Management of the infected shoulder prosthesis: a retrospective analysis and review of the literature

Patrick Weber · Sandra Utzschneider ·
Patrick Sadoghi · Hans-Joachim Andress ·
Volkmar Jansson · Peter E. Müller

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Abstract Experience with infected shoulder arthroplasty is limited. Treatment options are either one- or two-stage reimplantation, débridement with retention of the prosthesis, resection arthroplasty or arthrodesis. We retrospectively analysed ten patients with an infected shoulder prosthesis and evaluated the diagnostic and therapeutic management as well as the clinical outcome, assessed by the Constant score, Neer's criteria and the mean abduction ability. We identified an infecting organism before surgery in nine patients. Four patients were treated by two-stage exchange reimplantation, five by resection arthroplasty and one underwent serial débridement combined with vacuum-irrigation therapy. Infection was eradicated in all patients of this series. The mean Constant score in resected patients was 32.7, in patients treated by stage exchange 40.1 (no difference) and we measured 90 points in the patient with retention of the implant. In patients treated by resection arthroplasty, merely the mean abduction yielded a better result (63 vs 31°) than in patients treated by two-stage exchange—with the pain level being identical in both groups. Treatment of infected shoulder implants in patients who often have to deal with concomitant diseases remains unsatisfactory. Two-stage exchange procedures yielded only slightly better functional results than resection arthroplasty, which should be consid-

ered in cases of elderly or chronically ill patients because it offers good pain relief. Serial débridement combined with irrigation therapy is a new method which offers good clinical results, however with an unknown risk of persisting infection. The authors recommend isolating the infecting organism prior to surgery to allow the administration of organism-specific antibiotics as early as possible during surgery in order to efficiently eradicate the infection.

Introduction

In 1894 Jean Péan implanted the first shoulder prosthesis in a 37-year-old baker suffering from tuberculous arthritis. The implant was reasonably functional, but this was also the first case diagnosed for an infection and only two years later the prosthesis had to be removed [1, 2]. More than 110 years later, infection after shoulder arthroplasty is still a major complication with reported cases of between 1 and 4% in primary arthroplasty and even higher rates after revision surgery [3–6]. Diagnosis is not always easy and mostly consists of a combination of clinical symptoms, laboratory tests and radiological investigation such as conventional radiography, indium scans and microbiological swabs [7]. Increased susceptibility to infection is recorded in patients with diabetes mellitus, lupus erythematosus and rheumatoid arthritis. In addition, immunosuppressive chemotherapy, systemic steroid therapy, multiple steroid injections or previous operations of the affected shoulder were included among the causes for 66% of infections in shoulder arthroplasty [6, 8–10]. To our knowledge, there are few studies analysing the management of infected shoulder prostheses. Treatment options are one- or two-stage exchange, irrigation and débridement, resection arthroplasty, chronic suppression or even arthrodesis or amputation [4, 6, 11–22].

P. Weber · S. Utzschneider · P. Sadoghi · V. Jansson ·
P. E. Müller (✉)

Department of Orthopaedic Surgery, Campus Grosshadern,
Ludwig-Maximilians-University Munich,
Marchioninstr. 15,
81377 Munich, Germany
e-mail: peter.mueller@med.uni-muenchen.de

H.-J. Andress
Department of Trauma Surgery, Altperlach,
Schmidbauerstr. 44,
81737 Munich, Germany

The primary aim of this retrospective analysis was to evaluate, with respect to current literature, the diagnostic management, risk factors, therapy options and outcome following infected shoulder arthroplasty including its rate of failure. The second study aim was to compare of the outcome of resection arthroplasty versus two-stage exchange.

