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ORIGINAL STUDY

Surgical treatment algorithm for infected shoulder arthroplasty
A retrospective analysis of 17 cases

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There is no consensus regarding treatment of periprosthetic shoulder infections. We retrospectively reviewed 17 patients diagnosed with a periprosthetic shoulder infection. Patient demographics, preoperative diagnostics, therapeutic management and functional outcome were evaluated. The Constant-Murley score (CMS), Simple Shoulder Test (SST), Visual Analogue Score (VAS) and Disabilities of the Arm, Shoulder and Hand score (DASH) were used to assess clinical outcome. Pre-and intraoperative culture results and laboratory data, including C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR), were analyzed.

Three patients were treated by two-stage revision arthroplasty, 5 by resection arthroplasty with implantation of a cement spacer, 8 by resection arthroplasty without spacer and one patient underwent polyethylene exchange and serial debridement. The mean follow-up was 4.7 years (range : 1-9.3). The CMS was 27.8 for the resection arthroplasty group, 22.7 for the two-stage revision group and 20.6 for the resection arthroplasty with spacer group. No patients received chronic antibiotic suppression. Mean CRP value was 3.7mg/L (range : 0.2 -11.1). Infection was monobacterial in 8 patients and polymicrobial in 9. The most common organisms were *Coagulase negative staphylococcus* (CNS) (13/17) and *Propionibacterium spp.* (7/17). Complications included two humeral fractures.

At a mean follow-up of 4.7 years, all but one patient were considered free of infection. Worst functional results were seen with the implantation of a definitive cement spacer. Two-stage revision arthroplasty remains the gold standard in chronic infections, but is associated with a high complication rate. One-stage revision to a reverse shoulder arthroplasty (RSA) is an attractive alternative in selected cases. A surgical treatment algorithm for infected shoulder arthroplasty is proposed.

Keywords : shoulder ; infection ; periprosthetic infection ; total shoulder arthroplasty ; reverse shoulder arthroplasty ; resection arthroplasty ; hemiarthroplasty ; antibiotic cement spacer.

INTRODUCTION

Periprosthetic joint infection (PJI) is one of the most devastating complications after a total joint replacement. The incidence of deep infection after primary anatomical total shoulder replacement is 0%-3.9% and 4%-15% in case of revision surgery (*21*). Higher incidence rates between 2% and

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18.8% have been reported for reverse shoulder arthroplasty (RSA) (*2*). With shoulder replacement being increasingly performed, diagnosis and treatment of infection will become a major challenge in the future. Literature about PJI of the shoulder is scarce and diagnostic and therapeutic algorithms are based on more extensive experience with PJI of the knee and hip. Treatment options consist of a long course of intravenous antibiotics, one- or two-stage revision arthroplasty, arthroscopic or open debridement with retention of the components, resection arthroplasty, arthrodesis and amputation. The purpose of this retrospective study was to evaluate risk factors, diagnostic procedures, pain relief, patient satisfaction, functional outcome and complications for all patients treated for infected shoulder prosthesis at a single tertiary orthopaedic center.

MATERIAL AND METHODS

This study was approved by the Institutional Review Board of the Leuven University Hospital (B3220072867/S50810). Between January 2001 and January 2012, 23 patients were treated for an infected shoulder prosthesis. At the time of review, four patients had died of unrelated causes and 2 patients could not be evaluated because of end-stage dementia. Informed consent was obtained and 17 patients were retrospectively reviewed. This cohort included 7 patients who have been reported by Verhelst *et al*, and who were again evaluated (*21*). Diagnosis of deep infection was made based upon the criteria proposed by Parvizi *et al* (*12*). Patient age, sex, dominance, smoking, alcohol use, comorbidity, previous surgery and the use of pain medication were recorded. The American Society of Anesthesiologist Score (ASA) was used to classify general physical status. The Constant-Murley score (CMS), the Visual Analogue Scale (VAS), the Simple Shoulder Test (SST) and the Disabilities of the Arm, Shoulder and Hand score (DASH) were used for functional assessment. Pre- and postoperative blood analysis for C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) was reviewed. Subjective outcome was rated as unsatisfactory, fairly satisfactory, satisfactory and excellent. Infections were classified as acute, subacute and late according to the criteria of Sperling *et al* (*16*). An infection was considered acute when it developed less than 3 months after initial surgery, subacute between 3 months and 1 year and late if it developed more than 1 year postoperatively. For each patient multiple intraoperative tissue samples were obtained for aerobic and anaerobic culture. Culture of fluid obtained by implant sonication was only recently introduced in our unit and was used in 6 cases. Sonication was performed in sterile containers.

