Infection (2014) 42:511–519
DOI 10.1007/s15010-014-0584-6

CLINICAL AND EPIDEMIOLOGICAL STUDY

Characteristics and treatment outcomes of 69 cases with early prosthetic joint infections of the hip and knee

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Received: 16 August 2013 / Accepted: 3 January 2014 / Published online: 29 January 2014

Abstract
Purpose Early prosthetic joint infection (PJI) can be treated with an intensive surgical debridement and implant retention (DAIR) of the prosthesis if (1) the prosthesis is stable, (2) the pathogen is not a difficult-to-treat microorganism, (3) symptoms have lasted for <3 weeks and (4) a sinus tract is absent.
Methods We retrospectively evaluated the treatment outcome of early PJI in the hip and knee in a single orthopaedic centre. An early PJI was defined as a prosthesis infection within 3 months after primary implantation or revision surgery for a non-infectious cause.
Results We identified 69 patients with confirmed early PJI, with a median age of 71 (range 33–84) years. Only 64 % presented with ≥2 acute signs of infection. The most commonly isolated bacteria were coagulase-negative staphylococci (38 %) and *Staphylococcus aureus* (25 %). Surgical procedures included DAIR (50 cases, 69 %) and two-stage exchange (19 cases, 31 %). At last follow-up, five of remaining living 67 patients (7.5 %) had a relapse of infection. The overall relapse-free survival of the prosthesis after 2 years was 92.3 % (95 % confidence interval 82–97 %) with no significant difference between DAIR and exchange of prosthesis.
Conclusion Our data suggest that an early PJI should be treated with DAIR as a less invasive procedure whenever possible according to the established treatment algorithm.

Keywords Early prosthetic joint infection · Implant retention · Treatment outcome · Biofilm · Two-stage exchange

Parts of the study were presented as an ePoster at the ECCMID meeting in Berlin, Germany, 27–30 April 2013 (Abstract Nr. 778).

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Introduction

A periprosthetic joint infection (PJI) is a medical problem that is becoming increasingly important worldwide due to the increased usage of artificial joints [1]. PJI can be caused by direct inoculation of bacteria to the implant or by haematogenous seeding [2]. In the former case, bacteria from the commensal skin flora around the surgical site or from contamination by the healthcare provider are introduced to the implant during or soon after surgery. The widest accepted classification of PJI, proposed by a group from the

Mayo Clinic, distinguishes between a stage 1 (or early), in which the infection occurs in the first 3 months after surgery, a stage two (or delayed), in which the infection occurs between 3 and 24 months after surgery and typically has a more indolent presentation with a pain-free interval, and a stage three (or late), which includes infections that occur after 2 years and which are frequently caused by haematogenous dissemination of microbial pathogens [3, 4]. Based on this classification, in 2004 Zimmerli et al. [2] proposed an individual treatment algorithm for each stage to attain a high success rate with the least invasive surgical procedure. Briefly, a delayed infection always needs an exchange of the prosthesis, whereas early (onset <3 months postoperative) or haematogenous infection can be cured by debridement and retention of the prosthesis provided that (1) the prosthesis is stable, (2) the duration of symptoms does not exceed 3 weeks, (3) there is intact skin and soft tissue and (4) the causative pathogen is susceptible to a biofilm-active antibiotic [2].

More recently, there has been intensive discussion on the optimum period of time after surgery that defines an early infection, with the definitions ranging between 2 weeks and 3 months [2, 3, 5–7]. In addition, there is a wide range in the definition of the maximum length of time (between 8 and 30 days) that clinical signs and symptoms may present after which a debridement and retention (DAIR) approach may still lead to a successful outcome [8, 9]. In the recently published Infectious Diseases Society of America (IDSA) guidelines by Osmon et al. [7] a DAIR strategy is recommended (evidence grade 2A) if infectious symptoms occur early, i.e. within 30 days postoperatively, or if the length of symptoms is <3 weeks. In the study reported here, we retrospectively analysed the characteristics and outcome of early PJI in a 5-year cohort of hip and knee arthroplasties in a single centre. Since our centre defined an early PJI as occurring within the first 3 months postoperatively [2], we had the opportunity to investigate if there was any difference in outcome after DAIR if the definition of an early PJI was shortened from 3 months to 1 month. We speculated that patients with an early PJI present not only with typical acute inflammatory signs and symptoms. We also attempted to determine whether there was a difference in the clinical outcome of PJI if the signs and symptoms lasted longer than 3 weeks before a surgical procedure was performed.

