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One-stage revision for infected shoulder arthroplasty: prospective, observational study of 37 patients

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A R T I C L E I N F O

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Level of evidence: Level IV; Case Series; Treatment Study

Background: Periprosthetic joint infection is a severe complication of joint replacement surgery. Thus two-stage exchange remains the gold standard, one-stage exchange is now widely recommended. We hypothesized that, for patients with chronic periprosthetic shoulder infection (PSI), treatment with a one-stage exchange would be an effective approach to eradicate infection, relieve pain, and restore function to the involved shoulder.
Materials and methods: This monocenter cohort study in a Bone and Joint Infection Referral Center (11/2003-05/2020) included all patients with confirmed PSI treated by one-stage revision. Data were extracted from the prospective database, including demographics, infection characteristics, and functional evaluations (range of motion and Constant Score at admission and last follow-up). The primary outcome was the 2-year reinfection-free rate.
Results: We included 37 patients. The refection-free rate was 5%. The most commonly isolated pathogen was *Cutibacterium acnes* (68%), isolated alone (15 patients, 41%) or as polymicrobial infections (10 patients, 27%). The Constant Score increased significantly from 24 to 53 ($P = .001$). Range of motion (forward elevation, abduction) was also significantly improved after surgery. Mean active forward elevation increased significantly by 45° from 60° to 105° postoperatively ($P < .001$), mean abduction increased by 42° from 55° to 97° ($P < .001$).
Discussion: Results from our prospective cohort-extracted series suggest that one-stage revision is a reliable treatment with a low infection recurrence rate. Improved functional outcomes can be achieved with one-stage exchange. Our patients' overall functional results were similar to those previously reported for one-stage revision and better than those reported after two-stage exchange. Patients with multiple previous surgeries seem to have worse functional outcomes than the subgroup without surgery before the index arthroplasty.
Conclusions: Our results and literature search findings suggest that one-stage revisions effectively eradicate PSIs, with good functional outcomes.
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Periprosthetic joint infection (PJI) is a severe complication of joint replacement surgery. The higher number of shoulder replacements inevitably leads to more periprosthetic shoulder infections (PSIs), directly impacting morbidity and health care costs. The PSI incidence after primary total shoulder arthroplasty ranges between 1.1% and 10%.[12,13] It increases further for reverse shoulder arthroplasty and with every subsequent revision.[25,29] Moeini et al[25] found that PSI's risk increased for reverse shoulder arthroplasties in men (8%). As reverse total shoulder arthroplasty is 1 of the main surgical treatments in shoulder trauma in the elderly PSI's rate will continue to increase. PSI treatment aims to eradicate infection, reduce pain, and preserve function. The surgical management of these infections remains controversial, as observed by Aïm et al,[2] with most authors favoring two-stage revision and considering it the standard. However, two-stage exchange arthroplasty requires a second operation incurring higher morbidity due to limited

This study was approved by the local Ethics Committee (PP 14-034).
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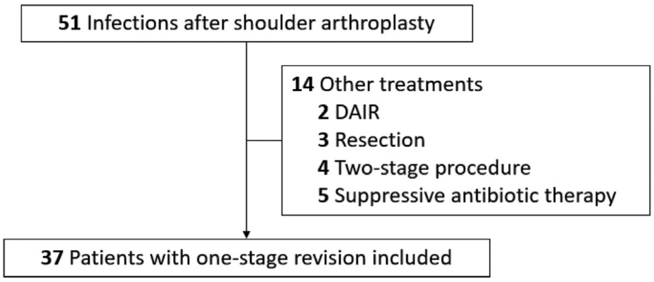

Figure 1 Flow chart. *DAIR*, débridement and irrigation with implant retention.

mobility between procedures, with higher costs for the health care system and the patients, and higher risk of postoperative complications.[2,5] Other treatment options are débridement-synovectomy and irrigation with implant retention, which is associated with high failure rates in chronic infection,[21] or resection arthroplasty and arthrodesis which obtain poorer functional outcomes.[28,32]

In contrast, one-stage exchange consists of extensive synovectomy, removal of all implant components and cement, followed by reimplantation during the same procedure.[17] Less patient morbidity, lower medical costs, and shorter duration of disability are to be expected, as has been proven for knee or hip surgery.[18,19,23]

Functional evaluation after PSI surgery has rarely been reported.[4,16]

The objective of this prospective study on a cohort-extracted series was to analyze the infectious and functional outcomes of patients managed with one-stage-exchange arthroplasty for chronic PSI.

