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Management of periprosthetic infection after reversed shoulder
arthroplasty

Running title: Management of PSI

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ABSTRACT

Background

Periprosthetic shoulder infection (PSI) remains a devastating complication after reverse shoulder arthroplasty (RSA). Currently, scientific data related to the management of PSI is limited, and the optimal strategy and related clinical outcome remains unclear. Guidelines from the Infectious Diseases Society of America for the management of periprosthetic joint infection are mainly based on data from patients after hip and knee arthroplasty. The aim of this study was to evaluate whether these guidelines are also valid for patients with PSI after RSA. In addition, the functional outcome according to the surgical intervention was assessed.

Methods

An RSA database was retrospectively reviewed to identify infections after primary and revised RSAs, diagnosed between 2004 and 2018. Data collected included age, sex, indication for RSA, causative pathogen, surgical and antimicrobial treatment, functional outcome and recurrence.

Results

Thirty-six patients with a PSI were identified. Surgical treatment was subdivided into: débridement and implant retention (DAIR) (n=6; 17%); 1-stage revision (n=1; 3%); 2-stage revision (n=16; 44%); multiple stage revisions (> 2 stages) (n=7; 19%); definitive spacer (n=2; 6%) and resection arthroplasty (n=4; 11%). The most common causative pathogens were *Staphylococcus epidermidis* (n=11; 31%) and *Cutibacterium acnes* (n=9; 25%). Four

patients (11%) were diagnosed with recurrence, all of them were initially treated with a DAIR approach. The median follow-up was 36 months (range 24-132 months).

Conclusion

PSI is typically caused by low-virulent pathogens, which often are diagnosed with a delay resulting in chronic infection at time of surgery. Our results indicate that treating patients with chronic PSI with DAIR has a high recurrence rate. In addition, implant exchange (i.e. 1- and 2-stage) does not compromise the functional result as compared to implant retention. Thus, patients with chronic PSI should be treated with implant exchange. Future research should further clarify which surgical strategy (i.e. 1 versus 2-stage exchange) has a better outcome overall.

Level of evidence: Level III; Retrospective Cohort Comparison; Treatment Study

Keywords: Reverse shoulder arthroplasty; Periprosthetic joint infection; *Cutibacterium acnes*; Periprosthetic shoulder infection; Functional outcome; Surgical treatment

Reverse shoulder arthroplasty (RSA) is a good surgical option for massive cuff-tear arthropathy, arthrosis and proximal humeral fractures in the elderly^{14,29}. With an aging population, the number of procedures for these indications and therefore their related complication (e.g. periprosthetic joint infection (PJI)) rates will rise. The rate of infection after RSA has been reported to range between 1% and 10%, and increases with every revision procedure⁴². As there is still a lack of high-quality studies related to the diagnosis and treatment of this complication, management is often based on the outcome of small cohort studies or guidelines from PJI after hip and knee arthroplasty.

Treatment modalities for periprosthetic shoulder infection (PSI) are débridement and implant retention (DAIR), 1-, 2- or multiple stage revision, definitive treatment with antibiotic spacers, resection arthroplasty, and chronic antibiotic suppression^{7,11,20,22,38}. The aims of the treatment of PSI are to eradicate infection, to provide adequate pain relief, and to improve function. These aims are not different from those for the management of PJI of the lower extremity. However, there are considerable differences between these regions such as anatomy and biomechanics. For example, the shoulder has a greater reliance on periarticular soft tissues to maintain function, which is affected negatively by each revision surgery⁴². Therefore, one should be careful with extrapolating management protocols from PJI of the lower extremity to PSI^{26–28,39}. Furthermore, the microbiological spectrum is different. PJI after hip and knee arthroplasty is mainly caused by *Staphylococcus aureus*²⁸, whereas the most common pathogens responsible for PSI after RSA are coagulase-negative staphylococci and *Cutibacterium acnes*^{26,27}. In case of these low-virulent pathogens, the diagnosis is challenging, and therefore often delayed³⁹.

