Above-knee amputation shows higher complication and mortality rates in line with lower functional outcome compared to knee arthrodesis in severe periprosthetic joint infection

M. Schnetz,
R. Maluki,
L. Ewald,
A. Klug,
R. Hoffmann,
Y. Gramlich

From Berufsgenossenschaftliche Unfallklinik Frankfurt am Main, Frankfurt, Germany

Aims
In cases of severe periprosthetic joint infection (PJI) of the knee, salvage procedures such as knee arthrodesis (KA) or above-knee amputation (AKA) must be considered. As both treatments result in limitations in quality of life (QoL), we aimed to compare outcomes and factors influencing complication rates, mortality, and mobility.

Methods
Patients with PJI of the knee and subsequent KA or AKA between June 2011 and May 2021 were included. Demographic data, comorbidities, and patient history were analyzed. Functional outcomes and QoL were prospectively assessed in both groups with additional treatment-specific scores after AKA. Outcomes, complications, and mortality were evaluated.

Results
A total of 98 patients were included, 52 treated with arthrodesis and 47 with AKA. The mean number of revision surgeries between primary arthroplasty and arthrodesis or AKA was 7.85 (SD 5.39). Mean follow-up was 77.7 months (SD 30.9), with a minimum follow-up of two years. Complications requiring further revision surgery occurred in 11.5% of patients after arthrodesis and in 37.0% of AKA patients. Positive intraoperative tissue cultures obtained during AKA was significantly associated with the risk of further surgical revision. Two-year mortality rate of arthrodesis was significantly lower compared to AKA (3.8% vs 28.3%), with age as an independent risk factor in the AKA group. Functional outcomes and QoL were better after arthrodesis compared to AKA. Neuropathic pain was reported by 19 patients after AKA, and only 45.7% of patients were fitted or were intended to be fitted with a prosthesis. One-year infection-free survival after arthrodesis was 88.5%, compared to 78.5% after AKA.

Conclusion
Above-knee amputation in PJI results in high complication and mortality rates and poorer functional outcome compared to arthrodesis. Mortality rates after AKA depend on patient age and mobility, with most patients not able to be fitted with a prosthesis. Therefore, arthrodesis should be preferred whenever possible if salvage procedures are indicated.

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Correspondence should be sent to Y. Gramlich; email: yves.gramlich@bgu-frankfurt.de

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Introduction
Chronic periprosthetic joint infection (PJI) of the knee presents a major medical, social, and financial challenge.[1] Treatment success is limited in elderly patients with multiple comorbidities and difficult-to-treat pathogens,[2,3] and repeated revisions lead to high mortality rates.[4] Additionally, increasing soft-tissue and bone defects impede revision total