Materials and methods

Ten patients with the diagnosis of infected shoulder prosthesis were included in this study between 1998 and 2008. The aetiology of primary arthroplasty was osteoarthritis in three patients, a subcapital humeral fracture in another three (as a primary procedure), non-union or necrosis of the humeral head after fracture in yet another three and a chondrosarcoma in one patient. Initial implantations were total joint replacement in three patients, hemiarthroplasty in four, inverse prosthesis in two and isoelectric prosthesis in the one patient with the chondrosarcoma. In three patients the initial procedure was performed elsewhere. In one patient a periprosthetic fracture had to be treated after the initial surgery. One patient of our series had been treated previously by a two-stage exchange revision for infected shoulder prosthesis. In this patient we only evaluated the result of the treatment of the reinfection.

All patients had serious concomitant diseases such as malignant disease in two cases, a history of craniocerebral injury in three, severe alcohol abuse in two, dialysis in one, severe liver cirrhosis in one and one patient suffered from chronic polyarthritis.

In order to substantiate the clinical suspicion, confirmation of diagnosis was obtained by laboratory analysis and radiological examination with blood tests including C-reactive protein (CRP) and a white blood cell count (WBC). In patients with fistula, microbiological swabs were taken before the procedure and in other patients the joint itself was aspirated. In the case of remaining doubt about the infection, an indium-labelled white blood cell scan was performed.

Surgical therapy

In each case the therapy was individually based, depending on the local bony situation, the patient's age, their general medical condition and expectations and their compliance.

In five patients a resection arthroplasty was performed and in one of those five a cement spacer was implanted. This spacer had to be removed due to persisting infection and repeated dislocation. Finally a resection arthroplasty was performed. Four patients were treated by two-stage exchanges. In three of them an inverse prosthesis was

implanted and in one a hemiprosthesis. The earliest reimplantation of the prosthesis was performed after six weeks with normal parameters of CRP and WBC and the wound showing no signs of infection.

In one patient with an inverse prosthesis we performed a serial débridement with vacuum-irrigation therapy. Details of all patients and surgical procedures performed before the infection are reported in Table 1.

For the irrigation therapy we used the V.A.C. Instill® system (KCI, Amstelveen, The Netherlands). During the first intervention we changed the polyethylene insert and the irrigation system was inserted. The irrigation solution (sodium-saline) was pumped through one drain into a piece of foam which had been placed in the wound. On the other side of the foam the solution was pumped off the wound through two tubes with a negative pressure of 125 mmHg. By using this setting we facilitated an equal distribution of the instillation fluid in the infected wound combined with an intermittent removal of the used instillation fluid in order to support the cleaning and drainage of the wound bed and the removal of infectious material. The foam was exchanged every four to five days.

The changing of the foams continued until three consecutive negative microbiological swabs were obtained and afterwards the antibiotic treatment was continued for three more months. Five operations were needed before there were three negative swabs and the wound could be closed. The time range between the first and the last operation was 28 days.

No patient in this series was on antibiotics before surgery and every patient received, on the advice of our microbiologist, an organism-specific intravenous antibiotic immediately after the swabs were taken. Postoperatively, the antibiotics were given until CRP and WBC were in a normal range but at least for a time period of ten days.

At follow-up the patients were assessed with a focus on their range of motion (ROM) and their Constant score [23] and we used the Neer rating scale [24] for those patients who still had their prosthesis in situ. The results were graded as “excellent”, “satisfactory” or “unsatisfactory”. A result was graded as “unsatisfactory” if the criteria for satisfaction were not met or if the patient needed a further revision procedure. Any patient who required chronic antibiotic suppression was considered to be still infected and rated as “unsatisfactory”. All complications including re-operation were recorded and graded between 0 and 5 according to the classification of surgical complications proposed by Goslings and Gouma [25].