Guidelines for the management of PJI published by the Infectious Diseases Society of America (IDSA)²⁵ are mainly based on data from patients with PJI after hip and knee arthroplasty. These define the requirements for a successful débridement with implant retention (DAIR), namely early postoperative PJI (joint age <30 days), or acute hematogenous PJI with <3 weeks duration. Achermann et al¹ showed in a small study in patients with different types of shoulder arthroplasties, that considering these guidelines improves the outcome of patients with PSI. We analyzed the same research question in a larger and more uniform cohort of patients. The aim was to evaluate whether these guidelines are also valid for patients with PSI after RSA. In addition, the functional outcome according to the surgical intervention was assessed.

MATERIAL AND METHODS

This is a retrospective cohort study conducted at the University Hospitals Leuven. The study time period was 2004 to 2018 and the protocol was approved by the hospital's Ethics Committee (S59937).

An RSA database was reviewed to identify infections after primary or revision RSAs. Data collected included age, sex, presence of diabetes mellitus, Body Mass Index (BMI), smoking status, indication for the RSA, causative pathogen, surgical and anti-microbial treatment, functional outcome and recurrence rate. Inclusion criteria consisted of all consecutive adult patients with an infected primary or revised RSA treated in our center. Exclusion criteria were patients with an infection after any other shoulder prosthesis than RSA (i.e. hemiarthroplasty, total shoulder arthroplasty), patients with a history of a native septic shoulder arthritis, an infection after rotator cuff repair, or a fracture-related infection after internal fixation. The minimum follow-up period was 24 months. The interval between implantation of the prosthesis and infection was categorized in line with the IDSA guidelines²⁵, with an 'acute' infection being classified as those occurring within 4 weeks after implantation or with symptoms not more than 3 weeks, and with 'chronic' infections occurring after these time limits.

In order to substantiate the clinical suspicion of infection, laboratory analysis was obtained, including C-reactive protein (CRP) and a white blood cell (WBC) count. In case of remaining doubt, an indium-labelled white blood cell scan was performed. An arthroscopic procedure to obtain biopsies was planned when, after these tests, the diagnosis was still uncertain.

PSI was retrospectively defined following the recently developed major and minor diagnostic criteria for PSI during the International Consensus Meeting on Orthopedic Infections¹⁷. A minimum of five cultures was obtained during every procedure. To culture slow-growing microorganisms, cultures were continued for 14 days. When cultures were positive, isolates

were analyzed with standard laboratory identification methods, and an extended susceptibility testing was obtained. Treatment success was defined as described by Parvizi et al¹²: 1) infection eradication, characterized by no clinical failure (healed wound without fistula or drainage and painless joint), and no infection recurrence caused by the same organism strain; 2) no subsequent surgical intervention after reimplantation surgery owing to infection, and 3) no death caused by a condition directly linked to PJI (including sepsis, necrotizing fasciitis). Shoulder function was assessed using the AO neutral 0-method³² and the Constant-Murley Score (CMS)⁸.

RESULTS

Epidemiological data

Overall, 36 patients were identified with a PSI after primary or revision RSA (Table I). All patients presented with at least one major diagnostic criterion as stated by the International Consensus Meeting on Orthopaedic Infections¹⁷: (1) Presence of a sinus tract from the skin surface to the prosthesis; (2) Gross intra-articular pus; (3) Two positive tissue cultures with phenotypically identical virulent organisms. In our cohort there were no patients with only minor criteria. There were 21 males (58%) and 15 females (42%), with a median age of 71 years (range 42-88 years). One patient died due to sepsis and multi-organ failure two weeks after the diagnosis of PSI. Therefore, this patient was not included in the outcome calculations (i.e. recurrence rate and functional outcome).

Regarding cardiovascular risk factors, there were nine (25%) patients with diabetes mellitus and 13 (36%) with obesity (BMI > 30kg/m²). The mean BMI was 28 (range 15-46). Additionally, 13 (36%) patients were active smokers at the time of diagnosis.

Indications for primary RSA were cuff-tear arthropathy (n=19; 53%), comminuted proximal humeral fractures (n=7; 19%), osteoarthritis/avascular necrosis (n=7; 19%), and failed anatomic prosthesis or osteosynthesis (n=3; 8%).

