Treatment Solutions Are Unclear for Perimegaprosthetic Infections

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Abstract

Background Infection about a megaprosthesis is a dreaded complication. Treatment options vary from débridement alone to staged revisions, arthrodesis, and amputation. Indications for how to treat this complication are unclear.

Questions/purposes We therefore determined (1) the incidence of perimegaprosthetic infections, (2) the methods of treatment, (3) the number of patients who failed their original treatment plan, and (4) the characteristics of the infection.

Methods We retrospectively identified 291 patients who had megaprotheses implanted between 2001 and 2011 and identified all those surgically treated for a perimegaprosthetic infection during that time. We defined a treatment

failure as any unplanned reoperation or death due to uncontrolled infection. All patients with failure had a minimum followup of 1 year (mean, 3.3 years; range, 1–8 years).

Results Of the 291 patients, 31 (11%) had subsequent infections. Surgical management varied among irrigation and débridement ($n = 15$), single-stage revisions ($n = 11$), two-stage revisions ($n = 4$), and amputations ($n = 1$). Sixteen patients failed their original treatment plan: 13 required additional surgery and three died. Infections were mostly chronic and single organism with five being methicillin-resistant *Staphylococcus aureus*.

Conclusions An 11% incidence of perimegaprosthetic infections is consistent with the increased risk of infection seen in other studies. A variety of surgical methods were employed at our institution and by those contributing to the literature without clear evidence of superiority of one method over another. Given the complicated medical and surgical histories of these patients, individualization in decision making is necessary.

Level of Evidence Level III, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

The use of megaprotheses for both oncologic and nononcologic indications continues to grow. While infection is a dreaded complication in any arthroplasty, it is an even more difficult situation in patients with megaprotheses, creating difficult treatment decisions. Infection rates in patients with megaprotheses have been quite high yet variable, with studies ranging in rates from 3% to greater than 30% [4, 8–11, 18–20, 26, 33, 36] and even as high as

43% in revised, previously infected patients with megaprotheses [2]. Studies performed in patients with standard arthroplasty have identified many possible, sometimes conflicting, and site-specific risk factors for developing periprosthetic infections, such as increased BMI, male and female sex, American Society of Anesthesiologists status of greater than 3, diabetes, bilateral THAs in the same operative setting, revision surgery, systemic steroid use, and surgical site drainage [27, 31, 34, 35], which may be reasonably extended to infections about a megaprosthetic implant.

Prophylactic methods, such as the use of a drain tube in standard knee arthroplasties [31], the use of appropriately timed preoperative or periprocedural (ie, dental) antibiotics [22, 35], preoperative screening and decolonization of nasal *Staphylococcus aureus* [32], or improved soft tissue coverage strategies (eg, gastrocnemius flaps for proximal tibial implants) [3, 14], reportedly reduce the risk of infection. Implant characteristics may also play a role. Silver-coated megaprotheses, when compared to uncoated titanium implants, reportedly have decreased infection rates [17] and silver appears to not produce toxic effects in rabbits [12] or humans [15]. Gosheger et al. [11] reviewed 197 patients with megaprotheses and those with cobalt-chrome implants had more infections than those with titanium implants. Thus, while a concerted effort to prevent periprosthetic infection is underway, this complication remains a major problem. A general consensus on the best way to manage these infections when they do occur is lacking. Multiple treatment strategies have been reported, including one- and two-stage revisions of the implants, irrigation and débridement with retention of hardware, resection arthroplasty with bracing, arthrodesis, and amputation, all with varying levels of success [9, 13, 16, 19, 21, 28, 36, 37].

Given the relative rarity of indications for megaprotheses, currently reported series [6, 7, 9, 13, 16, 17, 19, 21, 37] of perimegaprosthetic infections are small, ranging from case reports of one to a retrospective review of 66 patients. However, the heterogeneity inherent in these cases makes comparisons difficult and there is always some degree of individualization in choice of treatment. Since these patients typically have complex problems, identification of factors associated with failure is important and perhaps key to determining treatment algorithms. Determining which patients will benefit from the protracted and more aggressive two-stage revision versus those that can be managed more conservatively or should undergo ablation at the outset would benefit surgeon and patient alike.