Materials and methods

Study design and population

The Schulthess Clinic Zurich is a specialized 160-bed orthopaedic centre with a high rate of surgical interventions (7,491 inpatient and 1,221 outpatient treatments documented in 2012; 804 primary hip and 579 knee arthroplasties). We retrospectively reviewed all early types of infection after a knee or hip prosthesis implantation (either after primary arthroplasty or revision surgery) presenting in the Schulthess Clinic between January 2005 and June 2010. Clinical information on infection was retrieved from the prospectively managed database on all PJI from the Infectious Diseases Clinical Consulting Service and from the hospital information system managed by the Schulthess Clinic in Zurich. Patients with a delayed infection (onset of symptoms 3–24 months after the last surgery) as well as patients with an incomplete follow-up were excluded.

Definitions

Prosthetic joint infection was diagnosed if one or more of the following criteria were fulfilled: (1) visible purulence of a preoperative aspirate or intraoperative periprosthetic tissue (as determined by the surgeon); (2) presence of a sinus tract communicating with the prosthesis; (3) microbial growth in a preoperative joint aspirate, intraoperative periprosthetic tissue or sonication fluid of the removed implant [2, 7]. We defined a very early PJI as a prosthesis infection with symptom onset ≤1 month after primary or revision surgery of the knee or hip prosthesis [2] and an early manifestation at ≥1 and ≤3 months. In the case of a non-healing wound discharge postoperatively, we defined the onset of symptoms 14 days after the surgical operation. If an infection was diagnosed with a revision surgery due to wound discharge or postoperative hematoma within 14 days, the date of the revision operation was defined as the onset of symptoms.

Patients with PJI symptoms were defined as those with ≥2 and <2 typical acute inflammatory signs (such as pain, purulent wound discharge, erythema, swelling/induration or warmth of the joint, optionally fever), respectively, and by chronic symptoms, such as sinus tract, or other non-specific signs, such as hematoma, joint effusion or luxation or elevated inflammatory serum biomarker only.

Surgical and antibiotic treatment of early infection

The surgical approach was individually determined at the surgeon's discretion in discussion with the Infectious Disease Consulting Service. There were mainly three potential approaches: (1) DAIR; (2) one- or two-stage exchange of the implant; (3) resection arthroplasty. If only parts of the prosthesis were removed, we considered the surgical procedure to be a DAIR. For the best outcome with a DAIR, orthopaedic surgeons always went for an arthrotomy instead of for an arthoscopy for a better infection control and for cultivating bacteria originating from biofilm and not planktonic bacteria. During the study

period, exchange of all mobile parts, type of lavage and second-look surgeries were individually determined at the surgeon's discretion.

The duration of the antibiotic treatment was planned either for 3 months, in the case of patients with hip prosthesis, or for 6 months, for patients with knee arthroplasty, as recommended in guidelines [7]. An initial intravenous therapy of at least 14 days was planned [2, 7].

Outcome evaluation

Follow-up visits were performed at the Outpatient Department of Schulthess Clinic. The patients were followed up for relapse of infection, new infection or death. We defined a relapse of infection if: (1) the signs and symptoms of a persistent infection (i.e. communicating sinus tract with the prosthesis) were present after 21 days of an adequate surgical and antibiotic treatment, and/or (2) the same pathogen either as a monobacterial or polymicrobial infection was re-isolated within 2 years after infection diagnosis and/or (3) if death was directly related to the PJI diagnosis [10–13]. Cases of death were allocated to be infection or non-infection related. Patients who died early due to the sequelae of a sepsis (e.g. pneumonia) or late to any illness were not defined as relapses. A revision operation within 21 days after the first therapeutic surgical procedure was not considered to be a relapse. The most invasive surgical approach was reported as the definitive surgical treatment. A new infection was defined as a PJI at the same anatomical site upon the isolation of a different microbial pathogen. Successful response was postulated if the patient had no signs and symptoms of relapse and was not receiving suppressive antibiotic treatment after a follow-up period of at least 24 months.