RESULTS

Demographic data (Table I)

There were 9 men and 8 women. Mean age at review was 67.7 years. The dominant side was affected in 8 patients. There were 11 left and 6 right shoulders. Only 4 patients had no comorbidity and were classified as ASA-1. The ASA-score was 2 in nine patients and 3 in four patients. Four patients were smokers. Body-mass index (BMI) was 28.13 kg/m^2 on average. In 5 patients BMI was more than 30 kg/m^2. Eight patients were using pain medication because of shoulder complaints. The index procedure was a RSA in 7, a hemiarthroplasty in 5, a revision to a hemiarthroplasty in 2, a revision to a resurfacing prosthesis in 1, an anatomical total shoulder arthroplasty (TSA) in 1 and a revision to RSA in 1. The primary aetiology for joint replacement was rotator cuff arthropathy or omarthrosis in 9, fracture in 7 and rheumatoid arthritis in 1 patient. The mean age at the index procedure was 60.5 years (range : 34-74). Of the primary procedures, 5 were performed at our hospital and 12 elsewhere. Seven patients had previous surgery on the affected shoulder before implantation of the prosthesis that became infected. Four patients underwent 2 surgeries prior to the index procedure and one patient 3. Mean time interval between surgery and diagnosis of infection was 18.8 months (range : 1-81). According to the criteria of Sperling *et al*, five infections were classified as acute, 7 as subacute and 5 as chronic (*16*).

Preoperative diagnostics

A sinus tract communicating with the prosthesis was present in 9 patients. Seven patients had a pathogen isolated by culture from at least 2 tissue or fluid samples obtained from the affected shoulder joint. One patient had no sinus tract and only one

Table I. — Demographic information

No.	Age at initial surgery (yrs)	Gender	Initial surgery	Underlying joint disorder	Risk Factors	Number of previous surgeries	Time to infection (months)	Initial treatment	Definitive treatment	Time to definitive treatment (months)	Follow-up (months)	Complications
1	74	F	RSA	RCA	/	0	Acute (2)	/	Open debridement and polyethylene exchange	2	112	
2	49	M	Revision RSA	Fracture	Smoking, ethyl abuse	1	Acute (2)	Open debridement	2-stage revision	13	84	
3	72	F	RSA	RCA	/	2	Subacute (3)	Open debridement	2-stage revision	9	50	Humeral fracture
4	74	F	RSA	RCA	Sarcoidosis, COPD, DM	1	Subacute (8)	Arthroscopic debridement	2-stage revision	2	35	
5	34	M	Revision Resurfacing	Omarthrosis	Smoking, BMI>35	3	Acute (2)	Open debridement	Resection + spacer	1	12	
6	68	M	RSA	Omarthrosis	Heart disease	0	Subacute (4)	Open debridement	Resection + spacer	8	73	Humeral fracture
7	61	F	Hemiarthroplasty	Omarthrosis	BMI>30,carotid stenosis, breast cancer	0	Late (49)	Open debridement	Resection + spacer	21	85	
8	64	M	RSA	RCA	BMI>30, cerebro-vascular disease	0	Subacute (4)	Open debridement	Resection + spacer	3	67	
9	70	F	RSA	Fracture	DM	2	Subacute (4)	Open debridement	Resection + spacer	15	87	
10	38	M	Hemiarthroplasty	Fracture	Smoking	0	Subacute (5)	Open debridement	Resection arthroplasty	22	97	
11	36	F	Revision Hemiarthroplasty	Fracture	Smoking, BMI>30	2	Acute (1)	Open debridement	Resection arthroplasty	79	12	
12	53	F	TSA	RA	RA	0	Late (81)	Open debridement	Resection arthroplasty	1	87	
13	73	F	Hemiarthroplasty	Fracture	Heart disease	0	Acute (1)	Open debridement	Resection arthroplasty	8	44	
14	57	M	Hemiarthroplasty	Fracture	Ethyl abuse	0	Late (36)	/	Resection arthroplasty	2	40	
15	66	M	Hemiarthroplasty	Omarthrosis	BMI>30, heart disease, IBD	0	Subacute (3)	Open debridement	Resection arthroplasty	28	33	
16	69	M	Revision Hemiarthroplasty	Fracture	Heart disease	2	Late (36)	Open debridement	Resection arthroplasty	29	20	
17	70	M	RSA	RCA	/	0	Late (80)	/	Resection arthroplasty	87	18	