The median follow-up was 36 months (range 24-132 months). The median time between implantation of the prosthesis and diagnosis of infection was 68 weeks (range 1.5-832 weeks). Overall, two infections (6 %) were classified as acute and 34 (94%) as chronic infection.

Microorganisms

The most common intra-operatively cultured microorganisms were *Staphylococcus epidermidis* (n=11; 31%), *C. acnes* (n=9; 25%) and *S. aureus* (n=6; 17%). Five patients (14%) had a polymicrobial infection with two or more isolated pathogens. Two patients (6%) were culture-negative. In one of these patients, PSI was diagnosed by the presence of a sinus tract, in the other patient by the combination of a positive indium-labelled white blood cell scan and the presence of pus during surgery. All patients were retrospectively defined as a 'definite' PSI following the recently developed diagnostic criteria for PSI during the International Consensus Meeting on Orthopedic Infections¹⁷.

Overall, three patients (8%) had a hematogenous PSI with *S. aureus*. One of these was diagnosed with a *S. aureus* infected lumbar spine fusion, six months earlier. The second patient had sepsis in combination with arthritis of other native and prosthetic joints. The third suffered from sepsis and multi-organ failure.

In five patients (14%) arthroscopic biopsies were taken. Three out of five (60%) patients had a positive result with the same pathogen diagnosed at time of revision surgery. In one patient (20%) culture results showed an additional pathogen (*S. epidermidis*), compared to the intra-operative cultures (*C. acnes*; polymicrobial infection). Another patient (20%) had negative

arthroscopic biopsies, however the intra-operatively cultures and sonication were positive for *C. acnes*.

Treatment

In total, four experienced surgeons were involved in this study (WJM, FV, SN, PD). In each case, therapy was individualized and chosen at the surgeons' discretion based on the local bone stock, patient's age, general medical condition, expectations, and compliance. There was no prospective standardized treatment algorithm. All surgical procedures were performed under general anesthesia, in a beach chair position and with reuse of the initial surgical approach. Fistulas, when present, were excised. During the débridement, a minimum of five cultures was sampled. Superficial, skin, or sinus tract samples were avoided. Normal saline was used as irrigation solution. In case of a 2-stage revision, a prefabricated (e.g. Synimed Synergie Ingénierie Médicale, France; Tecres Medical, Italy) or a custom-made antibiotic containing shoulder spacer was used during the first stage.

Six different surgical treatments were performed: DAIR (n=6; 17%); 1-stage revision (n=1; 3%); 2-stage revision (n=16; 44%); multiple stage revisions (> 2 stages) (n=7; 19%); definitive spacer (n=2; 6%) and resection arthroplasty (n=4; 11%). In our study, treatment with a definitive spacer consisted of the removal of the RSA, a thorough débridement, followed by the placement of a prefabricated (n=1; Tecres Medical, Italy) or a custom-made (n=1; due to severe humeral bone loss) antibiotic containing shoulder spacer. In case of DAIR, mobile parts (i.e. inlay) were exchanged in 2 out of 6 cases (33%).

In seven patients (20%), cultures were still positive at time of definitive reimplantation (i.e. five 2-stage and two multiple stage patients) and an additional course of targeted antibiotic therapy was prescribed for 4-12 weeks. All 2-stage revision cases received six weeks of

antibiotics after explantation of the prosthesis followed by an antibiotic-free interval of two weeks.

Recurrence rate and treatment success

Within the group of patients that were available for a minimum follow-up of 24 months (n=35), four (11%) had a recurrence. All of these patients were treated with a DAIR approach, meaning that recurrence in this group occurred in four out of six patients (80%). These patients with recurrence after DAIR were all classified as chronic infections. None of these patients received an antibiotic with activity on surface-adherent microorganisms, i.e. on biofilms. Biofilm activity with respect to systemic antibiotic therapy is defined as rifampicin combinations against staphylococci and fluoroquinolones against Gram-negative bacteria⁴⁰. In addition, only one patient underwent an exchange of the inlay. All of the patients that underwent a DAIR approach had serious comorbidities (e.g. cardiac). Three patients with recurrence were revised using a 2-stage exchange (Table I), and in one patient a resection arthroplasty was performed. All these patients were infection-free at the most recent follow-up.