We therefore determined (1) the incidence of perimegaprosthetic infections, (2) the methods of treatment, (3) the number of patients who failed their original treatment plan, and (4) the characteristics of the infection.

Patients and Methods

From an institutional database, we identified 291 patients who had megaprotheses implanted for both oncologic and nononcologic indications from 2001 to 2011. Within that group, 40 patients were identified and treated for infections about their megaprotheses. A patient with a perimegaprosthetic infection was defined as someone who had a culture-proven infection or culture-negative infection that met clinical criteria for infection of his or her prosthesis (fever, elevated inflammatory markers, pain, abnormal fluid, or periprosthetic abscess) [27, 29, 30]. For this study, we excluded nine patients who (1) had infections treated only medically, (2) had a followup of less than 1 year postoperatively, (3) had infected pelvic and saddle implants, or (4) were lost to followup. These exclusions left 31 patients (Table 1). There were 20 women and 11 men. The minimum followup was 1 year (mean, 3.3 years; range, 1–8 years). No patients were recalled specifically for this study; all data were obtained from medical records. From the records, we extracted information related to the host factors, the infection, and the treatment (Table 2).

All patients were treated with culture-driven, antibiotic therapy in addition to surgical management. Culture-negative patients were treated with the (presumed) most appropriate antibiotic therapies, as deemed by the infectious disease specialist. Postoperative protocols, including such variables as drainage tubes, weightbearing, and motion allowance, varied according to surgeon preference. Data on erythrocyte sedimentation rate and C-reactive protein were missing for 14 and 13 patients, respectively, and were therefore difficult to evaluate given the large proportion of missing data points. Complete data on BMI and white blood cell count at the time of infection were missing for two patients each and operative times were missing for eight patients (index reconstruction surgery) and four patients (infection surgery) due to incomplete charting or records. Treatment failure was defined as an unplanned reoperation due to infection after his or her initial surgical management of this infection or a death related to the infection.

Results

With 31 of 291 patients with megaprotheses undergoing surgical management for infection, the incidence at our institution was therefore 11%.

Treatment strategies greatly varied, with most patients undergoing either single ($n = 7$) or multiple ($n = 8$) irrigation and débridements with retention of hardware or single-stage revisions ($n = 11$). Four patients underwent a two-stage revision and one underwent a primary amputation

Table 1. Patient demographics with time to infection from implant placement and infecting organism(s)