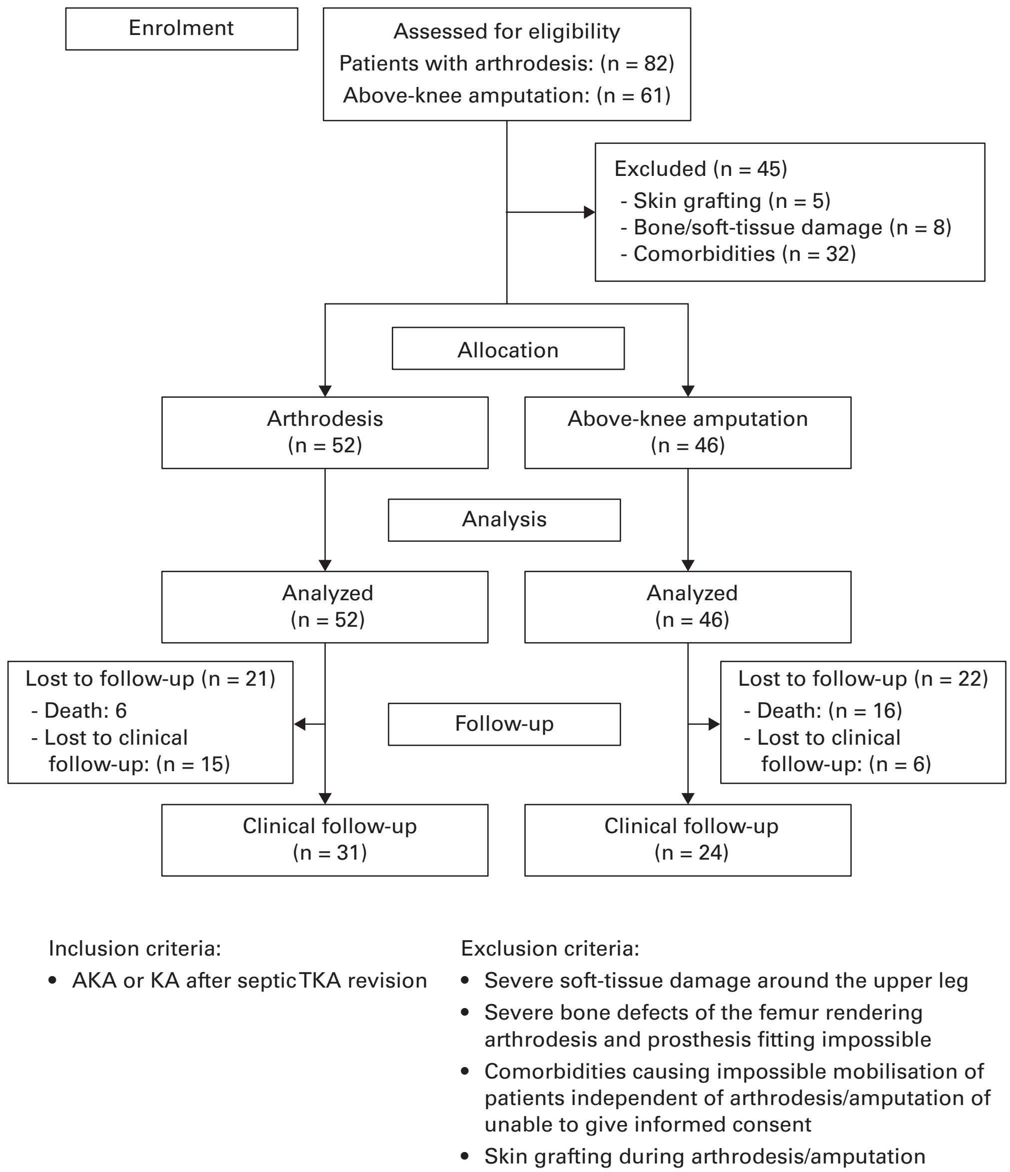

Fig. 1

Standardized Consolidated Standards of Reporting Trials (CONSORT) flow diagram for patient allocation. AKA, above-knee amputation; KA, knee arthrodesis; TKA, total knee arthroplasty.

knee arthroplasty (TKA). In these cases, arthrodesis or above-knee amputation (AKA) are often the only treatment options.[5]

Arthrodesis is a limb-preserving treatment option in patients with compromised extensor mechanisms and loss of bone stock, with similar disease remission rates compared to modular knee revision arthroplasty, but poorer functional outcomes.[6] However, results are patient-dependent, and infection control prior to arthrodesis is crucial to achieve good results.[7] In cases where infection control cannot be achieved or can only be achieved with multiple revision surgeries, a permanent sinus or AKA are often considered. AKA in septic patients presents a major challenge, and the level of the amputation should be carefully considered to guarantee infection control while enabling subsequent use of a prosthesis.

Although PJI cases of the knee are increasing, and a concordant rise of chronic, difficult-to-treat cases can be expected,[1] treatment algorithms for these cases have not yet been well established. The promising prospect of AKA to treat the infection with a single surgical intervention is tempered by the risk of impaired wound healing and limited mobility. Arthrodesis could be favourable regarding mobility, but complications requiring further surgical treatment and the risk of recurrent PJI might limit treatment success. Previous studies consist of either small case series limited by poor data on functional outcomes and/or clinical histories with individual case reports on arthrodesis or AKA.[8-12] While individual questionnaires are often helpful to evaluate clinical outcomes, complementary use of established scores would facilitate comparison between studies.

Table I. Patient demographic data and comorbidities.