There was no recurrence reported after 1-stage revision, 2-stage revision, multiple stage revisions, definitive spacer implantation or resection arthroplasty after a minimum follow-up of 24 months (Table II). Of the seven patients who had positive cultures at time of definitive reimplantation, there were no cases of recurrence documented at the most recent follow-up. Overall, treatment success was 86% (n=31/36)¹².

Functional outcome

According to the AO neutral 0-method, mean elevation at the latest follow-up was 71° (range 45-98°) with the best function for the 1- and 2-stage revision groups (120° and 98°,

respectively) (Table II). Mean scapular abduction at the latest follow-up was 65° (range 44-91°), with the best function for the 1- and 2-stage revision groups (120° and 91°, respectively). According to CMS, resection arthroplasty showed the poorest CMS (12). Compared to other procedures, the 1- and 2-stage revision groups showed the highest CMS (42 and 34, respectively).

DISCUSSION

Infection remains one of the most challenging complications after shoulder arthroplasty³⁰. As high-quality prospective trials for the diagnosis and treatment of PSI are limited, management is often based on the outcome of small cohort studies or guidelines for PJI after hip and knee arthroplasty²⁵. Although similarities are present between these anatomical locations, there are varying functional and weight-bearing demands when comparing the shoulder to the hip and knee joint^{9,10,33}. Our study indicates that treating patients with chronic PSI with DAIR has a poor outcome. Thus, the requirements for successful implant retention are equal to those for patients with PJI after total hip and knee arthroplasty, as previously shown in a smaller cohort of patients with different types of shoulder arthroplasty¹.

Adequate diagnosis is the first step in the management of PSI. Due to the high percentage of low-virulent causative pathogens, the diagnosis of PSI is more challenging, as compared to PJI in other joints. Many patients with PSI present with non-specific clinical signs, such as shoulder pain, swelling and functional impairment^{21,34}. Therefore, accurate diagnosis of PSI requires a high clinical suspicion and the use of several laboratory tests³⁹. In our center joint aspirations are not routinely included in the diagnostic pathway of PSI. Although recent consensus guidelines support the use of diagnostic aspirations¹⁵, the level of evidence in case of PSI is currently not convincing and studies question their added value^{13,23}. Furthermore, although often found as causative PSI pathogens, the interpretation of culture results from an

aspiration with low virulent organisms can be challenging²³. As an alternative, tissue cultures can be retrieved using diagnostic arthroscopy. In our study, five patients underwent an arthroscopic procedure to retrieve tissue biopsies and in 80% of these cases relevant pathogens were discovered. Akgün et al², published a high sensitivity (80%) and specificity (94%) for diagnostic arthroscopic biopsies and stated that it is a useful diagnostic tool in patients with suspicion, but no clear evidence, for PSI. Based on the above-mentioned data, arthroscopic biopsies have our preference over synovial fluid puncture in case of suspicion of PSI, especially when other diagnostic tests (e.g. nuclear imaging) are inconclusive.

The second step in the management of PSI is the surgical approach. Although multiple surgical treatment strategies for PSI have been proposed in the literature, most of these are extrapolated from PJI after hip and knee arthroplasty. In our patient cohort, a 2-stage revision was the preferred intervention. Within this group of 16 patients (46%), no recurrence was documented in combination with an acceptable functional outcome after a minimum of 24 months follow-up. Our results confirm previously published data that this approach represents a viable treatment option for eradicating infection and restoring function^{7,9,24,31,36}. George et al¹⁸ undertook a systematic search of relevant publications and found a better clinical outcome after 1-stage revision (mean CMS of 51) compared to 2-stage revision (mean CMS of 44). However, the authors stated that when considering studies that compared the pre- and postoperative CMS, the difference was not statistically significant. The rates of eradication of infection were similar for the two procedures. Furthermore, the number of RSA cases in the included studies was very low. Till today, no studies directly compared both treatments for PSI¹⁶. Therefore, although some studies suggest that 1-stage revision is superior, even for patients in whom the causative pathogen is low-virulent or unknown^{4,16,20}, currently the indication for 1-stage versus 2-stage revisions and their related outcome – especially in case of RSA – remains unclear¹⁶. It is important to mention that 1-stage revision in case of RSA