Patient	Age (years)	Sex	Diagnosis	Implant	Time to Infection (months)	Organism
1	43	Female	RA	Total femur	0.75	MSSA
2	80	Male	Periprosthetic fracture	PFA	36	MRSA
3	67	Male	Periprosthetic fracture	PFA	2	<i>Klebsiella</i>
4	56	Female	Metastatic breast cancer	PFA	44	Culture negative
5	77	Female	Periprosthetic fracture	PTA	0.75	CNS, <i>Proteus mirabilis</i> , <i>Serratia</i> , <i>Enterococcus</i> , Diphtheroids
6	74	Female	Periprosthetic fracture	Total humerus and proximal ulna	34	MRSA
7	25	Male	Osteosarcoma	DFA	5	MSSA, <i>Escherichia coli</i> , <i>Enterococcus</i> , <i>Bacillus</i> , CNS
8	63	Male	Radiated bone nonunion	PFA	34	<i>Clostridium</i>
9	78	Male	Failed THA	PFA	1	<i>Enterococcus</i>
10	93	Female	Periprosthetic fracture	PFA	36	MSSA
11	50	Female	Periprosthetic fracture	DFA	54	CNS
12	77	Female	Periprosthetic fracture	DFA	0.5	<i>Candida</i>
13	47	Male	Trauma	PTA	7	MSSA
14	75	Female	Trauma	DFA	13	MRSA
15	51	Female	Chondrosarcoma	PFA	29	Culture negative
16	63	Male	Failed TKA	DFA	17	<i>Candida</i>
17	48	Female	RA	DFA	1	<i>E coli</i> , <i>Actinomyces</i>
18	79	Male	Path fracture (Paget's disease)	PFA	5	<i>Pseudomonas</i> , Diphtheroids, <i>Citrobacter</i>
19	85	Female	Periprosthetic fracture	Total femur	2	VRE, <i>Pseudomonas</i> , <i>Klebsiella</i> , <i>Proteus</i>
20	68	Female	Osteosarcoma	PFA	48	<i>Streptococcus agalactiae</i>
21	75	Female	Trauma with nonunion	PFA	0.5	<i>Acinetobacter</i> , MSSA
22	73	Female	Failed THA	PFA	0.75	MRSA
23	80	Female	Osteosarcoma	DFA	4	MSSA
24	72	Male	Chondrosarcoma	Total humerus and hinged elbow	1	MRSA
25	27	Female	Trauma with nonunion	DFA	58	<i>Staphylococcus lugdenensis</i>
26	54	Female	Osteosarcoma	Total femur	0.5	MSSA, <i>Pseudomonas</i> , <i>Enterococcus</i>
27	45	Male	Metastatic renal cell cancer	PTA	1.5	CNS
28	10	Female	Osteosarcoma	DFA	20	Culture negative
29	15	Female	Osteosarcoma	DFA	48	MSSA
30	61	Male	Trauma	DFA	95	<i>E coli</i>
31	77	Female	Periprosthetic fracture	DFA	4.75	<i>Pseudomonas</i> , <i>Proteus</i>

RA = rheumatoid arthritis; PFA = proximal femoral arthroplasty; PTA = proximal tibial arthroplasty; DFA = distal femoral arthroplasty; MSSA = methicillin-sensitive *Staphylococcus aureus*; MRSA = methicillin-resistant *Staphylococcus aureus*; CNS = coagulase-negative *Staphylococcus*; VRE = vancomycin-resistant *Enterococcus*.

for treatment of infection. All patients were simultaneously treated with culture-driven antibiotics or, in the case of negative cultures, those antibiotics deemed appropriate by the infectious disease specialist.

Sixteen of the 31 patients subsequently had treatment failures, with three deaths and 13 patients requiring

additional unplanned surgical procedures. The remaining 15 of the 31 patients required no further surgical intervention after they completed their original treatment plan and there were no deaths within this group (Table 2). In the irrigation and débridement and single-stage revision combined group, most patients had a treatment failure

Table 2. Comparison of variables between the treatment success and treatment failure groups

Variable	Number of patients		
	Total	Treatment failure	Treatment success
Component			
PFA	11	7	4
DFA	12	6	6
PTA	3	2	1
Total femur	3	0	3
Total humerus	2	1	1
Diagnosis			
Cancer/pathologic fracture	12	5	7
Trauma/periprosthetic fracture	14	14	6
RA	2	1	1
Failed arthroplasty	3	2	1
Organism			
MRSA	5	3	2
Polymicrobial	8	5	3
Fungal	2	1	1
Single organism	13	6	7
Negative culture	3	1	2
Surgical treatment method			
Irrigation and débridement(s)	15	9	6
Single-stage revision	11	6	5
Two-stage revision	4	1	3
Amputation	1	0	1
Wound vacuum			
No	23	12	11
Yes	8	4	4
Chronic oral antibiotic suppression			
No	21	10	11
Yes	10	6	4
Diabetes			
No	19	11	8
Yes	12	5	7
Autoimmune disease			
No	19	10	9
Yes	12	6	6
Vasculopathy			
No	27	13	14
Yes	4	3	1
Renal disease			
No	26	12	14
Yes	5	4	1
Active cancer			
No	21	10	11
Yes	10	6	4
Charlson Comorbidity Index			
0–2 points	17	9	8
≥ 3 points	14	7	7