Statistical analysis

GraphPad Prism 6 software (GraphPad, San Diego, CA) was used for the statistical calculations and for the construction of figures. The probability of relapse-free survival and the 95 % confidence interval (95 % CI) was estimated using the Kaplan–Meier survival method. Cox proportional hazard analysis was used for the comparison of relapse-free survivals of different surgical subgroups. Observations were censored at the time of diagnosis of infection relapse. Categorical variables were compared by the chi-square test or Fisher's exact test.

Results

Baseline characteristics

Between January 2005 and June 2010, 864 patients with a possible PJI of the knee ($n = 456$) or hips ($n = 408$) treated at the Schulthess Clinic in Zurich were documented in the databank of the Infectious Disease Service. Of these, 75 (8.7 %) patients presented with symptoms of PJI in the early postoperative period within 3 months after surgery. Six patients were excluded because of an incomplete follow-up, leaving 69 early infections for further analysis (28 knee, 41 hip prostheses). Characteristics of all 69 patients are summarized in Table 1. The left side of the hip or knee joint was more affected by an early infection (60.9 vs. 39.1 %).

Table 1 Baseline characteristics of 69 patients with an early periprosthetic joint infection

Baseline characteristics	*n* (%)[a]
Median age, years (range)	71 (33–84)
Females	34 (49.3)
Primary implantation of the prosthesis	
Schulthess Clinic	55 (79.7)
External hospital	14 (20.3)
Last surgical procedure before infection	
Primary implantation	37 (53.6)
Revision surgery	32 (46.4)
1	19
≥2	13
Localization of joint prosthesis	
Knee	28 (40.6)
Hip	41 (59.4)
Underlying joint disorder	
Degenerative	58 (84)
Posttraumatic	6 (8.7)
Rheumatoid arthritis	4 (5.8)
Osteosarcoma	1 (1.4)
Comorbidity	
Diabetes mellitus	10 (14.5)
Obesity	20 (29.0)
Neoplasia	5 (7.2)
Immunosuppression	12 (17.4)

There were 28 cases of PJI of the knee and 41 cases of PJI of the hip

[a] Data are presented as a number with the percentage given in parenthesis, unless indicated otherwise

Symptoms

The median time between the last surgical procedure and onset of symptoms of infection was 14 days, and until diagnostic and therapeutic surgical intervention for infection 22 days (Table 2). Of the 69 cases, the first symptoms of infection manifested within 30 days in 58 cases (84 %) and between 30 and 90 days in 11 cases (16 %). In 60 (87 %), the symptoms lasted <3 weeks until a diagnostic and therapeutic surgical revision for infection was performed.

Table 2 Characteristics of the 69 cases with early periprosthetic joint infection

Characteristics	*n* (%)[a]
Pathogenesis	
Perioperatively acquired (exogenous)	62 (89.9)
Hematogenous	7 (11.1)
Time to manifestation of symptoms (days), median (range)	
Last surgical intervention to onset of symptoms	14 (2–68)
Very early presentation (≤1 month)	58 (84)
Early presentation (>1 month to ≤3 months)	11 (16)
Last surgical intervention to infection diagnosis	22 (2 – 92)
Length of symptoms ≤3 weeks	60 (87)
Length of symptoms >3 weeks	9 (13)
Duration of symptoms until surgical management of infection	5 (0–78)
Symptoms, *n* (%)	
≥2 inflammatory signs and symptoms[b]	44 (64)
+ fever	15
<2 inflammatory signs and symptoms	12 (17)
Wound dehiscence or discharge only	8
Persistent pain only	3
Warmth only	1
Sinus tract	5 (7)
Other signs and symptoms	8 (12)
Hematoma	3
Joint effusion	2
Joint luxation	2
Elevated inflammatory biomarker only	1
Antibiotic treatment, median months (range)	3.5 (0.3–8.3)
Intravenous (days)	17 (7–126)
Knee, median month (range)	6.1 (1.3–8.3)
Hip, median month (range)	3.1 (0.3–6.7)
Surgical treatment, *n* (%)	
DAIR	50 (72.5)
+ exchange of polyethylene inlay	17
+ exchange of a part of the prosthesis	9
Two-stage exchange of the prosthesis	19 (27.5)
As the initial surgical approach	12
Within 20 days after initial DAIR	7