For the assessment of ROM and the Constant score we compared the patients treated with resection arthroplasty and those treated with two-stage exchange and considered the patient treated with irrigation therapy separately. A

Table 1 Demographic data and surgical details of the ten patients

Patient	Sex	Age	Side	Primary indication	Risk factors	Further surgeries or local problems before the infection	Procedure performed
1	M	52.9	2	Subcapital humerus fracture	Atrophy of the frontal lobe after severe craniocerebral injury	Periprosthetic fracture	Resection arthroplasty
2	M	57.6	2	Pseudarthrosis after subcapital humerus fracture	Chronic alcoholic	Lesion n. axillaris	Resection arthroplasty
3	F	33.0	2	Chondrosarcoma	Malignity	None	Resection arthroplasty
4	F	79.5	2	Subcapital humerus fracture	Subarachnoidal bleeding in PMH, chronic alcoholic	Large chronic fistula	Resection arthroplasty
5	F	89.1	2	Subcapital humerus fracture	Severe hypertension with cardiac insufficiency	None	Resection arthroplasty
6	M	50.2	2	Osteoarthritis	Spastic hemiparesis after severe craniocerebral injury	Two-stage exchange because of infection	Two-stage exchange
7	M	64.9	2	Osteoarthritis	Chronic alcoholic, chronic lymphatic leukaemia	None	Two-stage exchange
8	F	65.6	2	Necrosis of the humeral head after subcapital fracture	IDDM, renal failure requiring dialysis	None	Two-stage exchange
9	F	69.4	2	Necrosis of the humeral head after subcapital fracture	IDDM, liver cirrhosis	None	Two-stage exchange
10	F	68.9	1	Osteoarthritis	Chronic polyarthritis	None	Serial débridement, vacuum-irrigation therapy
M:F		63.1	9 left, 4:6	9 left, 1 right			

PMH perimesencephalic haemorrhage, IDDM insulin-dependent diabetes mellitus

follow up radiograph was performed. In cases of suspected possible reinfection in postoperative care, the CRP and WBC levels were analysed and, if found positive, joint aspiration was performed.

In addition, we reviewed related publications, which are summarised in Table 2.

Results

Demographic data

The mean patient age at revision was 63.1 years (33.0–89.1). There were four men and six women, one right and nine left shoulders (Table 1). The mean time span between the implantation and the treatment of the infection was 1.6 years (0.6–3.1).

Preoperative diagnostics

All patients presented to our outpatient clinic with pain and/or limited ROM. Three patients had a persisting fistula. Results of WBC were available for all patients and CRP levels were available for nine of the ten patients. The mean WBC was 8.5 g/l (4–12.8) and the mean CRP 2.2 mg/dl (0.5–4.1). CRP levels were elevated in all patients except the one with the elevated WBC levels. In four of ten

patients radiological loosening of the stem was suspected. In all patients the preoperative swab of the fistula or the aspiration of the joint showed a growth of microbes, except one whose indium-labelled white blood cell scan showed aseptic loosening. Intraoperatively, we evacuated pus and synovitis and the swabs turned out to be positive after the procedure.

Microbiological results

The intraoperative swabs of all patients showed positive cultures and were identical with the preoperative swabs. In four patients we found *Staphylococcus epidermidis*, in one of them combined with *Enterococcus faecalis*. In two patients the organism was *Propionibacterium* spp., in two *Staphylococcus aureus* (methicillin-sensitive) and in one case *Staphylococcus AUREUS* combined with *Streptococcus agalactiae*. In the remaining two patients *Enterococcus faecalis* was the cause of infection.

Clinical results

All patients were available for follow-up analysis during a mean period of 4.0 years (range: 1.2–10). At their last follow-up none of the patients showed any sign of infection, including the patient with the removed cement spacer.