BMI, Body mass index ; COPD, Chronic obstructive pulmonary disease ; DM, Diabetes mellitus ; IBD, Inflammatory bowel disease ; RA, Rheumatoid arthritis ; RCA, Rotator cuff arthropathy ; RSA, Reverse shoulder arthroplasty ; TSA, Total shoulder arthroplasty.

positive culture of periprosthetic fluid. Diagnosis of PJI could be established because CRP, ESR and synovial polymorphonuclear percentage were elevated and purulence was present in the affected joint. Preoperative CRP values were available in 16 patients. Mean CRP value was 61.4 mg/L (range : 2.4-277.6 mg/L). One patient with a late infection with *Staphylococcus epidermidis* had normal CRP values. Preoperative cultures were available in 15 patients. These include joint fluid aspirations (n = 6), wound swabs from sinus tracts (n = 4) and tissue cultures from previous open debridement or arthroscopic lavage (n = 5). In eight patients the infectious organisms were identical to those obtained from intraoperative cultures at the definitive surgery. A different organism was found in 3 patients and in 3 patients intraoperative cultures remained sterile.

Treatment

Before referral to our center, 14 patients had already undergone procedures to treat the infection. An open debridement was performed in 7 patients. Four patients had this procedure done twice, one patient three times and one patient underwent nine open debridements prior to referral. In one patient an arthroscopic debridement and synovectomy was performed. The mean delay between the diagnosis of infection and the definitive treatment at our institution was 19.5 months.

Patient 1 was the only patient who presented with an acute infection and did not have previous surgery for infection. Treatment consisted of open debridement and polyethylene exchange with retention of the prosthesis. Intravenous antibiotics (vancomycin and clindamycin) were administered for 6 weeks. One subsequent open debridement and lavage was performed 5 months later, followed by 6 weeks intravenous antibiotics. Infectious parameters returned to normal and oral antibiotics (clindamycin) were continued for 24 months. Three patients had a two-stage revision arthroplasty. After removal of the prosthesis and thorough debridement a cement spacer was left in place. All patients received intravenous antibiotics until inflammatory parameters returned to normal. Our decision algorithm for reimplantation in 2-stage revision procedures is shown in figure 1. Reimplantation was performed on average 14 weeks (range : 10-21) after component removal. One long-stem RSA (Delta-3, DePuy, Warsaw, IN, USA) and 2 cuff tear arthropathy prostheses (DePuy) were implanted. Five patients underwent resection arthroplasty with the use of an