Material and methods

Study design and population

This monocenter, observational study was conducted in a Referral Center for Osteo-Articular Infection[11] from November 2003 to May 2020. All patients admitted in the center for PJIs are registered in the prospective PJI cohort (NCT 01963520, NCT 02801253). Each patient's epidemiological, clinical, microbiological, therapeutic (surgery and antibiotics), adverse event, and outcome data are entered prospectively.

The primary outcome for this cohort-extracted series was the 2-year reinfection-free rate.

All consecutive patients ≥18 year old with a confirmed chronic PSI treated with one-stage revision were included (Fig. 1). No patient was lost to follow-up.

PSI was defined as the isolation of the same microorganism from ≥2 cultures of preoperative joint-fluid aspirate and/or intraoperative tissue specimens or a sinus tract communicating with the prosthesis. Minor criteria included local inflammatory signs, C-reactive protein >5 mg/L and/or radiological findings (ie, periosteal bone formation, subchondral osteolysis).[26,27,34,35]

Microbiological diagnosis

Preoperative joint aspirates were obtained from all patients except patient 37, at least 2 weeks after discontinuing any ongoing antibiotic therapy. Joint aspiration was arthrography-guided in the department of radiology under strict sterile conditions.[33]

During surgery, 5 intraoperative samples of bone and/or synovium that appeared inflamed were collected before starting antibiotics. Tissue or bone specimens were disrupted by vigorous crushing in sterile mortars with sterile diluents. For cultures, aliquots of the resulting suspensions and/or synovial fluid were inoculated onto PolyViteX chocolate agar (incubated under 5% CO_2) and anaerobic Columbia Agar plates (bioMérieux; Marcy-l'Étoile, France), and into aerobic (Hemoline; bioMérieux) and anaerobic enrichment broths (Schaedler broth; bioMérieux). Aerobic and anaerobic cultures were incubated, respectively, for 10 and 14 days. On day 10 or 14, or earlier when bacterial growth was visible, broths were subcultured on PolyViteX chocolate agar and anaerobic Columbia Agar plates, and incubated at 37°C for 48 hours.[32] Bacteria were identified to species with the rapid ID 32A kit (bioMérieux) and, since January 2012, by matrix-assisted laser-desorption ionization mass spectrometry (biotyper; Bruker Dalton, Bremen, Germany). Antibiotic-susceptibility testing used the standard disk-diffusion method, according to the recommendations of the French Society of Microbiology.[7] Molecular biology methods (polymerase chain reaction) were not used to identify microorganism.

Ethics statement

All patients gave written informed consent, and the cohort was approved by a local Ethics Committee (PP 14-034).

Surgical procedure

The medical—surgical management strategy was decided during multidisciplinary consensus meetings involving at least 1 orthopedic surgeon, 1 infectious diseases specialist, and 1 microbiologist. It was guided by the PSI type according to Tsukayama's classification,[31] surgical risk, anatomical and functional status of the infected joint, and the isolated microorganism's antibiotic susceptibility.

All patients underwent one-stage exchange. Surgery was done under general anesthesia in the beach chair position. The previous skin incision was resected and a deltopectoral approach was used. If there was a fistula, it was excised with wide resection of the surrounding skin. All infected tissues were resected with enlarged synovectomy and the prosthesis was dislocated. The humeral prosthesis was removed, as was the cement and the cement plug. An X-ray was taken to confirm that all cement had been removed. If necessary, a proximal humeral longitudinal osteotomy was undertaken to allow extraction. Preparation of the medullary canal required excision of inflamed tissue and cement, if present, and reaming of the canal. When an osteotomy was performed, it was closed with cerclage sutures. No bony protection of the humeral shaft was needed to prevent further fracturing of the humeral diaphysis. The glenoid baseplate was removed and the infected tissue around the baseplate was resected.