Characteristic	Total	Arthrodesis	AKA	p-value
Total, n	98	52	46	
Mean age, yrs (SD; range)	72.6 (12.3; 34 to 95)	74.0 (12.0; 49 to 95)	71.0 (12.7; 34 to 93)	0.240*
Female sex, n (%)	59 (60.2)	29 (55.8)	30 (65.2)	0.340†
Comorbidities				
Mean BMI, kg/m² (SD; range)	29.9 (9.2; 0 to 54)	31.1 (6.5; 20 to 54)	29.1 (10.8; 0 to 50)	0.422*
Hypertension, n (%)	71 (72.4)	39 (75.0)	32 (69.6)	0.443†
Diabetes, n (%)	27 (27.6)	13 (25.0)	14 (30.4)	0.548†
Smoking, n (%)	13 (13.3)	2 (3.8)	11 (23.9)	0.003†
Median CCI (IQR)	3 (1.00 to 4.00)	3 (3.00 to 4.00)	2 (1.00 to 4.00)	0.006‡
Median CCI age (IQR)	6 (4.75 to 7.00)	6 (6.00 to 7.00)	5 (4.00 to 7.25)	0.045‡
Clinical data				
Mean number of revisions prior to arthrodesis/AKA (SD; range)	7.85 (5.39; 1 to 26)	4.92 (2.82; 1 to 12)	11.09 (5.71; 1 to 26)	< 0.001‡

*Independent-samples *t*-test.
†Chi-squared test.
‡Mann-Whitney U test.
AKA, above-knee amputation; CCI, Charlson Comorbidity Index; CCI age, Charlson Comorbidity Index age-adapted; IQR, interquartile range; SD, standard deviation.

We aimed to compare two large cohorts of knee arthrodesis (KA) and AKA patients in failed septic revision knee arthroplasty based on complete clinical history and functional follow-up using established scores and individual questionnaires. We hypothesized that postoperative mortality is high in both groups depending on identifiable risk factors with a trend towards AKA.

Methods

Patient selection. We selected patients treated at an academic referral centre for arthroplasty and traumatology, specializing in fracture-related infection and PJI. Patients treated in our hospital for PJI of the knee between June 2011 and May 2021, with a KA salvage procedure or AKA, were included. Patients with AKA for other reasons were excluded, even when knee arthroplasty was present. For detailed inclusion and exclusion criteria, see Figure 1. During the study period, 10.8% of patients with PJI of TKA were treated with KA (2011 to 2017) and 6.0% of patients with PJI of TKA were treated with AKA (2012 to 2021). Treatment decisions for either KA or AKA were made individually for each patient after multidisciplinary counselling. Patients with multi-resistant bacterial infection or severe bone defects in the tibia, extending to the diaphysis, were predominantly recommended AKA. Soft-tissue defects around the knee or lower leg alone were not an absolute indication for performing AKA when skin grafting or soft-tissue reconstruction was possible. Patients for whom AKA was the only treatment option and prosthesis fitting was unlikely (e.g. due to severe bone or soft-tissue loss above the knee), and patients with severe comorbidities and who were unable to mobilize after AKA or KA, were also excluded. The patients were divided into either an arthrodesis or an AKA group. Patients were retrospectively included and prospectively followed up when inclusion criteria were met (Figure 1). The study was approved by our institutional review board (approval: 2021-2661_1-evBO), and informed consent was obtained from all patients. A total of 98 patients, 52 after arthrodesis and 46 after AKA, were included (Table I).

Surgical procedure. All surgical procedures were performed by two experienced surgeons. The possibility for revision TKA was considered in every patient and, if rejected, a salvage procedure was performed as previously described.[13] Treatment decisions were based on age and comorbidities, microbiological results, bone stock, and soft-tissue status (including the extensor mechanism), as well as patient choice. In cases of arthrodesis, an uncemented modular cementless intramedullary arthrodesis system was used as previously described (KAM-TITAN; Peter Brehm, Germany) (Figures 2a to 2c).[6] The implant is made of shot-blasted titanium and consists of two separate modular femoral and tibial components. For patients proceeding to KA, a two-stage exchange was performed using antibiotic-loaded polymethyl methacrylate (PMMA) bone cement spacers (stabilized using external fixation rods) with antibiotic mixed into the PMMA spacer according to antibiograms and bacterial isolates if available. During removal of TKA, at least three to five tissue samples were obtained and sent for culture. If the antibiotic in PMMA did not match the subsequent antibiogram, another exchange procedure was performed using appropriate additional antibiotics within a new PMMA spacer whenever possible. In the presence of ongoing infection, an additional debridement with change of the PMMA spacer was performed. After the last surgical debridement, at least six weeks of antimicrobial therapy was administered. In the absence of ongoing infection, and following treatment with antibiotics, a KAM-TITAN modular arthrodesis system was implanted as previously described.[6] Postoperatively, early mobilization with full weightbearing was initiated with physiotherapy.