DAIR Debridement and implant retention, *PJI* periprosthetic joint infection

There were 28 cases of PJI of the knee and 41 cases of PJI of the hip

[a] Data are presented as a number with the percentage given in parenthesis, unless indicated otherwise

[b] ≥2 manifestations of inflammation, such as pain, purulent wound discharge, erythema, swelling/induration and/or warmth of the joint

Forty-four patients (64 %) showed ≥2 typical acute inflammatory symptoms, such as pain, erythema, wound discharge, swelling/induration or local warmth of the joint (Tables 2, 3). Fifteen of these patients also developed fever, of whom ten had positive blood cultures and two died due to sepsis. Twelve patients (17 %) had only one documented inflammatory sign of infection, and signs of a chronic infection, such as the sinus tract, were documented in five patients. In eight patients, non-inflammatory signs and symptoms, such as haematoma, joint effusion or luxation or elevated inflammatory serum biomarker, were the only leading symptoms of the infection.

Diagnostic procedure

In the majority (67 of 69) of patients, microbial growth was detected preoperatively and/or intraoperatively. The two patients with culture-negative PJI showed highly infection-suspicious intraoperative signs according to the orthopaedic surgeon, but were treated with antibiotics for 3 and 20 days, respectively. The mean number of intraoperatively retrieved tissue biopsies was 5.6 (range 2–11) in order to facilitate the differentiation between the causal pathogenic organism and contaminants. The most commonly isolated microorganisms were *S. aureus* (17, 38 %) and coagulase-negative staphylococci (26, 25 %) with methicillin resistance in one of 17 (6 %) and 24 of 26 (92 %) strains, respectively (Table 3). Many virulent microorganisms, such as *Staphylococcus aureus*, *Streptococcus pyogenes*, *S. agalactiae*, *S. dysgalactiae* subsp. *equisimilis* or *Bacillus cereus*, presented with acute clinical manifestation, whereas many patients with low-virulent pathogens, such as coagulase-negative staphylococci, *Enterococcus faecalis* or *Propionibacterium acnes* presented with delayed (sinus tract) or nonspecific symptoms (Table 3).

Antibiotic treatment

The median duration of antibiotic treatment was 3.1 and 6.1 months for hip and knee PJI, respectively (Table 2), calculated for all patients, including the two cases of early death due to sepsis at day 9 and 27, respectively. Initial intravenous therapy was performed for at least 14 days in 56 of 69 cases (81 %). Antimicrobial treatment was chosen according to susceptibility testing of the pathogen with an initial empirical treatment consisting of an intravenous broad-spectrum beta-lactam antibiotic in combination with rifampin. In two patients with a culture-negative PJI, the intravenous empirical treatment was followed by an oral treatment with a fluoroquinolone (ciprofloxacin or levofloxacin) and rifampin. In patients with a *Staphylococcus* species or *Propionibacterium acnes* PJI, a rifampin-combination regime was given as a potent antimicrobial substance against bacteria in the biofilm [14, 15]. The infectious diseases consultant chose the combination antimicrobial

Table 3 Microbiological characteristics with a description of the signs and symptoms of 69 patients with early periprosthetic joint infection

Microbial pathogen		Symptoms/signs of PJI				
Type of early PJI infection	*n* (%)	≥2 inflammatory signs/symptoms[a]	+ fever	<2 inflammatory signs/symptoms	Sinus tract	Other signs/ symptoms[b]
Monobacterial	64 (92.7)	44 (64 %)	15	12 (17 %)	5 (7 %)	8 (12 %)
Staphylococcus aureus[c]	17	16	6	1	0	0
Coagulase-negative staphylococci[d]	26	13	0	7	2	4
Streptococcus pyogenes	1	1	0	0	0	0
Streptococcus dysgalactiae subsp. *equisimilis*	1	1	1	0	0	0
Streptococcus agalactiae	2	2	1	0	0	0
Enterococcus faecalis	1	0	0	0	1	0
Bacillus cereus	1	1	1	0	0	0
Escherichia coli[e]	3	2	1	1	0	0
Citrobacter koseri[e]	2	1	0	1	0	0
Pseudomonas aeruginosa[e]	1	0	0	0	0	1
Enterobacter cloacae[e]	1	1	1	0	0	0
Haemophilus parainfluenzac	1	0	1	0	0	1
Proteus mirabilis[e]	1	1	0	0	0	0
Propionibacterium acnes	3	1	0	1	0	1
Granulicatella adjacens	1	0	1	1	0	0
Clostridium hastiformis	1	0	1	0	1	0
Candida famata	1	0	0	0	1	0
Polymicrobial[f]	3 (4.4)	2	0	0	0	1
Culture negative	2 (2.9)	2	1	0	0	0