During the surgical excision procedure, 5 intraoperative specimens from synovial, glenoid, and humeral sites were obtained. Specimens were immediately transported to the microbiology laboratory and handled as described above.

Finally, after saline washing the shoulder joint, a new glenoid baseplate was implanted. In case of bone defect we used a graft or an augmented implant. There was no glenoid reimplantation if the defect was too important. Then the humeral component was implanted. The humeral implant was most often cementless; however, when it was cemented, no antibiotics were added. The polyethylene inlay was adjusted to obtain maximum stability. A standard layered closure was used with a suction drain.

Antibiotic therapy

The antibiotic regimen, started during surgery after tissue samples were obtained for cultures, was defined during multidisciplinary consensus meetings and was prescribed by the infectious disease specialists. No presurgical antibiotic prophylaxis was administered.

Initial antibiotic choices were based on preoperative joint-fluid–culture findings and the patient's history, and then adjusted to subsequent intraoperative culture and antibiotic-susceptibility–testing results. Antibiotics were administered via a central venous catheter. Drug choices, their routes of administration and doses were described previously.[20] For Cutibacterium infections, clindamycin, cefazolin, or amoxicillin was used. Vancomycin was added to that initial intravenous (IV) regimen for patients with multiple previous surgeries (≥3) and stopped after 1 week if only *C. acnes* had been isolated. From January 2004 to December 2012, combination therapy with rifampicin was prescribed systematically. Since January 2013, rifampin has only been given when rifampin-susceptible Staphylococcus was also isolated from intraoperative samples (polymicrobial infection). Cefazolin, clindamycin, and vancomycin were always administered by continuous IV infusion and serum antibiotic levels were monitored, as described previously.[20,28-30] When local and general infection evolution was favorable and antibiotic gastrointestinal tolerance was good, the route was switched to oral intake. Oral treatment of choice was clindamycin or amoxicillin for *C. acnes* infection, and levofloxacin and rifampicin for susceptible staphylococcal infections. A follow-up consultation to assess treatment compliance, effectiveness, and tolerance was scheduled 1 or 2 weeks after the patient's discharge.[20]

Antibiotic therapy lasted 12 weeks for all patients from 2004 to 2016. Since 2017, all patients completed 6 weeks of antibiotics, except for those at high risk of relapse: multiple operations (≥3), patients receiving chemotherapy or immunosuppressants, Child-Pugh B or C cirrhosis, sickle-cell anemia, irradiated bone, or implants that had required a large bone graft.

Study endpoints

The primary endpoint was 2-year, follow-up, reinfection-free rate, considering the following events: reinfection including relapse with the same bacterium and new infection with a microorganism different from the initial PSI.

The secondary endpoint was the patient's functional outcome 2 years after one-stage–exchange arthroplasty, as assessed with the Constant Score[8] and range of motion (°) evaluation.

Patients were seen prospectively shortly after discharge and at 3, 6, 12, and 24 months after surgery, then every 2 years. Patients unable to attend follow-up visits were contacted by phone to assess their health and prosthesis evolution.

Statistical analyses

These analyses were computed with StatView (version 5.0; SAS Institute, Cary, NC, USA). Qualitative variables were compared with a nonparametric Mann-Whitney U test and the Chi^2 test. Intragroup variations were analyzed using the Wilcoxon test. Quantitative data are expressed as mean (± standard deviation). For all the analyses, $P < .05$ defined statistical significance.

Results

Included patients

Among the 37 patients (24 men, 13 women; mean age 69 years ± 11; mean body mass index 25.7 ± 4.8 kg/m^2) included, 11 (30%) were diabetic; 7 (19%) patients had other notable comorbidities: 3 chronic renal failure (creatinine clearance <30 mL/min), 2 rheumatoid arthritis, and 1 each had human immunodeficiency virus infection, multiple myeloma, or pemphigus.

According to Tsukayama's classification,[31] the PSIs were initially classified as: early postoperative for 7 (19%) patients or late chronic for 30 (81%). At admission to our department, all patients' PSIs had lasted >30 days. The mean duration of PSI symptoms was 13 ± 17 months before one-stage revision (range 2 to 213 months).