AKA was performed when necessary at the most distal level to allow infection control and soft-tissue coverage, and subsequent fitting of a prosthetic limb where possible (Figures 2d to 2f). During the final arthrodesis and AKA surgical procedures, tissue samples were obtained for further microbiological analysis. In cases where samples were negative, intravenous antibiotic therapy was continued for two weeks. After AKA, antibiotic therapy was continued until satisfactory wound healing. After arthrodesis, patients with positive tissue samples were treated for a minimum of six weeks, using biofilm-targeting systemic antibiotics. For postoperative pain management, exposed nerves or transected nerve stumps were infiltrated with local

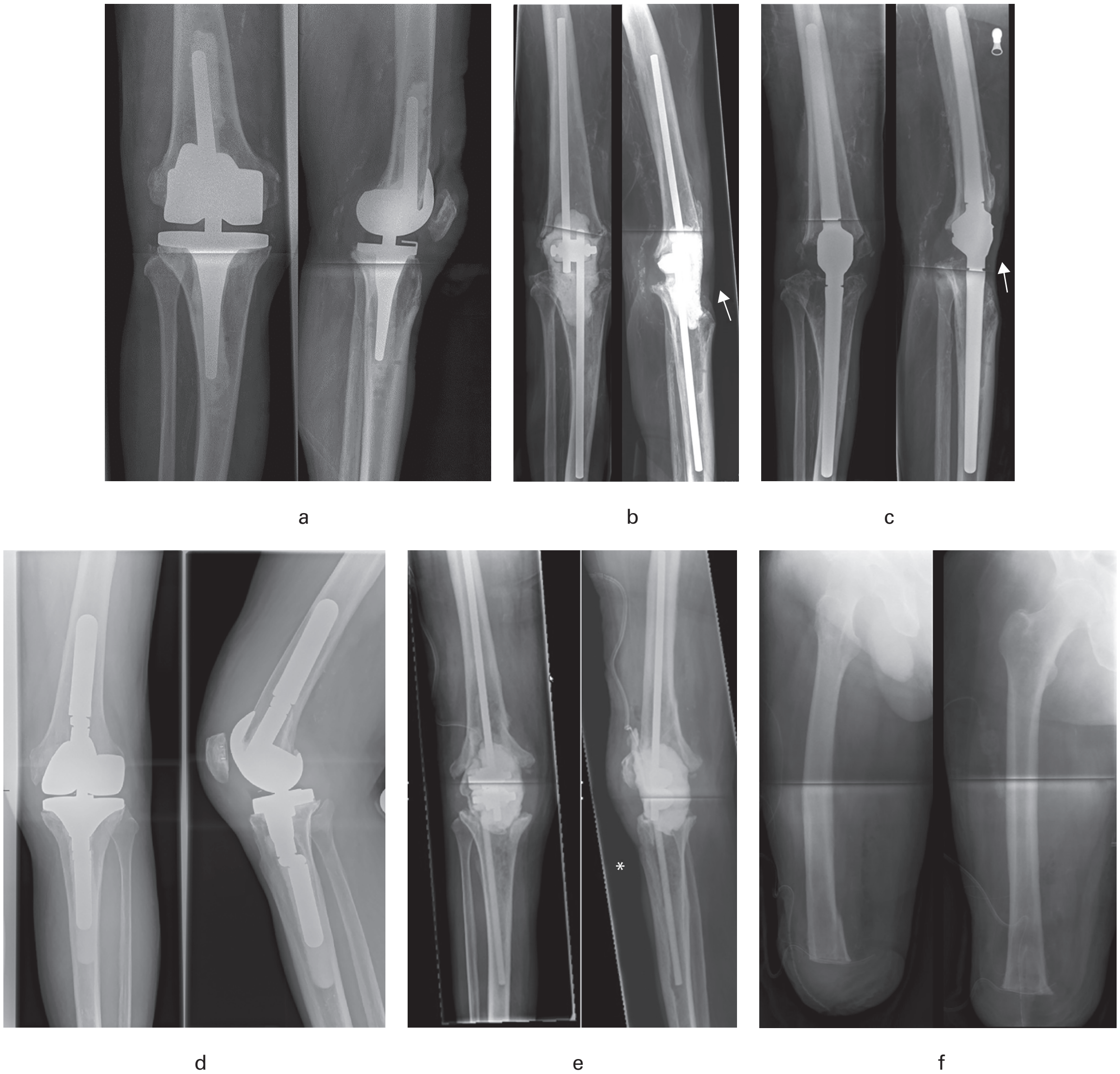

Fig. 2

Anteroposterior and lateral radiological images of two patients with intended two-stage revision arthroplasty undergoing multistage implant revision after periprosthetic joint infection (PJI) of the knee. a) In patient 1 (77-year-old male), after removal of the total knee arthroplasty (TKA), b) a polymethyl methacrylate (PMMA) spacer was implanted. During removal of the TKA, osteolysis in the patella and damage in the quadriceps tendon were recorded. However, due to the severity of the infection with ongoing wound discharge, a multistage revision was necessary. During treatment, it became apparent that substantial parts of the patella and extensor mechanism were damaged, and the patella was subsequently lost (white arrow). c) Knee arthrodesis using KAM Titan modular knee arthrodesis system was performed. d) In patient 2 (73-year-old male), before removal of the TKA, the patient already had impaired soft-tissue cover over the patellar tendon due to a sinus. e) A PMMA spacer was implanted. The patellar tendon was damaged by infection. However, despite the use of local and systemic antibiotics, the patient had ongoing wound discharge, so additional revisions were required, leading to additional damage to the patella tendon. f) Due to soft-tissue damage of the skin and extensor mechanism, including the tibial tuberosity (white asterisk in e)), above-knee amputation was performed without flap cover, allowing the subsequent fitting of a prosthetic limb.