can be contraindicated due to severe glenoid bone loss which requires a staged reconstruction. This is one of the primary reasons why only one patient in this cohort was treated with 1-stage exchange, and most with 2-stage exchange followed by, for example, introduction of a custom glenoid baseplate in a later phase⁵. In our study, six patients (17%) underwent a DAIR approach. The recurrence rate in this population was high (n=4; 80%). The outcome could be expected as all cases were chronic PSIs, and therefore not an indication for a DAIR approach²⁵. In these cases, failure rates up to a 100% were previously published for PJI of the upper extremity³⁵. Finally, the two patients who underwent permanent spacer implantation and the four patients who underwent resection arthroplasty all showed eradication of infection at the latest follow-up of a minimum of 30 months with no significant difference in functional outcome. Verhelst et al³⁸ reported no difference in infection control or functional outcome for patients treated with resection arthroplasty after PSI, compared to those with prosthesis removal and prolonged spacer implantation. It has to be stated that these options are preserved for low-demand patients, patients with severe comorbidities who cannot undergo follow-up surgeries, or in case of uncontrollable infection that does not respond to other types of surgery³⁸.

The third aspect in the management of PSI is the systemic antimicrobial treatment. An important aspect is the use of biofilm-active antibiotics (e.g. rifampicin for *staphylococci* infections) to eradicate infection in case of a DAIR approach^{3,37,40,41}. In our study cohort, none of the DAIR patients who presented with recurrence, received a biofilm-active antibiotic agent, also partially explaining the previously mentioned high recurrence rate in this group. With respect to duration, guidelines for PJI after hip and knee arthroplasty are mainly followed. After explantation of the prosthesis, for example, four to six weeks of pathogen-specific antimicrobial therapy is recommended²⁵. In case of DAIR, there is no specific guideline regarding the duration of antimicrobial therapy. Thus, each case should be discussed

in a multidisciplinary team⁴. Most studies prefer four to six weeks antimicrobial therapy for acute shoulder PJI treated with DAIR^{11,16} and three months for low-virulence organisms (e.g. *C. acnes*)^{6,25}.

Finally, the outcome of PJI is negatively impacted when caused by oxacillin-resistant *S. aureus* and *S. epidermidis*¹⁹. In our study six out of the 11 (55%) *S. epidermidis* isolates were oxacillin-resistant. Therefore, we prefer the use of a glycopeptide as first line empiric therapy. Regarding Gram-negative organisms the local multidisciplinary team should individually discuss empiric antimicrobial therapy. In our population only a single pathogen was found to be resistant to amoxicillin/clavulanic acid. When susceptibility results are available, antimicrobial therapy should become targeted as soon as possible.

Several limitations regarding our study should be mentioned. First, the study design was retrospective, leading to a reduced level of evidence and difficult interpretation. Another limitation was the small sample size of 36 patients. However, our RSA cohort size is larger than most prior reports. We admit that a larger number of patients in a multicenter study would offer more information and would increase the study's scientific value. Furthermore, during the study period, a lot of the treatment decisions were made at the discretion of the individual treating physician, which caused heterogeneity in the different management protocols. This again proves the importance of standardized treatment protocols based on recently published guidelines^{15-17,25}.

CONCLUSION

PSI is typically caused by low-virulent pathogens, which often are diagnosed with a delay, resulting in chronic infection at time of surgery. Our results indicate that treating patients with chronic PSI with DAIR has a high recurrence rate. In addition, implant exchange (i.e. 1- and 2-stage) does not compromise the functional result as compared to implant retention. Thus,

patients with chronic PSI should be treated with implant exchange. Future research should further clarify which strategy (i.e. 1 versus 2-stage exchange) has a better outcome overall.