During index arthroplasty 12 (32%) patients underwent anatomic and 25 (68%) reverse total shoulder arthroplasty. Indications for the index arthroplasty were: degenerative arthritis for 14 (38%), fracture for 13 (35%), rotator cuff arthropathy for 6 (16%), instability for 1 (3%), osteonecrosis for 2 (5%), and rheumatoid arthritis for 1 (3%).

Fifteen (41%) patients had undergone 1 to 4 previous surgeries on the involved shoulder, including 7 (19%) with 1 to 3 arthroplasty revisions for recurrent dislocation or rotator cuff tear without any history of PSI (Table I).

Nineteen (51%) patients had experienced failure of previous PSI management in another center with débridement-synovectomy and irrigation with implant retention for 10 (27%) patients, antibiotics alone for 6 (16%), and 1 (3%) underwent synovectomy and resection arthroplasty with glenoid spacer and antibiotics.

At admission to our hospital, none of the patients were febrile, 16 (43%) had a fistula that was active in 11 (30%), 32 (86%) were in pain and 35 (95%) had joint disability.

One-stage revision

Twenty-nine (78%) patients had a reverse total shoulder replacement, 6 (16%) underwent partial shoulder replacement for glenoid defect, and 2 (6%) had a total shoulder replacement. Thirty-four (92%) patients underwent revision with a standard humeral stem, and 3 with a long humeral stem; only patient 3 required a humeral bone graft with a standard humeral stem. Four patients had a glenoid bone graft: 1 each with total shoulder replacement or reverse total shoulder replacement and the remaining 2 with partial shoulder replacement.

Microbiological results

Thirty-six (97%) patients had positive intraoperative sample cultures confirming PSI. Patient 33, with a long history of antibiotic treatment before surgery, had negative intraoperative cultures, but preoperative joint-fluid–aspirate cultures were positive for *C. acnes* and the leukocyte count was 11,710/mm^3, with a differential of 64% neutrophils.

Among 36 preoperative joint-fluid–aspirate cultures, 34 (94%) were positive. Patients 21 and 22 with negative preoperative cultures had intraoperative sample cultures that isolated *Staphylococcus lugdunensis* or *C. acnes*, respectively. Only patient 37, who had no preoperative joint-fluid–aspirate, had a productive fistula; cultures of intraoperative samples yielded *C. acnes*.

Ten (31%) patients' intraoperative samples harbored polymicrobial infections but all of them always contained the same bacteria as those isolated from preoperative aspirates. The percentage of microbial species agreement between preoperative joint-fluid–aspirate and intraoperative specimen cultures was 67% (24/36). Seven monomicrobial preoperative joint-fluid aspirates had become polymicrobial (19%). Among 3 (8%) initially sterile aspirates, intraoperative sample cultures grew *C. acnes* for 2 or *S. lugdunensis*. Fourteen (38%) patients were taking antibiotics before being referred and 7 of them had discordant preoperative and intraoperative sample cultures.

Table I
Clinical, radiographic, serological, and surgical parameters and complications of 37 patients who underwent 1-stage prosthesis replacement after PSI.