Table 2 Overview of the treatment results of infected shoulder arthroplasties

Author/year	Number of patients	Therapy	Follow-up (years)	Number infection free (%)	Constant score	Neer ^a	ROM	Remarks
Braman et al. 2006 [33]	7	Resection arthroplasty	1.7 (1–3.5)	7 (100%)	-	7 unsatisf.	28° ABD, 8° ER	
Coste et al. 2004 [4]	42	Total	2.8	30 (71%)	38		74° ABD	
	5	Antibiotic therapy		2 (40%)	49			
	10	Resection arthroplasty		7 (70%)	30			
	8	Débridement		7 (88%)	27			
	3	One-stage exchange		3 (100%)	66			
	10	Two-stage exchange		6 (60%)	35			
	3	Spacer		3 (100%)	38			
	3	Other		2 (67%)	45			
Cuff et al. 2008 [19]	22 (17 infected arthroplasties)	10 one-stage, 12 two-stage exchange		17 (100%)	-		75° ABD, 25° ER	Postop. results are not differing between arthroplasties and infections in joints without prosthesis and are not differing between one- and two-stage exchange
Ince et al. 2005 [12]	9	One-stage exchange	5.7	9 (100%)	33			
Jerosch and Schneppenheim 2003 [13]	12		(0.5–2.5)	12 (100%)	48			
	2	Débridement		2 (100%)				
	8	Two-stage exchange		8 (100%)				
	2	Spacer		2 (100%)				
Mileti et al. 2004 [21]	4	Two-stage exchange after prolonged spacer	7.4	4 (100%)		2 satisf., 2 unsatisf.	80° ABD, 50° ER	
Rispoli et al. 2007 [15]	18 (13 infected arthroplasties)	Resection arthroplasty	8.3	13 (100%)		2 satisf., 16 unsatisf.	70° ABD, 31° ER	Postop. results are not differing between arthroplasties and infections in joints without prosthesis and are not differing between one- and two-stage exchange
Seitz and Damacen 2002 [17]	8 (5 infected arthroplasties)	Two-stage exchange	4.8	5 (100%)			ABD 48% of contralat. side, ER 55%	
Sperling et al. 2001 [6]	32	Total						
	21	Resection arthroplasty	6.5	15 (71%)			70° ABD, 31° ER	
	6	Débridement	8.3	3 (50%)		1 satisf., 2 unsatisf.		3 patients with reinfection had resection arthroplasty

	2	One-stage exchange	10	1 (50%)	180° ABD, 30° ER
	3	Two-stage exchange	4.8	3 (100%)	180° ABD, 30° ER
Strickland et al. 2008 [18]	19	Two-stage exchange	2.9 (2–6.7)	12 (63%)	89° ABD, 30° ER
Themistocleous et al. 2008 [22]	11 (4 infected arthroplasties)	Permanent spacer	-	4 (100%)	75° ABD, 25° ER
Total	164		4.58	135 (82%)	77.5° ABD, 28.4° ER
Antibiotic therapy	5			2 (40%)	
Resection arthroplasty	51		5.6	42 (82%)	62° ABD, 27° ER
Debridement	16		5.1	12 (75%)	
One-stage exchange	14		5.7	13 (92%)	180° ABD, 30° ER
Two-stage exchange	61		3.7	40 (80%)	92° ABD, 31° ER
Spacer	9		(2.8)	9 (100%)	75° ABD, 25° ER
Other	3			2 (67%)	

The mean results for each therapy are given under the total. The mean was only calculated for the patients for whom data were available

ABD abduction, ER external rotation

^a Neer's criteria are the following grades: excellent, satisfactory, unsatisfactory

The mean Constant score for the patients with removal or exchange of the prosthesis (nine patients) was 36 points (23–58). The patient with irrigation therapy had a Constant score of 90 points, an abduction of 130° and an “excellent” result according to Neer's criteria. More specific evaluation showed a mean value of 32.7 (23–40) in the patients with resection and 40.1 (26.5–58) in the patients with the exchange. Unsurprisingly, due to the small number of patients, this difference was not statistically significant ($p=0.25$, exact Mann-Whitney U test). More accurate analyses of the item “pain” of the Constant score (which can reach a maximum of 15 points in a pain-free patient) showed a mean value of 10 points in both groups. The mean abduction of the nine patients was 49.5°, with 31° in the resected patients group and 63° in the exchange patients group. Two patients of the exchange group were rated “satisfactory” and another two of the same group “unsatisfactory” according to the Neer criteria (Table 3). The radiological follow-up showed no signs of loosening in the patients with implants (Fig. 1). In the patients with resection arthroplasty we found proximal migration of the humerus (Fig. 2).