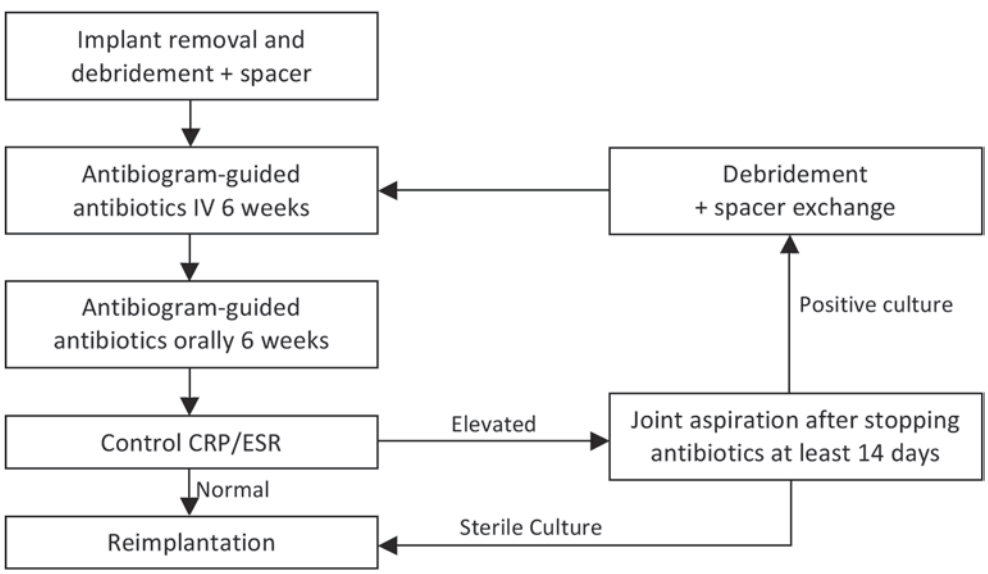

Fig. 1. — Algorithm for 2-stage revision procedures

antibiotic-loaded spacer. The implanted spacer was a stemmed spacer in 4 and a spherical spacer in 1 patient. Gentamycin-loaded cement (Refobacin R bone cement, Biomet, Warsaw, IN, USA) was used to make the spacers. A prefabricated spacer (Tecres Medical, Verona, Italy) was used in one patient (patient 8). Resection arthroplasty without the use of a spacer was performed in 8 patients. After removal of all foreign material and cement, the glenoid was reamed. Manual lavage with at least 12 liters of saline solution was performed. The decision whether or not a cement spacer was used was made intraoperatively based on the bone loss, loss of soft tissues and the size of the dead space after debridement.

Clinical results (Table II)

Mean follow-up was 4.7 years (range : 1-9). For all patients the mean DASH and CMS were 57.7 and 23.9 respectively. The VAS was 4.9 and the SST was 1.7 on average. The mean CMS was 27.8 (4-65) and the mean DASH 46.9 (6.9-85.8) for the 8 patients in the resection arthroplasty group. Pain relief was good with a mean VAS of 3.6 (0-5.5). However, shoulder function remained poor with an SST of 2.4 (0-6) on average. In contrast to the poor objective functional results, 6 patients were satisfied, one patient was fairly satisfied and for one patient the result was excellent. One patient (patient 16) was planned for revision arthroplasty 2 years after resection arthroplasty because he could not accept the functional impairment. Of the 3 patients treated with 2-stage revision arthroplasty one found the result fairly satisfactory and two satisfactory. The objective outcome scores showed a mean CMS of 22.7 (4-34), a mean DASH of 56.7 (36.7-90.8), a mean VAS of 5 (2-8) and a mean SST of 1.3 (0-2). Worst results were seen in the 5 patients who underwent resection arthroplasty with cement spacer implantation. Subjective rating showed unsatisfactory results in 2 and fairly satisfactory results in 2. The patient with the prefabricated spacer had best functional scores and subjectively rated results as satisfactory. Mean CMS and DASH were 20.6 (9-42) and 71.0 (43.3-92.5) respectively. The VAS was 6 (4-10) and the SST was 1 (0-3) on average.

Complications

One patient treated with resection arthroplasty with cement spacer sustained an undisplaced humeral fracture around the spacer. This was treated conservatively with a brace. A second humeral fracture occurred in a patient treated with a two-stage revision procedure. Fracture occurred at the tip of the stemmed spacer and was treated with a long-stem prosthesis at reimplantation.

Microbiological results

Multiple intraoperative cultures were obtained in all patients (mean 8, range 2-14). In one patient intraoperative cultures remained sterile. In seven patients a single infectious organism was isolated, 9 patients showed a polymicrobial infection. *Coagulase negative staphylococcus* (CNS) was isolated in 13/17 patients, *Propionibacterium spp*. in 7/17, *Staphylococcus aureus* in 2/17, *Peptostreptococcus spp*. in 2/7, *Corynebacterium spp*. in 2/17 and Methicillin resistant *Staphylococcus aureus* (MRSA) in one patient. Implant sonication was only recently introduced in our hospitals laboratory and was performed in the 6 most recent cases. Sonication fluid cultures were positive in 5 cases and showed identical organism to the intraoperative tissue cultures. In one case sonication fluid culture remained sterile. At a mean follow-up of 4.7 years, all but one patient were considered free of infection. No patients received chronic antibiotic suppression. Mean CRP value at last follow-up was 3.6 mg/L (range 0.2-11.1). Two patients treated with resection arthroplasty had persistent elevation of CRP and ESR values (patient 10 and 12). Both patients had no other signs of infection and subjectively rated outcome as excellent and satisfactory. One patient had rheumatoid arthritis which can explain the persistent elevation of CRP and ESR values. The second patient had no obvious reason for these findings and was considered to have a chronic low-grade infection.

DISCUSSION

In this study we retrospectively reviewed 17 patients treated for an infected shoulder prosthesis.