Patient	Shoulder procedures			Prior infection treatment	Mo		Draining sinus, 0/1	CRP, mg/L	Preoperative aspirate culture	Final culture	Complications
	Index	Previous number	Previous surgery		To infection	Infection to revision interval					
1	TSA	1		Antibiotics	2	60	0	60	*Peptostreptococcus magnus*	*Cutibacterium acnes, P.magnus*	Infection ×2 dislocation
2	RTSA	2	Arthroscopic rotator cuff repair	Antibiotics	2	4	1	23.1	*C. acnes*	*C. acnes*	None
3	TSA	1		Synovectomy	49	37	0	20.8	MS *S. capitis*	MS *Staphylococcus capitis*	None
4	RTSA	1		0	82	7	1	8.6	*C. acnes*	*C. acnes*	None
5	RTSA	1		Fistula excision ×3	13	3	1	17	*C. acnes*	*C. acnes*	None
6	TSA	1		0	11	18	0	31.6	*Streptococcus agalactiae*	*S. agalactiae*	None
7	RTSA	3	ORIF, material removal	Antibiotics	14	17	1	1.6	*C. acnes*	*C. acnes, Staphylococcus epidermidis, Staphylococcus aureus*	None
8	TSA	1		Synovectomy ×2 + antibiotics	<1	85	1	7.5	*P. magnus, S. epidermidis, C. acnes*	*P. magnus, S. epidermidis, C. acnes, S. capitis*	None
9	RTSA	1		Synovectomy + antibiotics	1	5	1	13.7	*S. epidermidis*	*C. acnes, S. epidermidis*	None
10	RTSA	2	Explorative arthroscopy	0	2	10	0	6.8	*C. acnes*	*C. acnes, Kocuria varians*	None
11	RTSA	4	TSA, RTSA, arthrolysis	0	7	2	0	5.7	*C. acnes*	*C. acnes*	None
12	RTSA	1		0	2	3	1	33.3	*C. acnes*	*C. acnes, S. epidermidis*	Died
13	RTSA	1		antibiotics	2	7	0	5	*C. acnes*	*C. acnes*	None
14	TSA	3	ORIF, TSA	antibiotics	<1	37	0	14.5	MR *S. capitis*	MR *S. capitis*	Dislocation
15	RTSA	1		0	5	10	0	14.9	*C. acnes*	*C. acnes*	None
16	RTSA	3	TSA, RTSA	Antibiotics	23	4	1	84.7	*Staphylococcus lugdunensis*	*S. lugdunensis*	dislocation
17	TSA	1		0	23	3	0	67.7	*C. acnes*	*C. acnes*	None
18	RTSA	3	ORIF, arthrolysis	0	1	4	1	NC	*Corynebacterium striatum, C. acnes*	*C. striatum, C. acnes*	Broken material
19	RTSA	1		Synovectomy	32	12	0	29	*Gram + cocci*	*Streptococcus dolosigranulum*	None
20	TSA	2	TSA	Fistula excision	2	7	1	49	*S. epidermidis*	*S. epidermidis*	None
21	RTSA	3	RTSA, change polyethylene insert	Synovectomy + antibiotics	<1	12	0	38.6	Sterile	*S. lugdunensis*	None
22	RTSA	4	TSA ×3	Synovectomy + antibiotics	<1	3	1	12.1	Sterile	*C. acnes*	None
23	TSA	1		0	9	13	0	24	*C. acnes*	*C. acnes*	None
24	RTSA	1		Synovectomy	3	10	1	6.5	*Pseudomonas aeruginosa*	*P. aeruginosa*	None
25	RTSA	2	Arthrolysis	Synovectomy + antibiotics	72	25	0	39.7	*Streptococcus mitis*	*S. mitis, S. aureus*	None
26	RTSA	1		0	>1	3	0	6.4	*C. acnes*	*C. acnes*	None
27	TSA	1		0	3	10	0	22.7	*C. acnes*	*C. acnes*	None
28	TSA	1		0	7	2	1	1.1	*C. acnes*	*C. acnes*	None
29	RTSA	4	Arthroscopic rotator cuff repair, synovectomy, dislocation	Synovectomy + antibiotics	7	27	0	45.4	*C. acnes*	*C. acnes*	None
30	TSA	3	ORIF, dislocation	0	40	7	0	42.6	*C. acnes*	*C. acnes + S. epidermidis*	None
31	RTSA	3	TSA, RTSA	Synovectomy + antibiotics	1	12	0	4.6	*S. aureus*	*S. aureus + C. acnes*	Infection
32	TSA	1		0	>1	4	0	5.4	*S. lugdunensis*	*S. lugdunensis*	Died
33	RTSA	1		Glenoid spacer, synovectomy, antibiotics	>1		0	5.5	*C. acnes*	Sterile	None
34	RTSA	3	Arthroscopic rotator cuff repair, humeral osteotomy	0	>1	10	0	42.4	*C. acnes*	*C. acnes*	None
35	RTSA	1		0	140	8	1	16.6	*C. acnes*	*Staphylococcus saccharolyticus*	None
36	RTSA	1		0	>1		1	27.5	*C. acnes, S. aureus*	*C. acnes, S. aureus*	Dislocation
37	RTSA	1		0	52	8	1	8.5	No preoperative sample	*C. acnes*	None

CRP, C-reactive protein; *MR*, methicillin resistant; *MS*, methicillin sensitive; *ORIF*, open reduction internal fixation; *RTSA*, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty; *PSI*, periprosthetic shoulder infections, *C. acnes*, cutibacterium acnes.