Table 2. continued

Variable	Number of patients		
	Total	Treatment failure	Treatment success
BMI			
< 18.5	2	0	1
18.5–25	4	3	1
25.1–30	4	3	1
> 30	19	8	11
Age at infection			
< 65 years	15	5	10
≥ 65 years	16	11	5
Time to infection			
Acute (< 1 month)	9	5	4
Subacute (1–6 months)	7	5	2
Chronic (> 6 months)	15	6	9
Operative time for implant			
< 2 hours	0	0	0
2–4 hours	14	7	7
> 4 hours	9	4	5
Operative time for infection surgery			
< 2 hours	21	9	12
2–4 hours	4	3	1
> 4 hours	1	0	1
Prior joint infection			
No	26	12	14
Yes	5	4	1
Tobacco use			
No	27	14	13
Yes	4	2	2
Immunosuppressive use			
No	26	13	13
Yes	5	3	2

PFA = proximal femoral arthroplasty; DFA = distal femoral arthroplasty; PTA = proximal tibial arthroplasty; RA = rheumatoid arthritis; MRSA = methicillin-resistant *Staphylococcus aureus*.

(15 failures versus 11 cleared infection). Within the irrigation and débridement only group, those who had multiple débridements, defined as more than one trip to the operating room for formal irrigation and débridement, had fewer failures than those who had only a single débridement (38% of the multiply débrided versus 86% of the singly débrided). Forty-six percent of the patients with single-stage revision failed while only 25% of the patients with two-stage revision failed. Finally, the one patient who underwent a primary amputation as treatment for infection went on to clear infection and required no further surgical intervention. Of the five patients with prior infections after arthroplasty, four patients had treatment failures requiring

further interventions. Of those four, three patients eventually underwent amputations.

Eleven of 17 patients 65 years or older experienced treatment failure while five of 14 patients younger than 65 years experienced failure. Of the 11 patients 65 years or older who failed, three died and eight required unplanned reoperations for uncontrolled infections. Five of those reoperations were amputations that ultimately resulted in the eradication of the infections.

Most patients had single-organism infections, and there were five infections with methicillin-resistant *S aureus* (Table 1). Three patients had negative cultures despite clinical evidence of infections. Nine patients' infections presented acutely, less than 1 month after megaprosthesis index surgery. Seven patients had a subacute presentation (1–6 months), and 15 presented chronically (> 6 months after megaprosthesis reconstruction).

Discussion

There is a growing use of megaprotheses in orthopaedics and a high risk of complications with these implants. One of the complications, as demonstrated in many series [6, 7, 9, 11, 13, 14, 16, 17, 19, 21, 25, 37], is the increased risk of infection. Most reports on this are relatively small in number with substantial heterogeneity. The variation in the patient population cannot be understated. They range from pediatric to elderly, with numerous different combinations of comorbidities and surgical histories. We therefore determined (1) the incidence of perimegaprosthesis infections, (2) the methods of treatment, (3) the number of patient who failed their original treatment plan, and (4) the characteristics of the infection.

This study has a number of limitations. First, despite being one of the larger series on perimegaprosthesis infection in the literature, the numbers remained small, particularly when divided into subgroups. Thus, it is not possible to determine factors associated with failure. Second, the patient population and treatment methods were heterogeneous. This made direct comparisons between treatments impossible and precluded the ability to perform a statistical analysis. Third, the key outcome measure, a treatment failure as defined by an unplanned reoperation or death due to infection, was also heterogeneous, as patients had varied types and degrees of failures. A failure, as defined here, ranged from an additional débridement to the requirement of amputation or death, representing a large morbidity spectrum such that one failure was not equal to another. Fourth, not all data on every patient were collected due to missing items in the electronic and paper records. In particular, a more complete laboratory value profile would have supported diagnoses; however, as pointed out by

multiple authors, clinical judgment after evaluating the entire clinical picture is essential when treating periprosthetic joint infections [27, 29, 30]. Finally, a retrospective review introduces several forms of bias into any study with its inherent heterogeneity and lack of control or randomization. Despite all of these limitations, we do believe contributing to and reviewing the available literature on this topic develops an increased understanding of this clinical scenario, which is important for improving study and patient care.