Independent of the surgical procedure performed, there was no correlation between clinical outcome and the initial diagnosis. The three patients who had an initial arthroplasty performed for osteoarthritis had a mean Constant score of 42.1, the three with a fracture scored 37.5 points and the three with necrosis of the humeral head after fixation of a fracture scored 41 points.

Complications

We found a postoperative paralysis of the radial nerve in one patient, and revision showed only partial improvement (grade 3 severity according to Goslings and Gouma). The patient with the cement spacer had to be revised two years after the procedure because of spacer dislocation and persisting infection. After removal of the spacer he showed no more signs of infection and the function had not worsened (grade 2). In one patient a spiral fracture of the humerus occurred during reimplantation which was treated with a longer stem and wire cerclages. The further course of this patient continued without complications (grade 2). In summary, according to the rating of Goslings and Gouma, we had one grade 3 and two grade 2 surgical complications [25].

Discussion

The infected shoulder prosthesis is a devastating complication. As experience of this condition is not as wide as with infected knee or hip implants, there is still a lack of consensus about the diagnostic and therapeutic strategies [24, 26–28].

Table 3 Clinical details and results (Constant score, active abduction, Neer's criteria)

	Stage exchange (4 patients)	Irrigation therapy (1 patient)	Resection arthroplasty (5 patients)	All patients
Constant score	40.1 (26.5–57)	61	32.7 (23–40)	38.5
Abduction	62° (30–100°)	90°	31° (20–50°)	49.5°
Neer's criteria	2 satisfactory, 2 unsatisfactory	Satisfactory	None	

Risk factors

Patients with major risk factors are prone to acquiring an infection after joint arthroplasty [6, 10]. In a study presented by Topolski et al. half of the patients had risk factors [7], whereas in our study all patients suffered from serious concomitant diseases. This is one of the reasons for the complex management of these patients. However, it also

seems that healthy patients are not as likely to develop an infection after total shoulder arthroplasty as those with pre-existing risk factors.

Diagnostic management

An infected implant is difficult to diagnose as symptoms may be minimal. Therefore, after shoulder arthroplasty

Fig. 1 **a, b** Anteroposterior (AP) and lateral views of the infected shoulder prosthesis with signs of loosening at the stem. **c** After resection and temporary implantation of a cement spacer. **d, e** AP and lateral views after reimplantation of an inverse prosthesis

Fig. 2 **a, b** Radiographs of the infected shoulder prosthesis.
c After resection arthroplasty

every painful shoulder joint should be considered as potentially infected, so immediate detailed diagnostic investigation is mandatory. In the literature the CRP level in infected implants is often increased whereas the WBC count is not, which is in line with our findings [19]. Not every infected patient shows radiological signs of implant loosening. In cases of suspected infection and positive results after joint aspiration, we performed no further investigation and concluded that the implant was definitely infected. In one case we performed an indium-labelled white blood cell scan which was negative. However, during surgery we found clear signs of infection which tends to prove the limited value of this diagnostic tool due to the rather limited experience with infected shoulder arthroplasties as demonstrated in a previous study by Strickland et al. [18].

In our study all swabs taken intraoperatively turned out to be positive after the surgical procedure, which is not in line with previous studies published in the literature [4, 13, 18], where only a small percentage of all swabs showed positive growth [12, 19]. Our organism spectrum was similar to the findings in most other studies, with *Propionibacterium* spp. and *Staphylococcus epidermidis* being the most common bacteria [7, 10, 12, 18, 29]. *Propionibacterium* is an agent frequently encountered in infected shoulder arthroplasties but only rarely seen in knee or hip infections.

We believe that a thorough preoperative investigation is mandatory to reach a definitive diagnosis of infection. Joint aspirations in particular are important, but here it is essential to stop the antibiotic treatment at least 14 days prior to the aspiration [30]. As most of the patients with an infected implant do not have a systemic infection, sufficient time should be spent on diagnostics since an infected implant which is treated as non-infected and vice versa can have serious consequences.