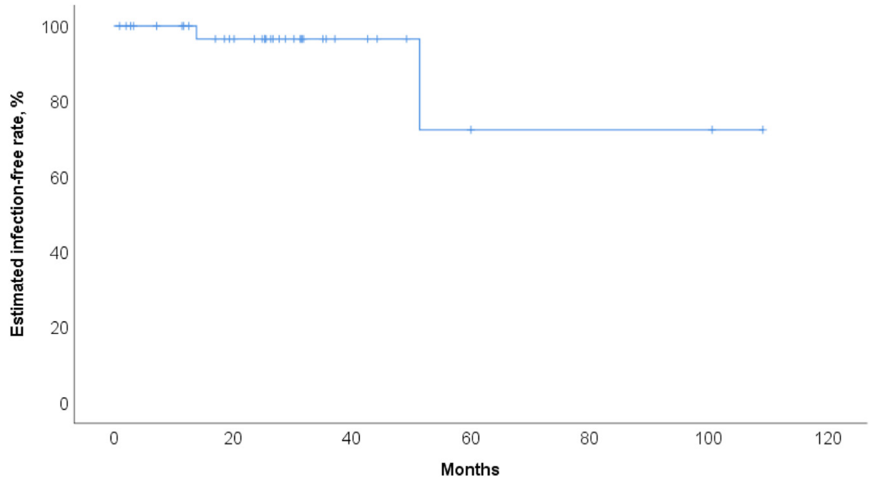

Figure 2 Kaplan-Meier curve of estimated cumulative probability of remaining reinfection-free after one-stage replacement arthroplasty for periprosthetic shoulder infection.

C. acnes was isolated from 25 (68%) patients' specimens; among them, 15 (40%) were monomicrobial infections; only 1 strain was clindamycin-resistant. Among 12 (32%) other patients' specimens that grew coagulase-negative staphylococci, 5 were monomicrobial and 7 were methicillin-resistant. Methicillin-susceptible *Staphylococcus aureus* and *Streptococcus* spp. were isolated from 4 and 3 patients, respectively. Patient 24 was infected with *Pseudomonas aeruginosa* (Table I).

Antibiotic therapy

Mean duration of total antibiotic therapy was 63 ± 22 days, which included IV administration lasting 28 ± 14 days. The most frequently prescribed initial IV antibiotic regimen combined vancomycin and clindamycin for 29 (78%) patients, based on the results of preoperative joint-aspirate cultures and the patients' histories and then adapted on the intraoperative cultures. When *C. acnes* infection was confirmed, treatment was continued with clindamycin (n = 10) or cefazoline monotherapy (n = 4) and susceptible *Staphylococcus* spp. isolated from 23 (62%) patients were treated with cefazoline and rifampicin. The most frequently prescribed oral regimens were clindamycin (n = 13), amoxicillin (n = 8), and levofloxacin combined with rifampicin (n = 6).

Functional outcomes and reinfection

After median follow-up of 26 (range 24-108) months, 35 (95%) patients had no clinical or radiographic signs of infection. The mean estimated probability of remaining reinfection-free at 2 years was 96.6% ± 0.03% (Fig. 2).

Two *C. acnes* relapses were recorded. The first occurred in patient 1 (Table I), a 64-year-old woman with no remarkable medical history, treated for *C. acnes*–*Peptostreptococcus magnus* PSI with clindamycin and rifampicin for 90 days (41 days IV); her PSI relapsed 4 years later. *C. acnes* was again isolated from that new episode. Indeed, the isolated *C. acnes* was not subjected to genotype identification to determine if it was the same. She underwent a second one-stage revision and received cefazoline and rifampicin for 3 months. Eight years later, she experienced a new PSI with *Staphylococcus epidermidis*, and again underwent one-stage revision and received antibiotics for 3 months; 26 months after the last surgery, she had no signs of infection.

