	*P. aeruginosa* + MSSA	*P. aeruginosa* + MSSA	Neg	Y	N	Y
32	N/A	*S. epidermidis* + *S. caprae*	Neg	Y	N	Y
33	N/A	Neg	Neg	Y	N	Y
34	*S. epidermidis*	*S. epidermidis*	Neg	Y	N	Y
35	N/A	Polybacterial	Polybacterial	N	Y	N

CoNS coagulase-negative *Staphylococcus*, *MRSA* meticillin resistant *Staphylococcus aureus*, *MSSA* meticillin-sensitive *Staphylococcus aureus*, *MSSE* meticillin-sensitive *Staphylococcus epidermidis*, *MRSE* meticillin resistant *Staphylococcus epidermidis*, *N* no, *n/a* not available data, *Neg* negative colture, *Y* yes

*In these cases, only one culture sample was positive, then were considered as contaminant microorganisms

ˆThe subject preseted persistent PJI with MRSE isolation after the reimplantation

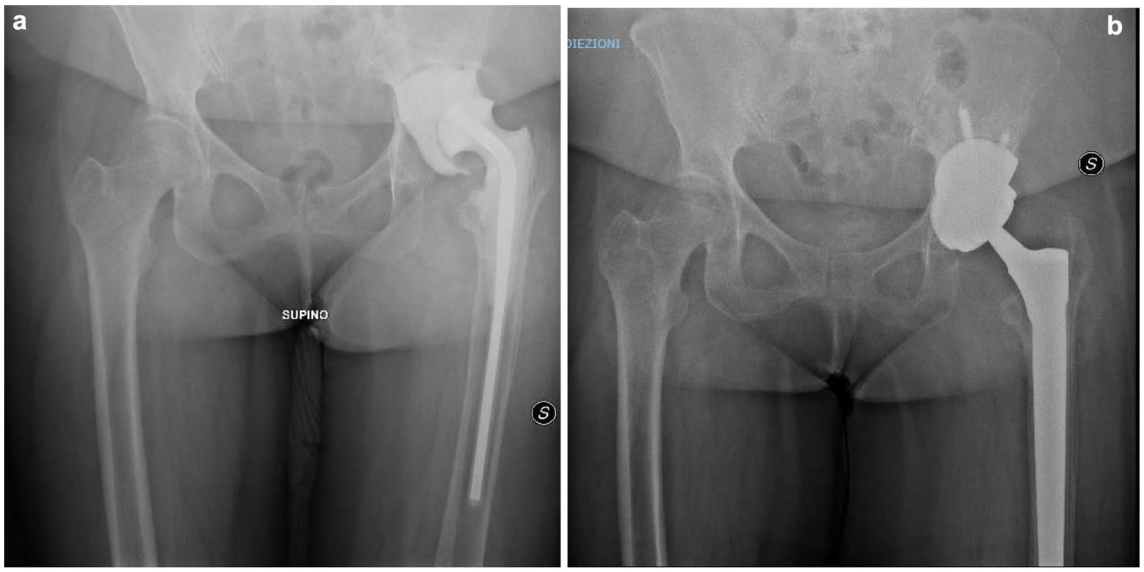

Fig. 1 Kaplan–Meier curve, with time free from infection as the endpoint of interest. **a** Post-operative radiographic results after spacer exchange procedure to eradicate recurrent polymicrobial PJI (MRSA and MRSE). Custom-made acetabular spacer has been used to fill acetabular defects, providing minor inter-stage complication and hip biomechanics preservation long stemmed spacer has been used to ensure more stable femoral spacer. **b** Post-operative radiographic result after reimplantation. Large acetabular defects have been approached with cup on cup technique with 2 iliac screws and revision stem. *MRSA* Methicillin resistant *Staphylococcus aureus*, *MRSE* Methicillin Resistant *Staphylococcus epidermidis*, *PJI* prosthetic joint infection