[a] ≥2 manifestation of inflammation, such as pain, purulent wound discharge, erythema, swelling/induration or warmth of the joint haematoma, joint effusion or luxation, elevated inflammatory serum biomarker only

[b] Haematoma, joint effusion or luxation, elevated inflammatory serum biomarker only

[c] Susceptibility testing: $n = 16$ methicillin susceptible, $n = 1$ methicillin resistant

[d] Coagulase-negative staphylococci included *Staphylococcus epidermidis* ($n = 22$), *S. haemolyticus* ($n = 2$), *S. capitis* ($n = 2$); $n = 24$ methicillin resistant, $n = 2$ methicillin susceptible

[e] No multidrug-resistant Gram-negative pathogens

[f] Polymicrobial infections included: *S epidermidis*, *Propionibacterium acnes* ($n = 1$); *Proteus mirabilis*, *S. aureus, Enterococcus faecalis* ($n = 1$); *S. epidermidis*, *E. faecalis* ($n = 1$)

drug according to antimicrobial susceptibility testing (preferably a fluoroquinolone) to avoid the emergence of rifampin resistance [16].

Surgical treatment

In the majority of patients ($n = 50$, 72.5 %), DAIR of the prosthesis as the most invasive procedure was performed. In 15 of these 50 patients (30 %), a second-look operation with a repeated DAIR was performed within 2–18 (median 6) days due to haematoma ($n = 1$), wound discharge ($n = 10$) or as routine ($n = 4$). In all but one DAIR (*S. aureus*, intervention at day 6), intraoperative tissue biopsies at the second-look operation were negative. These cases with repeated DAIR were not interpreted as treatment failure because the intervention was carried out within 21 days after the initial surgical process.

A complete two-stage exchange of the prosthesis was chosen in 19 patients (27.5 %); in seven of these patients this exchange occurred within 20 days of the initial DAIR (median 14, range 6–20 days). The reason for an exchange were (1) symptoms lasting for >3 weeks ($n = 4$), (2) diagnosis of a rifampin-resistant *Staphylococcus* ($n = 1$), (3) hepatopathy with intolerance to rifampin in the case of a staphylococcal PJI ($n = 1$) or (4) severely damaged periprosthetic tissue ($n = 13$). No resection arthroplasty or one-stage exchange of the prosthesis was performed. In the case of a two-stage prosthetic exchange, the median time between removal and replacement was 3.4 (range 0.5–14.9) months.

Table 4 Relapse of early periprosthetic joint infection

No.	Age, years (sex)	Joint	Infecting organism	Time after last surgery (months)	Durations of symptoms (days)	Surgical treatment	Antimicrobial treatment (total duration of treatment)	Time to relapse (months)
1	67 (F)	Hip	*Staphylococcus epidermidis* (MR)	0.5	1	DAIR	Amoxicillin-clavulanate iv, trimethoprim-sulfamethoxazole po (suppression)	3.1 during suppression medication
2	76 (F)	Hip	*Staphylococcus epidermidis* (MR)	0.8	1	DAIR, exchange of part of prosthesis	Vancomycin iv/R po, fusidic acid po/R po (3.6 months)	11.8
3	64 (M)	Knee	Polymicrobial (*Proteus mirabilis*, *Enterococcus faecalis, Staphylococcus aureus*) (MR)	0.4	1	DAIR	Imipenem-cilastin iv/R po, amoxicillin-clavulanate iv/R po, ciprofloxacin po/R po (6.1 months)	6.7
4	51 (F)	Hip	*Staphylococcus aureus* (MS)	0.3	44	DAIR. Bone sequester in situ	Flucloxacillin iv/R po, levofloxacin po/R po (4.5 months)	6.6
5	76 (F)	Hip	*Staphylococcus epidermidis* (MR)	0.9	12	Two-stage exchange, screw remained in situ	Daptomycin iv/R po, linezolid po/R po, trimethoprim-sulfamethoxazole po (suppression)	1.8 during suppression