The second relapse occurred in patient 31, a 59-year-old man with no other comorbidity (Table I); his PSI's samples grew *C. acnes* and methicillin-susceptible *S. aureus*. One year after one-stage exchange, *C. acnes* was isolated again. Treatment combined one-stage revision and 3 months of amoxicillin; 20 months after that last surgery he had no sign of infection.

Patients 12 and 32, respectively, died of infection-unrelated causes (cancer and respiratory failure) 23 months and 9 months post revision.

Functional outcomes are summarized in Table II. Compared to preoperative values, the mean postoperative Constant Score at 36 months improved by 29 points ($P < .001$), the increased mean active forward elevation by 45° ($P < .001$), mean abduction by 42° ($P < .001$) but not mean external rotation with only a 4° increase ($P = .73$).

The 15 patients with multiple prior operations on the involved shoulder before the index arthroplasty had a lower mean postoperative Constant Score but the difference was not significant (Table III). Their range of motion was also lower—but not significantly so—than the 22 patients without multiple previous interventions. A trend for greater forward elevation post intervention was found for the index arthroplasty group compared to patients with multiple surgeries ($P = .067$), and abduction also increased but not significantly.

Mechanical complications

Five patients experienced 6 (16%) mechanical events. Only 2 required reintervention. Three patients had 1 or 2 dislocation(s) of their reverse shoulder arthroplasties. Patient 1 suffered 2 dislocations 4 years after the last surgery that revealed a concomitant chronic infection (Table I). Patient 18's dislocation occurred 2 weeks after surgery; revision surgery consisted of hemiarthroplasty. Patient 16 had a dislocation but chose to be treated functionally; his last Constant Score was 30. Patient 14 had a periprosthetic fracture 1-year postsurgery and received conservative treatment; his last Constant Score was 70. Lastly, patient 18's humeral implant broke between the metaphysis and the stem after trauma 3 years after one-stage revision; it was well tolerated with a Constant Score of 50 and no revision surgery was undertaken.

Finally, 3 (8%) patients were reoperated with implant removal: 1 each for a mechanical event, an infection or a mixed event.

Table II
Functional status of the 37 prosthetic shoulders at admission and after prosthetic shoulder infection management with one-stage exchange arthroplasty.

Parameter	Before one-stage revision	At last follow-up after one-stage revision	*P* value
Constant Score (/100)	24 ± 15	53 ± 15	**.001**
Forward elevation (°) idem	60 ± 40	105 ± 42	**.001**
Abduction (°)	55 ± 36	97 ± 36	**.001**
External rotation (°)	11 ± 7	15 ± 21	.73

Results are expressed as mean ± standard deviation.
Bold values indicate statistical significance.

Table III
Functional status of the prosthetic shoulders at last follow-up following one-stage revision after multiple surgeries before arthroplasty vs. index arthroplasty.

Parameter	Multiple operations (n = 15)	Index arthroplasty (n = 22)	*P* value
Constant Score (/100)	48 ± 17	57 ± 12	.16
Increased forward elevation (°)	29	56	.067
Increased abduction (°)	30	50	.17
Increased external rotation (°)	2	5	.56

Results are expressed as mean ± standard deviation or the degrees of movement.

Discussion

PSIs are uncommon but their treatment remains a challenge. It is the most serious complication of the shoulder-arthroplasty procedure, causing pain, loss of function, and septicemia. PSI is the first cause of reoperation and is also the primary reason to perform exchange arthroplasty.

This prospective, cohort-extracted series of 37 patients treated with one-stage revision for chronic PSI had a low reinfection rate in 5% of patients. The most commonly isolated microorganism was *C. acnes* (68%), responsible for monobacterial (40%) or polymicrobial infection (28%). The Constant Score increased significantly by 29 points. Range of motion (forward elevation, abduction) was also significantly improved postsurgery.