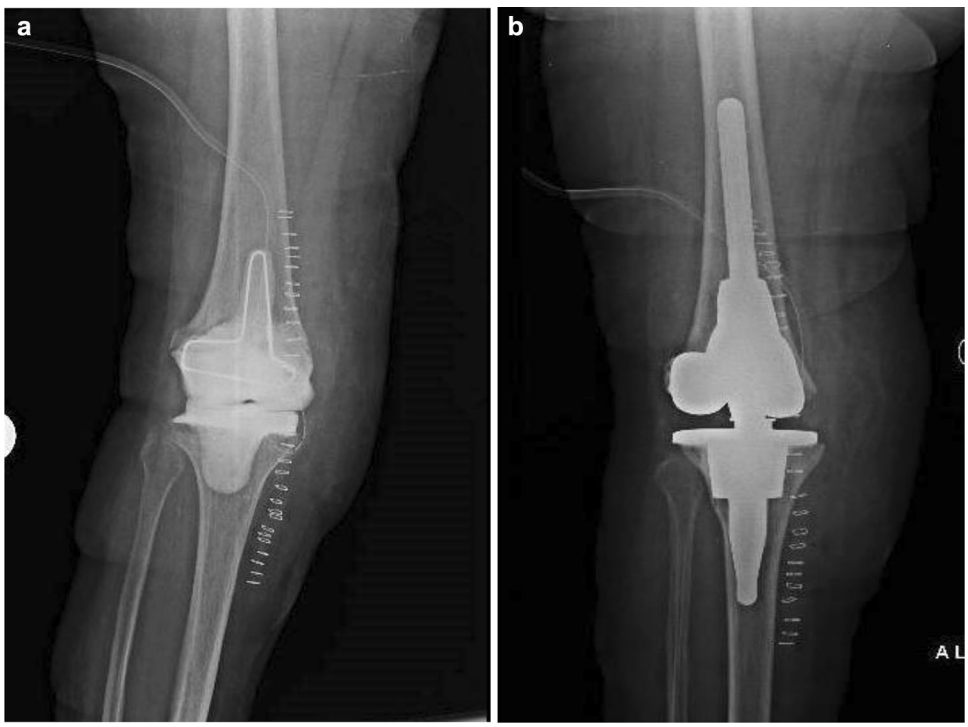

Fig. 2 **a** Post-operative radiographic results after spacer exchange procedure to eradicate recurrent coagulase-negative *Staphylococcus*—PJI. To fill large femoral metaphysary defect a custom-made articulated spacer has been used. Tibial spacer has been molded on the bone defect. **b** Post-operative radiographic result after reimplantation. To address bone defects have been used two femoral cone (diaphyseal and metaphyseal) with two posterior and two distal augments and a tibial cone. Hinged knee prosthesis has been used

and was managed with final prosthesis reimplantation and prolonged antibiotic therapy (Figs. 1, 2). Persistent PJI was recorded in seven cases (6 hips, 1 knee). One patient had a negative culture at the first stage, presented positive samples (*Streptococcus sanguinis*) during the spacer exchange and was treated with suppressive antibiotic therapy and spacer retention.