Table II. — Clinical and infectious results

No.	Fistula	Preop CRP (mg/L)	Preop Culture	Intraoperative Culture	Implant Sonication	Postop CRP (mg/L)	VAS	CMS	DASH	SST
1	No	61.7	CNS	CNS	/	1.7	9	14	80	1
2	Yes	30.5	CNS	CNS	/	1.5	2	30	36.7	2
3	No	na	na	CNS	/	5.2	8	4	90.8	0
4	No	68.6	S.epidermidis	P.acnes	P.acnes	1.1	5	34	42.5	2
5	Yes	20.3	Finegoldia magna, P.acnes	P.acnes, Peptostreptococcus magnus	P.acnes	5.8	4	14	81.3	0
6	No	59.6	Sterile	CNS, Propionobacterium	/	0.8	5	19	48.3	3
7	No	54.0	S.aureus	S.aureus, CNS	/	1.3	7	19	92.5	1
8	Yes	37.1	na	CNS	/	3.1	4	42	43.3	0
9	Yes	20.3	S.aureus	MRSA, Propionobacterium	/	3.9	10	9	89.8	1
10	Yes	19.7	Sterile	CNS	/	10.6	5.5	30	47.5	1
11	No	145.1	Corynebacterium	S.epidermidis	/	3.3	5.5	18	73.3	1
12	No	277.6	S.aureus	Sterile	/	11.1	1	26	40.8	3
13	No	109.4	S.aureus	S.aureus	/	2.6	4	20	67.5	2
14	Yes	35.7	E.coli,S.aureus	P.acnes, S.aureus, S.schleiferi, S.carnasus	Sterile	4	5	4	85.8	2
15	Yes	32.2	Enterococcus	CNS, Propionibacterium, Peptostreptococcus, C.perfringens	P.acnes, S.epidermidis	0.2	0	65	6.9	6
16	Yes	2.4	S.epidermidis	S.epidermidis	S.epidermidis	3	7	17	25.9	0
17	Yes	8.2	Sterile	P.acnes, S.epidermidis	P.acnes	1.3	1	42	27.5	4

CMS, Constant-Murley score ; CNS, Coagulase negative staphylococcus ; DASH, Disabilities of the arm, shoulder and hand score ; na, not available ; SST, Simple shoulder test ; VAS, Visual analogue scale.