There were 5 cases of relapse of PJI

R Rifampicin, *MR* methicillin resistant, *MS* methicillin sensitive, *iv* intravenous, *po* peroral, *F* female, *M* male

Outcome analysis

Two patients died due to sequelae of sepsis caused by *S. epidermidis* at day 9 and day 27 postoperatively, respectively. At last follow-up, 62 of the 67 remaining patients were free of infection (median 3.1 years, range 0.2–6.5 years) and five had a relapse of infection (median time to relapse 0.6 years, range 0.2–0.9 years) with isolation of the same microorganism ($n = 3$) or a persistent wound discharge or sinus tract > 3 weeks under continuous antibiotic treatment ($n = 2$) (Table 4). Causing pathogens were methicillin-resistant *Staphylococcus epidermidis* ($n = 3$), methicillin-susceptible *S. aureus* ($n = 1$) and one mixed infection with isolation of *Proteus mirabilis* and *Enterococcus faecalis*. Two patients died 4 and 11 months after surgery, respectively, due to a non-infectious reason. In seven cases (11.1 %), a new infection with another microorganism was documented.

The relapse-free survival of the prosthesis in 67 patients (69 minus 2 deaths due to sequela of sepsis) was 92.3 % (95 % CI 82.6–97 %) after 2 years (Fig. 1a). Stratified by surgical procedure, the relapse-free survival of the prosthesis was 91.6 % (95 % CI 79.2–96.8) for debridement with retention of the prosthesis and 94.2 % (95 % CI 65–99.2 %) for exchange of the prosthesis (Fig. 1b) after 2 years.

Outcome stratified according to time of manifestation of infection

Of the 69 patients, 58 (84 %) and 11 (16 %) developed signs of symptoms of infection within 30 days after surgery (very early) and between 30 and 90 days (early), respectively. All five relapses occurred in the group with very early manifestation of clinical symptoms (four relapses after DAIR, one relapse after a two-stage exchange of prosthesis). Among the patients treated with debridement and retention of the prosthesis, no significant difference in cure rate was calculated for patients with onset of symptoms at less than or more than 30 days after the last surgery (Fischer's exact test $P = 1$).

Outcome stratified according to duration of symptoms

Recently published expert recommendations and guidelines (evidence grade 2A) recommend treating a PJI with a DAIR if signs and symptoms have lasted <3 weeks [2, 7, 17]. Among our 69 patients, nine patients (13 %) showed clinical symptoms for >3 weeks until a diagnostic and therapeutic intervention was performed. Of these nine patients, four (44 %) were finally treated with a two-stage exchange, five were treated with DAIR of the prosthesis and two (one treated with DAIR and one