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LEGENDS

Table I Data related to the epidemiology, microbiology, treatment strategies and recurrence for patients with periprosthetic shoulder infection

Table II Surgical strategies and their related outcome

1 **Table I** Data related to the epidemiology, microbiology, treatment strategies and recurrence for patients with periprosthetic shoulder infection

N°	SEX	AGE	INDICATION PROSTHESIS	TYPE OF INFECTION ¹	PREVIOUS OPERATIONS	SURGICAL TREATMENT	CAUSITIVE ORGANISM	ANTIBIOTIC THERAPY (TYPE)	ANTIBIOTIC THERAPY (DURATION IN WEEKS)	RECURRENCE
1	M	61	AVN	Chronic	4	2-stage	<i>Cutibacterium acnes</i>	Amoxicillin	6	No
2	M	63	Cuff-tear arthropathy	Chronic	0	2-stage	<i>Staphylococcus epidermidis</i> ² + <i>Cutibacterium acnes</i>	Vancomycin, Levofloxacin	12 4	No
3	M	67	Fracture	Chronic	0	DAIR	<i>Cutibacterium acnes</i>	Flucloxacillin ³	6	Yes
4	F	66	Arthrosis	Chronic	0	DAIR	<i>Staphylococcus epidermidis</i>	Flucloxacillin ³	6	Yes
5	M	77	Cuff-tear arthropathy	Chronic	0	2-stage	Negative	Amoxicillin/ clavulanic acid	8	No
6	M	60	Cuff-tear arthropathy	Chronic	2	2-stage	<i>Staphylococcus epidermidis</i>	Flucloxacillin ³	5	No
7	M	76	Cuff-tear arthropathy	Chronic	0	2-stage	Negative	Ofloxacin	4	No
8	F	54	Arthrosis	Chronic	3	2-stage	<i>Cutibacterium acnes</i>	Clindamycin + Moxifloxacin	6	No
9	M	73	Fracture	Acute	0	DAIR	<i>Staphylococcus</i>	Clindamycin	6	No

							<i>s epidermidis</i>			
10	M	79	Cuff-tear arthropathy	Chronic	0	Definitive spacer	<i>Staphylococcus epidermidis</i>	Minocyclin	4	No
11	F	74	AVN	Chronic	1	2-stage	<i>Staphylococcus epidermidis</i>	Vancomycin	6	No
12	M	73	Failed hemiprosthesi	Chronic	1	1-stage	<i>Cutibacterium acnes</i>	Amoxicillin/ clavulanic acid	12	No
13	F	53	AVN	Chronic	1	2-stage	<i>Staphylococcus epidermidis</i>	Flucloxacillin, Clindamycin	2 4	No
14	M	42	Instability	Chronic	2	Multiple stages	<i>Cutibacterium acnes</i>	Amoxicillin/ clavulanic acid	7	No
15	F	64	Cuff-tear arthropathy	Chronic	0	Multiple stages	<i>Staphylococcus epidermidis</i> + <i>Cutibacterium acnes</i>	Linezolid	3	No
16	F	57	AVN	Chronic	3	Multiple stages	<i>Staphylococcus epidermidis</i>	Ofloxacin	4	No
17	M	72	Fracture	Chronic	0	2-stage	<i>Staphylococcus epidermidis</i> + <i>Cutibacterium acnes</i>	Rifampicin + Minocyclin + Clindamycin	6	No
18	F	88	Failed anatomic prosthesis	Chronic	1	Resection arthroplasty	<i>Streptococcus agalactiae</i>	Amoxicillin/ clavulanic acid	6	No