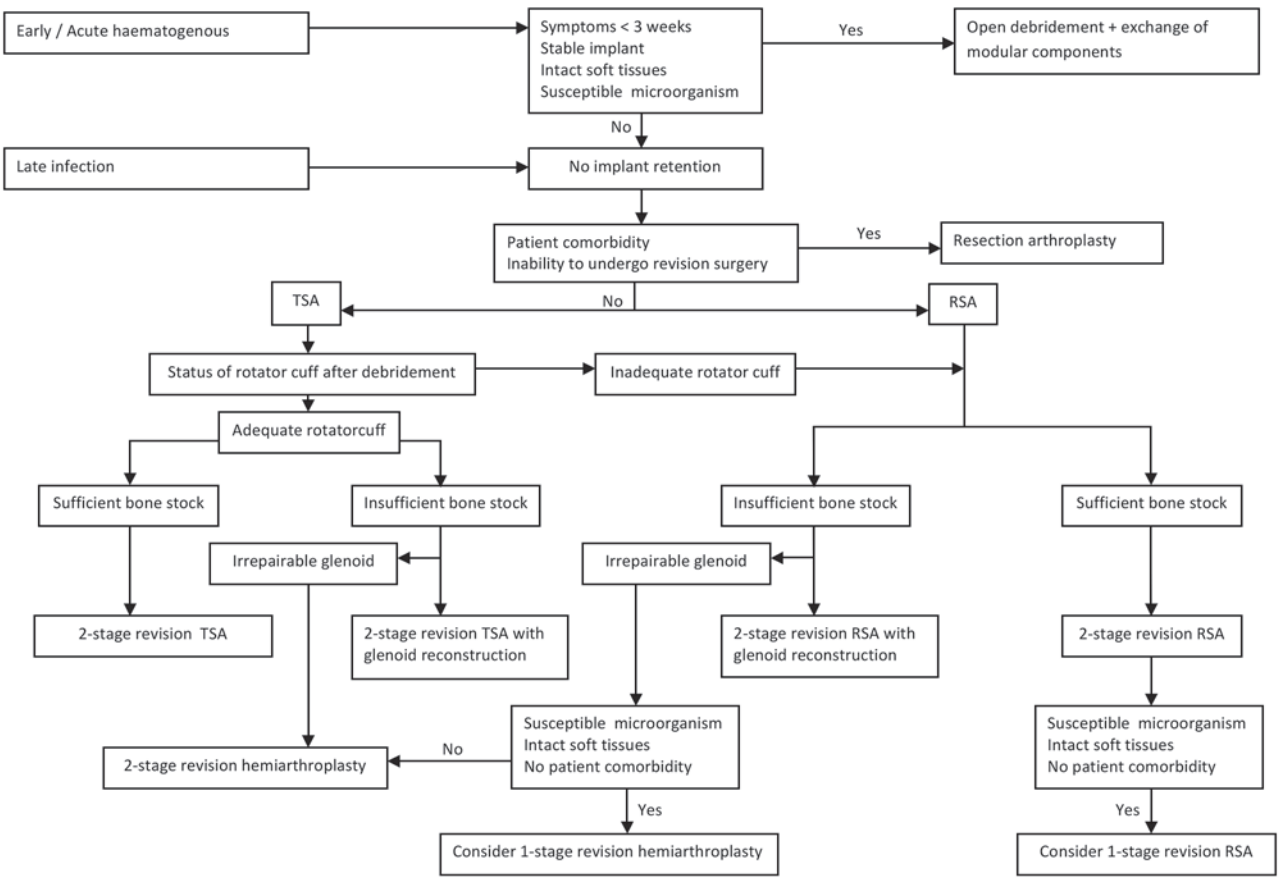

Fig. 2. — Surgical treatment algorithm for infected shoulder arthroplasty. RSA, reversed shoulder arthroplasty. TSA, anatomical total shoulder arthroplasty.

The main shortcoming of this study is the retrospective design and the small number of patients in each subgroup. Moreover outcome may be biased by patient selection in a tertiary referral center.

There are no clear guidelines for the treatment of this devastating complication. Based on our experience and review of the literature, we propose the treatment algorithm presented in figure 2.

Early and acute haematogenous infection can be treated with debridement with implant retention. The best results are achieved if patients have symptoms for less than 3 weeks, a stable implant, good soft tissue coverage and an antibiotic susceptible organism (*24*). If these requirements are met a success rate of 82% has been reported (*22*). Debridement of an infected shoulder can be performed by an arthroscopic or open procedure. In native shoulder septic arthritis a reoperation rate of 26%-50% was seen following arthroscopic treatment (*1,9,19*). In the presence of a shoulder prosthesis, persisting infection was reported in up to 50% of the cases (*16*). No reports comparing arthroscopic and open debridement were found in literature for shoulder arthroplasty. It is the authors' opinion that a thorough debridement can only be done with an open procedure. At the same time all modular components of the prosthesis should be exchanged, especially in case of a RSA (*23*). In our series 5 patients had an early infection. Four patients underwent initial debridement elsewhere and were referred with recurrent chronic infections. In these patients components were eventually removed. The fifth patient had an early infection of an RSA and an open debridement with polyethylene exchange was

performed. A second debridement was necessary after 5 months, no reinfection occurred after this procedure.

In a subacute or late infection implant retention is associated with a high rate of persisting infections. In the absence of high surgical risk and severe patient comorbidity, implant removal is recommended. A two-stage revision procedure is considered the gold standard. Good infection control and restoration of function can be achieved (*16*), however a high complication rate was reported. In a series of 19 two-stage revisions there were 7 (37%) persistent infections and 14 (73%) complications (*18*). Coste *et al* reported persisting infection in 40% of 10 two-stage revisions (*4*). A second problem with two-stage revision arthroplasty is the difficulty of the revision procedure. Reimplantation is not always possible due to inadequate soft tissues, insufficient bone stock or patient refusal. In a series of 28 patients, 12 (43%) declined a second-stage procedure because of acceptable function and pain relief with the use of a prosthesis made of antibiotic-loaded acrylic cement (Prostalac) (*8*). Especially the removal of an RSA may cause large bony defects. Removal of the glenoid base plate and a cemented humeral stem may leave the patient with insufficient bone stock available for the second-stage procedure (*23*). The use of an RSA for reimplantation permits a thorough debridement of all infected tissue, including suspicious remnants of the rotator cuff without compromising the restoration of function since this relies on the integrity of the deltoid. Sabesan *et al* reported 17 two-stage revisions using an RSA. After a mean follow-up of 46 months there were 5 dislocations requiring surgical intervention, but only one (6%) reinfection occurred (*15*). In our series 3 infected RSA's were treated by two-stage revision. No recurrent infections occurred, but the complication rate was high (1 humeral fracture, 30%). All cases were initially planned for revision RSA, however because of extensive glenoid bone loss, we decided intra-operatively to implant a hemiarthroplasty in 2 cases.