Our incidence of infection of 11% is consistent with 3% to greater than 30% in reported series [4, 8–11, 18–20, 26, 33, 36]. The available studies that specifically describe their respective treatment methods and findings on series of perimegaprosthesis infection were compared (Table 3). Consistent with these studies, we found higher infection rates in this population than in standard arthroplasties [27, 31, 34, 35]. Many of these patients have a history of radiated tissue, large prostheses with inadequate or marginal soft tissue coverage, and a history of multiple surgeries and revisions, which have frequently been cited as important factors associated with clearing infection [9, 13, 16]. Additional possible risk factors include longer operative times and larger exposures [14]. It appears unresolved as to whether undergoing chemotherapy is a risk factor for both acquiring these periprosthetic joint infections and for being able to clear them [24]. Donati et al. [6, 7] stated obvious signs of infection may be delayed until the end of a chemotherapy course and thus might mask identification of an infection. Hardes et al. [16] noted irradiated tissue is more likely to fail but found no difference with chemotherapy. They and other authors agree the state of the surrounding soft tissue is among the most important factors [9, 13, 16].

A number of operative management strategies have been described, including irrigation and débridement without revision of the prosthesis, one-stage revision of the prosthesis (primary exchange arthroplasty), two-stage revision of the prosthesis with a cement/antibiotic spacer, resection arthroplasty, arthrodesis, and amputation [2, 8, 9, 13, 19, 28, 33]. All of these methods have proven effective in some situations and failed in others (Table 3). Until indications for treatment are delineated, it will remain imperative that discussion with patient and family and proper individualization to the unique clinical picture are performed in accordance with the surgeon's judgment.

Half of our patients had a treatment failure, requiring unplanned reoperations, longer hospital stays, or in three cases, sustained deaths. Those 65 years and older were more likely to fail and accounted for all deaths. The four of five patients with prior joint infection who failed required high-level amputations and one required repeat débridements with chronic wound vacuum-assisted closure therapies and

Table 3. Comparison of studies in the literature describing perimegaprosthetic infection

Study	Infection rate	Surgical treatment	Surgical notes	Findings	Followup (months)*	Authors' conclusions
Flint et al. [9]	9%	11 two-stage revisions 4 amputations	6 revised without removal of well-fixed diaphyseal anchorage piece	8/11 revisions infection free at mean 33 months 3 revisions had infection recurrences 6/7 with infection less than 6 months after reconstruction had infection eradicated 2/8 with infection greater than 6 months after reconstruction had infection eradicated	42.4 (3–150)	Two-stage revision with retention of well-ingrown stem can lead to successful infection eradication Well-ingrown stem may act as barrier to infection spread Infection in previously irradiated bone impossible to eradicate Functional scores in patients with treated infection equivalent to other patients with noninfected megaprotheses
Holzer et al. [19]	6%	18 one-stage revisions	Anchorage components all well fixed, no infection in medullary canal	Infection eradicated in 14/18 78% success rate at 6 months	52 (18–135)	One-stage revision without anchorage part exchange justified in presence of infection with antibiotic-sensitive organisms
Hardes et al. [17]	Uncoated titanium implants: 18% Silver-coated implants: 6%	Titanium: 4 amputations, 1 rotationplasty, 6 two-stage revisions Silver: 1 single-stage revision	In silver-coated implants, singly surgically treated patient required only a exchange of prosthetic body without removal of stems	Infection rate substantially reduced with silver-coated implants Mutilating procedures (amputation, rotationplasty) unnecessary as treatment in silver-coated group	Titanium: unknown Silver: 21	Silver-coated megaprotheses reduce infection rate in the medium term Less aggressive surgery is necessary for silver-coated implants with infection
Grimer et al. [13]	34 patients (rate not disclosed)	36 two-stage revisions	All components removed, antibiotic cement spacer with Kuntscher nail minimum 6 weeks (mean, 10 weeks) before reimplantation (all components were cemented in bone)	24 had infection eradicated 2 required amputation 2 required repeat two-stage revisions 6 had late recurrence of infection (11–92 months) Overall infection control rate: 94% at 6 months, 91% at 1 year, 74% at 5 years, 65% at 10 years Only 1/7 with reinfection had infection eradicated (4 had amputations)	6–116	Two-stage revisions of massive endoprostheses are almost as effective at controlling infection as in conventional arthroplasties, particularly if additional surgical interventions are avoided and in nonirradiated bone There may be a role for one-stage revisions or not removing entire prosthesis in noncemented implants with solid bone-implant interface