19	M	65	Cuff-tear arthropathy	Chronic	0	DAIR	<i>Staphylococcus capitis</i> + <i>Cutibacterium acnes</i>	Clindamycin	8	Yes
20	M	77	Cuff-tear arthropathy	Chronic	0	Resection arthroplasty	<i>Staphylococcus aureus</i> ⁴	Clindamycin	14	No
21	M	77	Arthrosis	Acute	0	Definitive spacer	<i>Serratia marcescens</i>	Piperacillin/tazobactam, Levofloxacin	8 4	No
22	F	75	Fracture	Chronic	0	2-stage	<i>Staphylococcus epidermidis</i>	Vancomycin, Clindamycin	2 6	No
23	F	77	Fracture	Chronic	0	2-stage	<i>Staphylococcus epidermidis</i>	Piperacillin/tazobactam, Clindamycin	6 6	No
24	M	77	Cuff-tear arthropathy	Chronic	0	Resection arthroplasty	<i>Cutibacterium acnes</i>	Flucloxacillin	10	No
25	M	57	Cuff-tear arthropathy	Chronic	0	DAIR	<i>Staphylococcus aureus</i>	Flucloxacillin	10	Yes
26	M	70	Cuff-tear arthropathy	Chronic	0	Multiple stages	<i>Staphylococcus aureus</i>	Vancomycin	4	No
27	M	44	Fracture	Chronic	0	2-stage	<i>Staphylococcus aureus</i>	Flucloxacillin, Clindamycin	7	No
28	F	55	Cuff-tear arthropathy	Chronic	0	2-stage	<i>Cutibacterium acnes</i>	Clindamycin	6	No
29	F	74	Cuff-tear	Chronic	0	2-stage	<i>Cutibacterium</i>	Clindamycin	12	No

			arthropathy				<i>acnes</i>			
30	M	72	Cuff-tear arthropathy	Chronic	0	Resection arthroplasty	<i>Cutibacterium acnes</i>	Amoxicillin/clavulanic acid	2	No
31	F	67	Cuff-tear arthroplasty	Chronic	0	DAIR	<i>Staphylococcus epidermidis</i>	Flucloxacillin + Rifampicin, Levofloxacin + Rifampicin	3 3	No
32	F	73	Fracture	Chronic	0	Multiple stages	<i>Proteus mirabilis</i>	Vancomycin + Flucloxacillin, Linezolid + Flucloxacillin	2 10	No
33	F	81	Cuff-tear arthropathy	Chronic	0	2-stage	<i>Staphylococcus epidermidis</i>	Moxifloxacin	2	No
34	M	61	AVN	Chronic	1	Multiple stages	<i>Staphylococcus epidermidis</i> + <i>Cutibacterium acnes</i>	Vancomycin	6	No
35	M	67	Cuff-tear arthropathy	Chronic	0	2-stage	<i>Staphylococcus aureus</i>	Vancomycin	6	No
36	F	80	Cuff-tear arthropathy	Chronic	0	Multiple stages	<i>Staphylococcus aureus</i>	Meropenem	7 ⁵	/

2 ¹ Time of infection: acute = duration of symptoms ≤ 3 weeks or joint age ≤ 4 weeks, chronic = > 4 weeks joint age and/or > 3 weeks of symptoms.

3 ² Six of the 11 *S. epidermidis* strains were oxacillin-resistant (methicillin-resistant *S. epidermidis* = MRSE)

4 ³ Current guidelines do not propose oral flucloxacillin in case of implant-related infection.

5 ⁴ One of the six *S. aureus* strains were oxacillin-resistant (methicillin-resistant *S. aureus* = MRSA)

6 ⁵ Died two weeks after diagnosis due to sepsis and multi-organ failure

7 Abbreviations: *DAIR*, *Debridement and Implant Retention*; *M*, *Male*; *F*, *Female*; *AVN*, *avascular necrosis*

Stages	Number	Median time to diagnosis PSI (weeks)	Recurrence rate	Median duration AB (weeks)	CMS	Elevation/adduction (degrees)	Median follow-up (months)
DAIR	6	18 (range 2-68)	4 (80%)	6	13	82/86	42
One stage revision	1	80	0	12	42	120/120	44
Two stage revision	16	72 (range 6-832)	0	6	34	98/91	35
Multiple stages	6	212 (range 12-468)	0	5	26	58/44	25
Definitive spacer	2	50 (range 1.5-68)	0	9	18	55/50	48
Resection arthroplasty	4	70 (range 52-402)	0	8	12	45/45	56
Total	35¹		4				

Table II Surgical strategies and their related outcome

¹One patient died shortly after treatment due to sepsis and multi-organ failure and therefore was not included in the outcome calculations.

Abbreviations: *DAIR: Debridement and Implant Retention*; *CMS: Constant-Murley Score*