anaesthetic and peripheral nerve block catheters were appropriately placed. Patients fitted with a lower limb prosthesis were supervised by limb-fitting orthopaedic specialists and physiotherapists, followed by referral to a rehabilitation facility.

Outcomes. Data were obtained retrospectively and analyzed for complications, mortality, clinical outcome, and prosthesis-fitting. Prospective follow-up of functional outcome and mortality after a mean follow-up of 77.0 months (standard deviation (SD) 30.92) with a minimum follow-up of two years was obtained. Complications, indications and number of revision surgeries, and mortality rates were analyzed. Complications were divided into "major" requiring revision surgery and "minor" treated without revision. Functional outcomes and quality of life (QoL) were assessed using Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)[14] and 12-Item Short-Form Health Survey (SF-12)[15] questionnaire scores. The WOMAC stiffness sub-score was not obtained, and combined scores (range 0 to 88) were calculated using pain (range 0 to 20)

Table II. Complications and mortality after arthrodesis (n = 52) and above-knee amputation (n = 46).

Variable	Knee arthrodesis	AKA
Total complications, n (%)	12 (23.1)	27 (58.7)
Major complications, n (%)	6 (11.5)	17 (37.0)
Reinfection	6 (11.5)	17 (37.0)
Minor complications, n (%)		
Prolonged wound discharge	2 (7.7)	3 (6.5)
Superficial wound infection	3 (5.8)	4 (8.7)
General complications, n (%)		
Pneumonia	1 (1.9)	1 (2.2)
Urinary tract infection	3 (5.8)	2 (4.3)
Cardiovascular complications	0	2 (4.3)
Two-year mortality rate, n (%)	2 (3.8)	13 (28.3)
Time of death after surgery, n (%)		
Within 6 mths	0	4 (8.7)
Within 6 mths to 1 yr	1 (1.9)	6 (13.0)
Within 1 yr to 2 yrs	1 (1.9)	3 (6.5)
Survival after maximum follow-up, n (%)	17 (32.7)	19 (41.3)
Mean follow-up, mths (SD; range)	95.42 (20.00; 26 to 136)	56.20 (27.79; 24 to 125)
Cause of death, n (%)		
Sepsis	0	6 (13.0)
Organ failure	4 (7.7)	5 (10.9)
Pneumonia (including COVID-19)	1 (1.9)	1 (2.2)
Cancer	1 (1.9)	1 (2.2)
Age/death at home/no further information	5 (9.6)	2 (4.3)
Unknown	6 (11.5)	4 (8.7)