Therapeutic options

Débridement in combination with prosthetic retention has a high risk of subsequent persisting infection and is therefore usually only recommended in patients with an acute infection [6, 16]. Up to now, vacuum-irrigation therapy combining the irrigation and draining of the wound by means of a solution through intermittent application of negative pressure has only been described for periprosthetic knee or hip infections [31, 32]. In our patient the infection did not return after this treatment and the clinical outcome was encouraging, nevertheless five operations were needed in total. As the types of infecting bacteria were known before surgery, an organism-specific treatment could be started.

In the field of infected hip and knee implants, most experience is with two-stage exchange and therefore this is considered the standard procedure [26, 27]. With infected shoulder implants, most of the cases reported in the literature were treated with this procedure (Table 2). By using this treatment we achieved an eradication of the infection in all our patients but our clinical results were unsatisfactory, with a mean Constant score of 40 points. Our findings are in line with the majority of studies where an eradication of the infection is described [4, 13, 18]. The two-stage exchange seems to be the procedure which best compromises between reliable eradication of the infection and limited function after surgery. The one-stage exchange promises better functional results but bears a higher risk of persistent infection: only the findings by Ince et al. show sufficient eradication of infection after this treatment option [4, 6, 12].

Resection arthroplasty is often regarded as a type of last resort procedure after all other options have failed. The

Constant score results in our patients were worse than in the patients with reimplanted prosthesis because of the different functional outcome and strength only; there was no difference between the two groups concerning “pain”. This is consistent with the literature [4, 14, 15, 33]. Eradication of the infection was finally achieved in all patients as described in most other studies [4, 14, 15, 33]. In our opinion, in elderly and chronically ill patients resection arthroplasty should not just be regarded as a very last resort; it offers an option to eradicate infection with only one surgical procedure, promising good pain relief in patients, with the only disadvantage of limited function. In contrast to the hip or knee joints, the shoulder joint does not sustain an axial load. This is probably the reason why the results of resection arthroplasty and two-stage exchange in shoulder arthroplasty differ less unlike those of hip arthroplasty in the matter of the Girdlestone situation. However, elbow and wrist function should still be intact.

In two studies, which both included more patients than ours, persistent infection was reported in between 37 and 40% of the patients [4, 18]. In these studies, the infecting organism was only known before surgery in a few patients. Finally, in our own results we achieved an eradication of the infection in all our patients as did Ince et al. [12]. Their procedure was in line with ours, as a preoperative aspiration was performed and the infecting organism was known before surgery, which permitted the possibility to start an organism-specific antibiotic treatment during surgery, following it up with another lavage immediately afterwards. Since all our patients were thoroughly tested for infection prior to surgery, we have no control group to prove our theory. We nevertheless strongly maintain that the immediate organism-specific antibiotic treatment was a decisive factor for the definite decrease of infection rates reported by Ince et al. [12] and which we also found in our study.

This study has, however, some limitations. First, the small number of patients lessens the value of our conclusions. Second, the patient groups are not homogeneous. Nevertheless these shortcomings are also encountered in comparable, yet already published studies (Table 2).

Conclusion

All our patients suffered from serious concomitant diseases which constitute a major risk factor for infection in shoulder arthroplasty, even more than in hip or knee arthroplasties.

Sufficient time for diagnostics should be spent on every patient with a painful shoulder or a limited range of motion in order to rule out a possible infection. Preoperative aspiration should be performed to isolate the infecting

bacteria so that specific antibiotic treatment can be started immediately. Serial débridement with vacuum-irrigation therapy is a new treatment option in infected shoulder arthroplasty, promising the best results, however with a potential risk of persistent infection. In this study, with a limited number of patients, the two-stage exchange did not yield better results than the resection arthroplasty. Its value for elderly or chronically ill patients should nevertheless not be underestimated, because its pain relief results are comparable with those of the two-stage exchange while the procedure is faster and less exhausting for the patients.

Conflict of interest None.

Level of evidence Level IV.

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