Table 3. continued

Study	Infection rate	Surgical treatment	Surgical notes	Findings	Followup (months)*	Authors' conclusions
Donati and Biscaglia [6]	35 patients (rate not disclosed)	25 débridement, variable explants, gentamicin-PMMA beads 10 two-stage revisions with variable removal of implant, antibiotic cement spacer	Débridement only group underwent exchange of beads as deemed appropriate based on response Cement spacer group had impregnated gentamicin (1), vancomycin (7), cefamandole (2)	Gentamicin beads group: 19 healed (76%) Cement spacer group: 9 healed (90%)	Gentamicin beads group: 96 (24–169) Cement spacer group: 40 (22–84)	Antibiotic-impregnated cement spacers have been shown to be more effective in the rate and time of healing, frequency of repeated surgery, and functional results, as compared with PMMA beads In late infection, removal of implant and high local concentration of antibiotic are needed
Donati et al. [7]	11%	Surgical débridement (18) Surgical débridement + plastic surgery (7) Surgical débridement + gentamicin beads (9) Surgical débridement + local irrigation (32)		56 healed (85%), 10 remained infected Only 22 (39.5%) healed with first treatment 34 cases healed after different/combined procedures (maximum 8 operations, mean 2.6) 14 (25%) had amputations Removal of implant necessary in 24 Successful in 21, 5 were reimplanted Those healed had excellent to good functional MSTs scores	46 (2–109)	Obvious signs of infection may be delayed until end of chemotherapy course First choice of treatment is surgical débridement with local irrigation, though beginning to perform more two-stage revisions Must perform early and aggressive débridement Primary healing only possible in 1/3 of patients, with the rest requiring longer course with different treatments and high amputation rate (especially MRSA infections)
Yoshida et al. [37]	Case report: exposed, MRSA-infected hip endoprosthesis	Débridement, TNP and irrigation, and myocutaneous flap	After débridement, TNP with continuous saline lavage until negative cultures and good granulation base for flap coverage	Healed wound, patient ambulatory with crutches	24	First described case of combined TNP and irrigation with myocutaneous flap for the treatment of pelvic infection and skin and soft tissue defect with endoprosthesis exposure Encouraging result