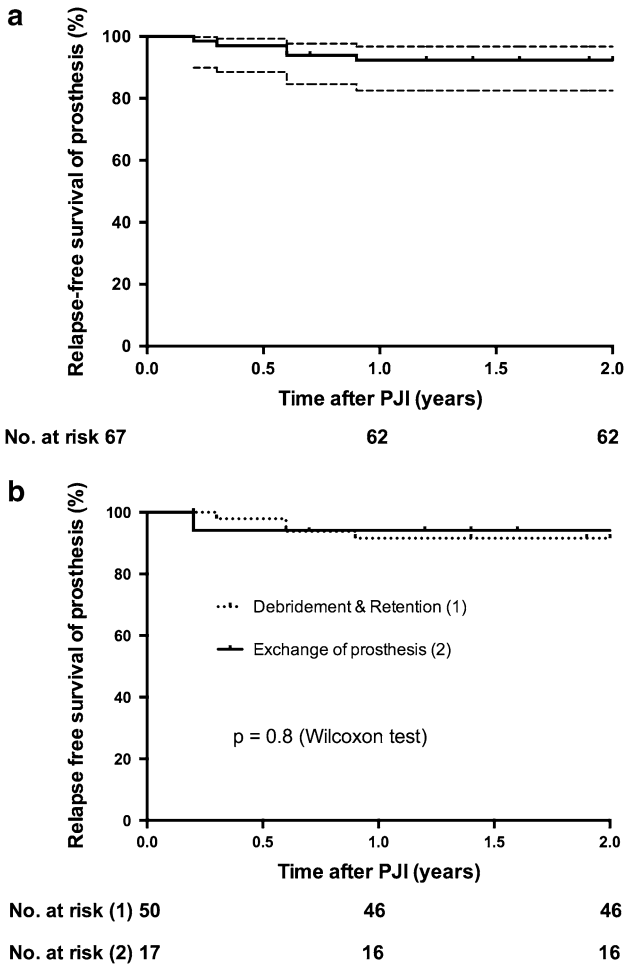

Fig. 1 **a** Kaplan–Meier curve with relapse-free survival of prosthesis in 67 patients (69 minus 2 deaths due to sepsis) was 92.3 % (95 % CI 82.6–97) after 2 years. *Dotted lines* 95 % Confidence interval. **b** Kaplan–Meier curve with relapse-free survival of prosthesis in 67 patients stratified, if treatment with a debridement and retention ($n = 50$) or exchange of the prosthesis ($n = 17$) was performed. The relapse-free survival of the prosthesis was 91.6 % (95 % CI 79.2–96.8) for DAIR (*dotted line*) and 94.2 % (95 % CI 65–99.2 %) for exchange of the prosthesis after 2 years. *PJI* Periprosthetic joint infection

with two-stage exchange) developed a relapse of infection. The possible reason for these relapses might have been a persistent biofilm infection due to a remaining screw after complete exchange of the prosthesis and a remaining bone sequester after DAIR.

Among all 60 patients with symptoms less than 3 weeks, 45 and five were finally treated with DAIR and two-stage exchange, respectively. Three patients developed a relapse of infection after DAIR. There was no significant difference in cure rates according to duration of symptoms of <3 or >3 weeks (Fisher's exact test $P = 0.4$).

Discussion

Our retrospective analysis of 69 early infections after implantation of a knee or hip prosthesis shows that only 64 % of the patients presented with ≥2 acute inflammatory symptoms. *Staphylococcus aureus* (25 %), coagulase-negative staphylococci (38 %) and Gram-negative bacteria (11.6 %) were the most commonly found causative microorganisms in early PJI, indicating that low virulent pathogens, such as coagulase-negative staphylococci, quite commonly cause early infection.

Two-thirds of the patients with early PJI showed ≥2 acute symptoms of an infection, such as pain, wound discharge, erythema, swelling/induration or warmth of the joint and/or fever. About one-third presented with only one acute inflammatory symptom, with signs of a chronic infection (sinus tract), or haematoma, joint effusion/luxation or elevated inflammatory serum biomarkers only. Typically, early infections are considered to be associated with acute infectious symptoms [2], but many patients suffer exclusively from nonspecific symptoms [18]. Based on our results, we conclude that even in early PJI nonspecific symptoms should raise the suspicion of a potentially deep PJI, and further diagnostic steps, such as arthrocentesis and synovial fluid analysis (total and white cell count, microbiological culture), should be initiated. In our study, the most commonly isolated microorganisms were coagulase-negative staphylococci. Thus, based on our results, these low-virulence microorganisms are not limited to delayed infection.

The goal of treatment in PJI is to cure the infection, prevent its recurrence and ensure a pain-free and functional joint [19]. Despite the recently published IDSA guidelines on PJI [7], the proposed therapeutic approach is still under debate since many recommendations are based on non-randomized observational studies and/or expert opinion. There is only one randomized double blinded prospective trial, with 33 patients demonstrating that in early staphylococcal PJI, DAIR is a successful treatment provided that a combination of rifampin with a fluoroquinolone (ciprofloxacin) is used [14]. Large cohort studies or randomized controlled trials with high power are still missing. In the USA, PJI is traditionally treated with a two-stage exchange, whereas in Europe the approach of extensive DAIR is more regularly used. DAIR is favoured if the prosthesis is stable, the pathogen is not a difficult-to-treat microorganism, symptoms have lasted for <3 weeks and the skin and soft tissue are intact [2]. For a successful debridement, mobile parts of the prosthesis (polyethylene inlay) should be replaced [20, 21]: Choi et al. [21] demonstrated that the lack of removal is an independent risk factor for treatment failure. In general, debridement and retention of the prosthesis is favoured