AKA, above-knee amputation; SD, standard deviation.

and activity (range 0 to 68) sub-scores only. In the AKA group, additional scores to assess clinical and functional outcomes were used, using the Parker and Palmer Mobility Score (PPMS)[16] as well as the Amputee Activity Score (AAS).[17] Additionally, an individual questionnaire containing six questions based on the questionnaire by Fedorka et al[9] was used. QoL was further evaluated using the EuroQol five-dimension five-level questionnaire (EQ-5D-5L), with index value calculations according to the published country-specific value sets.[18]

Statistical analysis. Statistical analysis was performed using SPSS 29.0 (IBM, USA) and RStudio (v2023.12.1; posit, USA). Continuous variables are presented as mean (SD), ordinal variables as median (interquartile range (IQR)), and nominal variables as number (%). The normality of the data was verified using a graphical method and the Shapiro-Wilk test. The groups were compared using the independent-samples *t*-test for continuous normal distributed variables, the Mann-Whitney U test for continuous or ordinal non-normal distributed variables, and the chi-squared test for categorial variables. Kaplan-Meier survival curves were used to analyze the time between arthrodesis or AKA and death, with post-hoc log-rank tests used to report differences between the groups. Multivariable logistic regression models were used to stratify patient variables associated with revision after AKA and mortality. Statistical significance of the model was reported with χ^2 and p-value, and explained variance using Nagelkerkes R^2. $p < 0.05$ indicated statistical significance.

Results

Patient characteristics. There was a significant difference between the arthrodesis and AKA groups regarding the Charlson Comorbidity Index (CCI),[19] with a more severe index in the arthrodesis group (p = 0.006, Mann-Whitney U test). Time between primary arthroplasty and AKA was longer compared to that between primary arthroplasty and arthrodesis, with significantly more revision surgeries until AKA compared to arthrodesis ($p < 0.001$, Mann-Whitney U test).

Complications. Following arthrodesis, infection-free survival (IFS), defined as implanted modular knee arthrodesis system without implant removal or permanent sinus, or new signs of infection, was achieved in 46 cases (88.5%). In six cases (11.5%), further revision surgery was required due to persistent PJI of the arthrodesis within the first four weeks. All patients were treated with debridement, antibiotics, and implant retention (DAIR). In one case DAIR was successful, while in the other five cases a permanent sinus was established as a salvage procedure (patient declined an amputation).

After AKA, IFS after one year was achieved in 36 cases (78.3%). Complications following AKA occurred in 27 patients. Of the patients with complications, 17 had major complications requiring revision surgery. In these cases, a mean of 3.71 (SD 2.91) additional procedures were performed. Compared to arthrodesis, significantly more major complications after AKA were recorded (p = 0.003, chi-squared test) (Table II).

Risk factors for surgical revision. A multivariable logistic regression model was used to determine risk factors for further surgical revision after AKA ($\chi^2 = 24.886$; p = 0.006; $R^2 = 0.571$; Supplementary Table i). Variables with significant influence on the risk of surgical revision included lower age at time of amputation (odds ratio (OR) 0.851 (95% confidence interval (CI) 0.740 to 0.978); p = 0.023), positive tissue culture samples