Table 3. continued

Study	Infection rate	Surgical treatment	Surgical notes	Findings	Followup (months)*	Authors' conclusions
Hardes et al. [16]	9%	One-stage revision (3) Two-stage revision (24)	Failure to reimplant in two-stage revisions primarily due to poor soft tissue conditions; salvage procedures were arthrodesis, rotationplasty, amputation, stump lengthenings	2/3 one-stage revisions failed 9/24 two-stage revisions unable to reimplant Mean revision surgeries per patient: 2.6 Mean duration of hospital stay: 68 days	32 (3–128)	Most important risk factor for failed limb salvage is soft tissue condition Irradiated tissue more likely to fail, chemotherapy made no difference Recommend two-stage revision for all infection scenarios except early low-grade infection (débridement/one-stage okay)
Kuhne et al. [21]	Case report	Knee arthrodesis and limb lengthening with IMN for callus distraction	Explanation and débridement performed; callus distraction performed over a distance of 11 cm in 4 months using an IMN with an external traction rope-winch system; plate osteosynthesis as definitive fusion procedure	Stable arthrodesis without recurrent infection Leg length allows foot to clear ground in swing phase	12 (after final fusion procedure)	Patient's young age and hope to avoid failure and amputation led to choice for arthrodesis IMN offers the ability to combine axial alignment, leg lengthening, and joint arthrodesis with one single treatment method and a high level of comfort for the patient
Ogose et al. [28]	Case report	Explanation of megaprosthesis and ischial weightbearing brace for ambulation	Failed I&D; required systemic steroids for Takayasu's arteritis; therefore, no reimplantation attempted	Ambulatory in brace without cane, positive emotional acceptance, and pain free Minor infection at 6 years' followup managed with local débridement and antibiotics	84	Resection arthroplasty with brace support is a viable option for perimegaprosthetic infection

Table 3. continued

Study	Infection rate	Surgical treatment	Surgical notes	Findings	Followup (months)*	Authors' conclusions
Current study	11%	I&D (15) Single-stage revision (11) Two-stage revision (4) Amputation (1)	Indications for megaprosthesis reconstruction varied (posttraumatic, oncologic, failed arthroplasty, etc)	16/31 patients failed and required unplanned surgeries or sustained a death Failures: I&D: 60% Single-stage revision: 55% Two-stage revision: 25% Amputation: 0% Age > 65 years: 73% History of prior joint infection: 80%	39.6 (12–96)	Numbers too small for analysis but age > 65 years and history of prior joint infection had high failure rates Most infections were chronic, > 6 months after reconstruction surgery Multiple débridements may be more likely to eradicate infection than single débridements Two-stage revisions and amputations (both primary and as salvage) led to clearance of infection more often than not No clear surgical method is best, must individualize to clinical picture

MRSA = methicillin-resistant *Staphylococcus aureus*; PMMA = polymethylmethacrylate; TNP = topical negative pressure; IMN = intramedullary nail; I&D = irrigation and débridement; MSTs = Musculoskeletal Tumor Society.

long-term, oral antibiotic suppression. The one patient who was successfully treated underwent a two-stage revision of components and has been free of recurrent infection for 3 years. When components were not revised, those who had multiple débridements had fewer failures. Most patients who had either two-stage revisions or amputations did not fail. Unfortunately, these numbers were very small, with only five patients satisfying these criteria. The one primary amputation performed and the five salvage amputations were all successful in eradicating infections, preventing further operative interventions and deaths.

Studies in the literature do support revisions with preservation of well-fixed stems and two-stage revisions (Table 3). Ultimate function and satisfaction are preserved once infection is cleared and prostheses are reimplanted [9, 13, 16, 19]. Candid discussions with patients regarding the high likelihood of multiple surgeries and the difficulty in eradicating infections in these situations are warranted. For those aged 65 years and older and those with recurrent infections, the high chance of failure must be emphasized.

Finally, in the standard arthroplasty literature, methicillin-resistant *Staphylococcus* infections have higher failure rates after the gold standard, two-stage revisions than those with sensitive organisms [1, 5, 23]. In the future, larger numbers may bear out which characteristics of infection may have prognostic value in perimegaprosthetic infections. However, it is reasonable to assume more virulent organisms requiring aggressive multistage revisions in standard arthroplasty will require the same in a megaprosthesis for a goal of infection clearance. And, given that most of our infections were at greater than 6 months after megaprosthesis reconstruction, the need for prolonged vigilance against infection in these patients is warranted.

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