because of a lower morbidity due to a less invasive surgery and reduction of cost due to a shorter hospital stay [22]. Our study showed a successful outcome with a prosthesis survival rate of 92 %, without a significant difference between retention and exchange of the prosthesis. These findings support the result of previously published studies—in particular the prospective randomized study by Zimmerli et al. [14, 23–25] in which the outcome of early staphylococcal infections was studied. These authors showed a 100 % treatment success with DAIR if rifampin was combined with ciprofloxacin and no radiological sign of loosening was detected [2]; without the use of rifampin, treatment success was only 58 %. Our study confirmed the good outcome of DAIR treatment with extension to other microbial pathogens than staphylococci. However, a number of studies have demonstrated a poorer outcome with debridement and retention if the patients were not properly selected or if a polymicrobial infection was diagnosed [11, 12, 26].

The duration of symptoms as an important risk factor for successful debridement and retention has been stressed in the relevant literature [2, 8]. Taking into account the low number of relapses in our study, we could not find any difference between patients treated with DAIR whose duration of symptoms was >3 or <3 weeks, respectively. The reason for treatment failure in four patients with DAIR was (1) suppressive treatment without rifampin from the beginning because of non-adherence (intravenous drug use) and liver cirrhosis, (2) intolerance to rifampin, (3) polymicrobial infection and (4) a remaining bone sequester after debridement. In the one patient with treatment failure after a two-stage exchange, a screw for a fixation device remained in situ and could not be removed, which caused persistent infection.

The patients enrolled in our study received a long-term antibiotic treatment, with a median duration of 3.1 or 6.1 months in the hip or knee PJI, respectively, based on European and American guidelines [7, 27]. A total treatment period of 3 months for hip PJI and 6 months for knee PJI had been recommended earlier [2]. The authors of a cohort study from Australia with 147 patients with early PJI recently reported that a shortened treatment course for <3 months is a risk factor for treatment failure [6]. However, more recently published studies favour shorter treatments [28–31], but no randomized controlled trials have been performed to date.

No consensus exists on the duration of the period of time after surgery that defines an early infection, with current definitions ranging from 2 weeks to 3 months [2, 3, 5–7]. In our study, no difference in outcome was seen between patients presenting with very early (≤30 days) manifestation of PJI and those presenting with early (30–90 days) PJI manifestation. This result underlines that the consequent use of rifampin in staphylococcal infections is likely to be more important, as well as the choice of DAIR as treatment option only after the proper selection of patients with a stable prosthesis.

This study provides important epidemiological and clinical data on early PJI and its treatment possibilities. It especially underlines the good outcome with DAIR in a properly selected cohort of patients and supports the data of a previously randomized controlled study of Zimmerli et al. [2] with extension to a variety of microbial pathogens. The limitations of our study are its retrospective design and the low number of patients with symptoms for >3 weeks or early symptom onset between 30 and 90 days; this latter limitation did not allow us to perform a risk factor analysis. Our study cohort was heterogeneous with respect to the different pathogens isolated and because we did not distinguish between primary and revision surgery procedures. The latter may have led in some cases to a low-grade infection being mistaken for an early infection after revision surgery.

In conclusion, our investigation shows that DAIR is not inferior to two-stage exchange of the prosthesis. Therefore, whenever possible, according to an established treatment algorithm, early PJI should be treated with DAIR, since it is less invasive. A high cure rate of >90 % can be reached with DAIR provided that patients are properly selected and an experienced multidisciplinary team of orthopaedic surgeons, infectious disease specialists and microbiologists evaluates each case.

Acknowledgments We thank Werner Zimmerli, M.D. for providing useful comments. This study was supported by a grant of the Hans-Paul Wälchli Foundation for Research (Lugano, Switzerland) and a fellowship grant supported by the Swiss National Science Foundation (Switzerland, PBZHP3_141483).

Conflict of interest None.

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