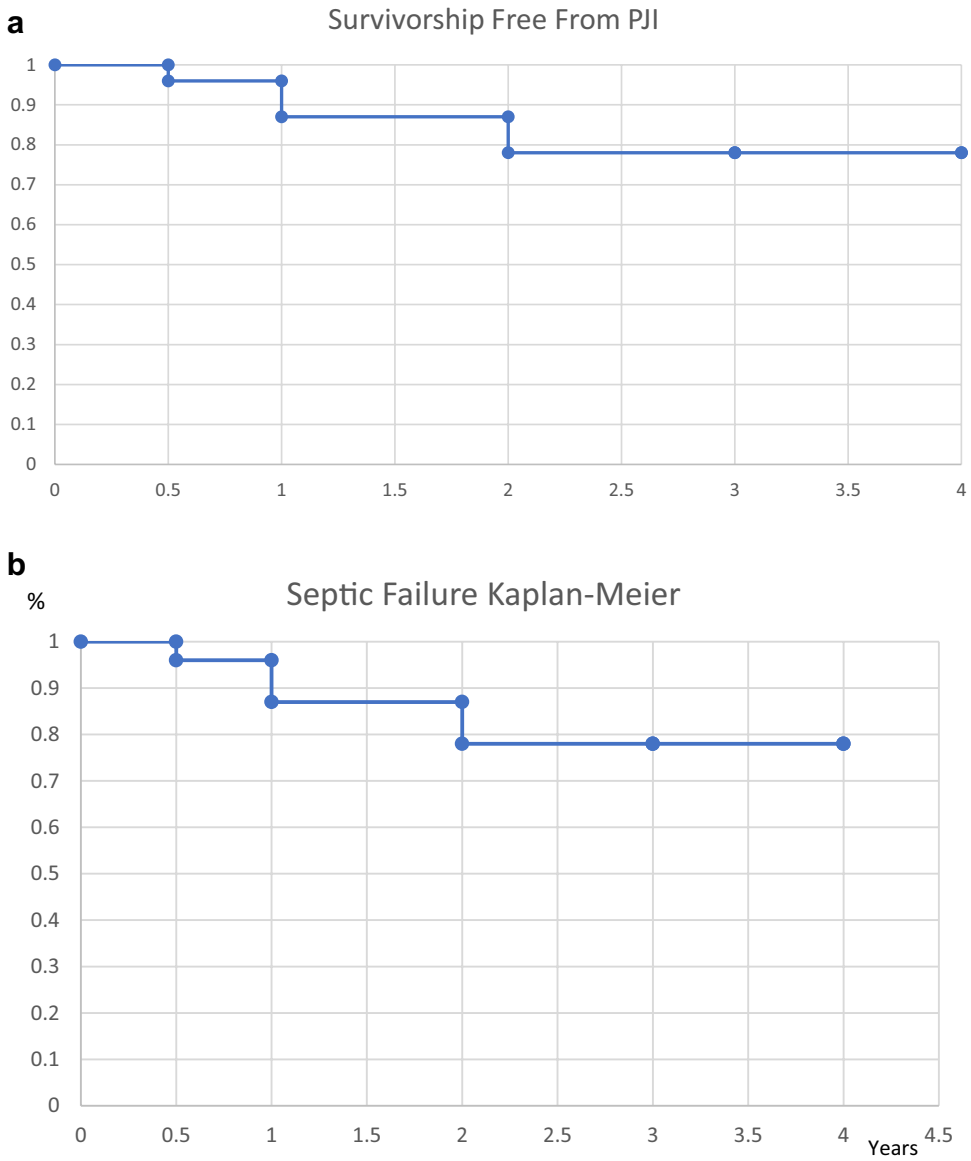

Fig. 3 **a** Kaplan Maier of survivorship free from infection. *PJI* periprosthetic joint infection. **b** Kaplan-Meier curve, with time free from infection as the endpoint of interest

Complications

Were recorded 2 (6.1%) spacer dislocations (1 knee, 1 hip) as a result of accidental falls and managed with reduction and conservative treatments, and 2 (6.1%) peri-spacer fractures following falls.

Survivorship

Overall survivorship, defined as being free from the recurrence of PJI or any kind of further surgery, was 72.8% at 51.8 months. The septic eradication rate was 78.8%, and septic failure was recorded in 7 cases (6 hips, 1 knee) (Fig. 3): 4 patients underwent Girdlestone procedures: 3 of which had suspicious histopathologic frozen-section exams and macroscopic intraoperative findings that were confirmed by intraoperative microbiological results and 1 with a persistent infection for 1 year after reimplantation. We also recorded 1 spacer retention managed by antibiotic suppressive therapy and 1 knee arthrodesis.

Survivorship in the reimplanted patients was 92%. Two patients required reoperation: 1 due to stiffness requiring open arthrolysis 3 years after THA and 1 case of wound revision due to dehiscence. Revision was recorded in two cases (2 knees): one case for tibial component subsidence after an accidental fall and 1 case of femoral revision due to persistent anterior knee pain.

Among the hip failures, 3 out of 6 patients presented with a history of recurrent dislocation of primary THA. Furthermore, 3 out of 6 presented with hepatitis C virus infection with hepatopathy or a history of injective drug abuse. The first case of hip septic failure presented with

diabetes mellitus complicated by soft-tissue defects, hepatitis C, atrial fibrillation and a history of recurrent dislocation with multiple surgeries and final proximal femur megaprosthesis and metallic cerclage implantation. After the PJI diagnosis, *Enterococcus* was found. The patient died a year after the final reimplantation due to generalized sepsis. Three other cases presented with fistula in communication with the prosthesis at the PJI diagnosis and the isolation of DTT bacteria (in 1 case both MRSA and MRSE, and in the 2 other cases, 1 with MRSA and 1 with MRSE). The septic knee failure presented with recurrent urinary tract infection, a BMI of 40 kg/m^2 and prior to the indexed procedure, the patient had undergone two previous spacer exchanges with a soft-tissue defect and subsequent spacer exposure; polymicrobial Gram-negative bacteria (with multi-drug-resistant *Pseudomonas*) were found.

Discussion

Spacer exchange due to recalcitrant PJI is not an uncommon procedure, and it is estimated to occur in 16–18% of all two-stage exchange arthroplasty procedures [14, 24].