Historically one-stage revision arthroplasty has been associated with higher reinfection rates (*16*). Advantages include a shorter hospital stay, lower medical costs, less patient comorbidity and no risk of glenoid erosions due to the presence of a cement spacer. The prerequisites for a one-stage revision are the isolation of a specific microorganism and adequate soft tissue coverage. Recently this procedure has regained popularity with the increased use of an RSA. In a series of 9 patients treated with one-stage revision, Ince *et al* reported no persisting infection after 5.8 years. A hemiprosthesis was used in 8 and a RSA in one patient. The patient with the RSA had better pain relief and an abduction of 110° compared to a mean abduction of 51.6° (*7*). In a series of 22 shoulders treated with a one- or two-stage revision using an RSA, there was no statistically significant difference in any outcome between one- and two-stage revisions (5). The extensive debridement was believed to be an essential factor in achieving this low recurrence rate. This was confirmed by Beekman *et al* who found no persisting infection and a low complication rate in 11 patients treated by one-stage revision RSA (*2*). In the largest series published including 26 one-stage revisions, best results for the CMS were seen with the use of an RSA compared to a bipolar or hemiprosthesis. However, these differences noted were not statistically significant (*10*).

In the elderly or compromised patient a resection arthroplasty is an accepted treatment for failed shoulder arthroplasty (*6*). It is effective in eradicating infection and in relieving pain in one half to two-thirds of patients. The arm is usually comfortable at rest, however poor shoulder function can be expected (*14*). Clinical results are worse when resection arthroplasty is performed for failed RSA because minimal musculature is left to maintain shoulder function (*11*). In contrast, preservation of the tuberosities has been associated with an improved clinical outcome (*21*). In our series 8 resection arthroplasties were performed and good infection control and pain relief was achieved in most patients. However some patients did have persistent pain and one patient was considered to have a chronic low-grade infection. Complete pain relief and eradication of infection cannot be guaranteed, on the other hand subjective outcome evaluation showed a high patient satisfaction. Surprisingly resection arthroplasty resulted in a better functional outcome and pain relief compared to 2-stage

revision in our series. This might be partially explained by patient selection in a tertiary referral center with many patients having comorbidities and multiple previous surgeries compromising results of 2-stage revision procedures.

The use of an antibiotic-loaded cement spacer as a definitive treatment is controversial. Proubasta *et al* first described the use of a permanent cement spacer (*13*). Improvement of infection control and shoulder function using a spacer was reported by some authors (*3,20*), but this was not confirmed in other reports (*21*). Larger head spacers were reported to have best functional results (*17*). Theoretically permanent spacer implantation may cause glenoid erosions possibly preventing future reimplantation. No severe bone erosions were reported with the use of commercially available or moulded well-fitting spacers, even after longer follow-up (*3,17,20*). However, severe glenoid erosions were reported with the use of handmade stemmed or spherical spacers (*21*). A definitive spacer also poses medicolegal concerns since spacers are not intended for permanent implantation. In our series 5 patients were treated with permanent cement spacer implantation with a mean follow-up of 64 months. Clinical results were poor and only one patient had a satisfactory outcome. Based on these results we now only use cement spacers as part of a two-stage revision procedure.

CONCLUSION

In conclusion, worst functional results were seen with the implantation of a definitive cement spacer. Two-stage revision arthroplasty remains the golden standard in chronic infections, but is associated with a high complication rate. One-stage revision to a RSA seems to be an attractive alternative in selected cases. Resection arthroplasty had best functional results in our series, probably due to patient selection in a tertiary referral center. It is an accepted salvage treatment for elderly or compromised patients with failed shoulder prosthesis however complete infection control and pain relief cannot be guaranteed.

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Ethical committee approval

This study was approved by the Institutional Review Board of the Leuven University Hospital (B3220072867/S50810).

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