Concerning periprosthetic infection of other joints, for example the hip, one-stage exchange arthroplasty obtained a good success rate, even when fistulizing.[23,35] Although two-stage exchange arthroplasty remains the gold standard, interest in one-stage exchange is rising. Maale et al's[22] review of one-stage revision of infected total joints established eradication rates comparable to those of two-stage revision (88% vs. 85%). Although different treatment options for PSIs have been described, a consensus about the best therapeutic strategy is still lacking.[9,32]

One-stage arthroplasty has been evaluated with promising results.[16] Its benefits include bone stock preservation, immediate reconstruction, less patient anxiety, and lower hospital costs.[17] Two-stage revisions can be high risk for patients unable to tolerate 2 major operations and anesthesia, and are associated with more physically debilitating complications, such as fibrosis, pain, and instability.[3,6]

Only a few studies compared efficacies of one- and two-stage exchanges in PSIs. Aïm et al's[2] recent systematic literature review and meta-analysis found that one-stage revisions seemed to provide better outcomes, with fewer reinfections, and complications than two-stage exchanges: reported reinfection rates ranged between 0 and 9.1%, with only one study describing 50% reinfections for one-stage exchange. For two-stage exchange, they found reinfection rates ranged between 3% and 40%. One-stage exchange seems to give better results than two-stage exchange, with 3-fold lower reinfection (7% [95% confidence interval (CI), 3.8-12.5%] vs. 21.3% [95% CI, 16-27.9%]) and almost 2-fold fewer complication rates (17% [95% CI, 11.9-23.9%] vs. 32/8% [95% CI, 25.8-40.6%]).

Mercurio et al[24] found that the pathogen-eradication rate was 96% with one-stage and 86% with two-stage revisions. Results from our prospective, cohort-extracted series suggest that one-stage exchanges are a reliable treatment with a low (5%) infection-recurrence rate.

Prerequisites for single-stage exchange are identification of a specific microorganism and determination of its antibiotic susceptibilities. *C. acnes* is a major inhabitant of adult human skin, where it resides within sebaceous follicles. The 68% *C. acnes* infection we found herein is >20% above reported rates.[1,24] That finding might be explained by our systematic search for *C. acnes* in every sample requiring prolonged culture. Hence, we cannot exclude that we might have treated some samples growing a nonpathogenic form of *C. acnes*.[10] Indeed, the isolated *C. acnes* was not subjected to genotype identification to determine its pathogenicity. Torrens et al[30] recently found that *C. acnes* was isolated in the deep layers of 18.8% of the patients undergoing primary reverse shoulder arthroplasty with antibiotic prophylaxis and standard chlorhexidine preoperative skin preparation. Positive cultures at the time of revision surgery may represent a true infection but may also be an unexpected contaminant of specimen procurement and culture incubation.[14] To avoid the risk of contaminating specimens during sampling and culture incubation, a strict method of tissue sampling was used.[33] Although a precise algorithm does not currently exist for PSI diagnosis, our patients' PSIs were diagnosed in the context of the overall clinical picture and not only the positive cultures.

Hsu et al[15] found single-stage revision to be effective for failed shoulder arthroplasty with *C. acnes* positive cultures. Among the 27 shoulders they studied that underwent arthroplasties and had positive cultures, none had a confirmed infection recurrence.

Functional outcomes seem to be better after one-stage revision than the two-stage procedure. Jacquot et al[16] found that patients with >1 surgical procedure had significantly poorer functional results. Their 6 patients who needed 2 successive procedures had significantly lower functional scores than the 26 patients who had undergone only 1 procedure (Constant Score, 36 vs. 49, respectively; $P = .04$). Furthermore, Mercurio et al[24] found that one-stage arthroplasty was the best treatment, considering postoperative flexion and abduction, compared with two-stage revision.

The overall functional outcomes of our cohort-extracted series were similar to those reported for one-stage revision.[2,17]

Patients with multiple previous operations seem to have worse functional outcomes than the subgroup without surgery before the index arthroplasty, even though the difference was not significant. Buchalter et al[6] reported similar results for their series of two-stage revisions for PSIs.

To our knowledge, no prospective analysis of one-stage revision for PSIs based on so many patients (n = 37) with long follow-up of functional scores has been published to date. However, one limitation of this study is that it was conducted in a single center with patients included over a long time period. A prospective comparative study between one- and two-stage exchanges is needed to confirm our findings.

Conclusion

The results of our prospective, cohort-extracted series suggest that one-stage revision is an effective strategy to eradicate PSI pathogens providing good functional outcomes. This strategy should now be considered as a first line treatment for chronic PSI.

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