Only three other studies have analyzed spacer exchange outcomes [14, 25, 26], respectively demonstrating 74 cases over 17 years, 96 cases over 13 years and 127 cases over 4.2 years. These studies have highlighted how subjects requiring an additional surgical debridement and spacer substitution presented with significantly more comorbidities and higher BMIs and incidence of rheumatoid arthritis [14]. In our study many patients (28%) presented with PJI as a late post-traumatic consequence, such as open fractures, multiple dislocations or polytrauma, which has already been described as a predictor of difficult PJI eradication [27, 28]. The subjects in our case series presented with elevated CCI in addition to resistant pathogens, and this background results in more complex surgical, anaesthesiologic and infectious disease treatments due to the frailty of patients combined with restricted medical resources.

Clinical outcomes measured with KSS and HHS presented a statistical ($p < 0.0001$) improvement, with final good scores recorded at the last medical consultation (66.2 and 68.3, respectively).

Similar to Gomez and Kozaily studies, in our reseach 22% of the patients did not reach the final prosthesis implantation [24, 26], presenting unfavorable septic findings and many risk factors for further failures. The survivorship of the implant was 72.8, slightly higher than the other case series.

Microbiological data

In our case series, the most represented bacteria were *Staphylococcus epidermidis* (28.8%, 8 out of 10 MRSE) followed by *Enterococci* (14.3%) and *Staphylococcus aureus* (11.4%, 2 out of 4 MRSA), while the percentage of culture-negative cases was 28.6%. Resistant bacteria were found in 36% of cases, and the most frequently found resistant bacteria were *Staphylococcus epidermidis* (53.8%). Tan et al. [14] found that 10.3% of the cases in their cohort had polymicrobial PJI and demonstrated that this kind of infection had a failure rate of 50.5%, and in their subsequent work, Kozaily et al. [14, 24] demonstrated that negative culture is associated with successful spacer exchange procedure. The septic eradication of this study provided good to excellent results (78.8%) and was comparable to the results in the literature. In our study, hip revision had higher rate of septic failure as compared with TKA revision. This may be explained by the more difficult soft-tissue exposition for surgical debridement and the presence of previous hardware, such as plates or wire cerclage, in our cases of THA revision.

Risk factors

All the septic failure cases presented with many risks factors and many previous surgical procedures coupled with DTT bacteria, although in literature there were conflicting evidence about the role of difficult to treat microorganisms as a predictors of treatment failures [14, 16, 29]. Recent study by Faschingbauer et al. [16] did not find association between DTT microorganism and recalcitrant infection despite previous literature agreed on this point.

The vast majority of the included patients presented with multiple comorbidities, and high CCI (4.0), difficult to treat bacteria, the failure of a previous two-stage procedure, often associated with difficult soft-tissue coverage and extremely poor residual bone stock. Furthermore has been reported how local disorder as cutaneous disease or vascular insufficiency of the limbs as well as high host grade are associated to the failure of spacer exchange [26].

Subjects presenting these comorbidities were more prone to develop a recalcitrant PJI and, to obtain radical eradication, a new surgical debridement with spacer exchange was seen as a viable solution in selected patients. A multispecialized approach supported by an infectious disease specialist and orthopedic and plastic surgeons with the proper expertise in musculoskeletal infections can direct effective therapies, as has been pointed out by Yeung et al. [30].

Limitations

This study contains several limitations that should be taken into account as: retrospective structure of the study and its

relatively low number of patients are strong limitations, but considering the low prevalence of a such surgical setting, the reported data can provide new perspectives for complex staged TKA revisions. Furthermore, the strict adherence to the inclusion criteria provided a single-surgeon homogeneous cohort of patients with a strong reduction in bias.

Conclusions

Spacer exchange is a viable solution in persistent PJI. Surgeons should be aware that subjects with multiple comorbidities, previous staged revision failures, soft-tissue impairment and DTT microorganisms are more prone to persistent PJI. In such settings, spacer exchange provides good clinical results and infection eradication with acceptable complication rate preventing arthrodesis or amputation. Given the clinical and surgical complexity of these cases, a multidisciplinary approach must be a cornerstone of care.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by AC, LC, AR and FC. The first draft of the manuscript was written by AC and all authors commented on previous versions of the manuscript. Entire research study was supervised by GB and AM. All authors read and approved the final manuscript.

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Availability of data and material Not available.

Code availability Not available.

Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethics approval Ethics approval was obtained by local institutional review board.

Informed consent Informed consent, publish consent and privacy and data consent were obteined from all the participant to the study.

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