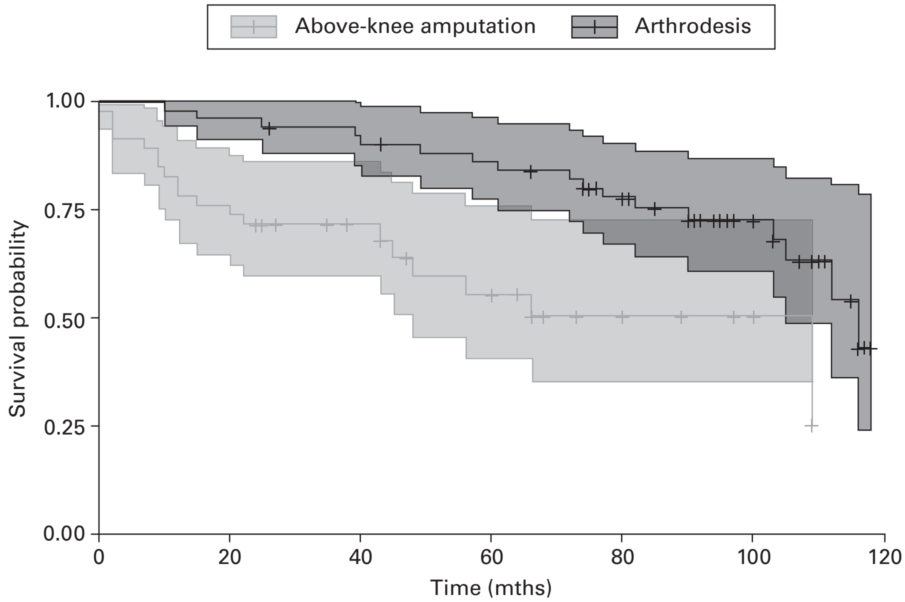

Fig. 3

Kaplan-Meier survival curve for the cumulative risk of mortality after arthrodesis and above-knee amputation ($\chi^2 = 10.668$; p = 0.001).

during amputation (OR 10.113 (95% CI 1.159 to 88.267); p = 0.036), and increased number of surgical procedures from primary arthroplasty to AKA (OR 1.280 (95% CI 1.011 to 1.621); p = 0.040).

Positive tissue culture specimens prior to, during, and at subsequent revision surgeries following AKA were analyzed (Supplementary Table ii). Tissue samples obtained during AKA were culture-positive in 20 (43.5%) patients. Compared to microbiological specimens obtained prior to amputation, tissue samples of 12 patients yielded the same organisms, while other bacterial isolates were found in eight patients. Newly found bacterial species included *Staphylococcus epidermidis* (n = 4), *Proteus mirabilis* (n = 1), *Bacteroides fragilis* (n = 1), *Staphylococcus capitis* (n = 1), and *Corynebacterium striatum* (n = 1).

Mortality. Mortality was assessed after a mean follow-up of 77.0 months (SD 30.92), with a minimum follow-up of two years. The two-year mortality rate was 3.8% (n = 2/52) after arthrodesis and 28.3% (n = 13/46) after AKA (Figure 3). Survival probabilities for arthrodesis with an estimated median of 116 months (95% CI 102 to 130) and AKA with an estimated median of 109 months (95% CI 46 to 172) were significantly different ($\chi^2 = 10.668$; p = 0.001). In a multivariable logistic regression model for mortality after AKA at the time of follow-up, risk factors were assessed ($\chi^2 = 19.105$; p = 0.004; $R^2 = 0.458$; Supplementary Table iii). Increased age at time of AKA was the only variable associated with a significant risk of mortality (OR 1.130 (95% CI 1.024 to 1.248); p = 0.015).

At follow-up, 17 patients (32.7%) after arthrodesis and 19 patients (41.3%) after AKA had died. Mean age at death was 83 years (SD 10) after arthrodesis and 80 years (SD 8.212) after amputation. Mean time of death after surgery was 66.29 months (SD 33.331) after arthrodesis and 25.74 months after amputation (Table II). While no patient died due to sepsis after arthrodesis, it was the leading cause of death with six patients (31.6%) after amputation.

Functional outcomes and quality of life. There was a significant reduction from preoperative to postoperative pain levels after arthrodesis (p < 0.001) but no significant reduction after AKA (p = 0.191). Comparing postoperative pain levels after arthrodesis and AKA, no significant difference between the groups was shown (p = 0.971). Neuropathic pain was reported by 19 patients (41.3%) after AKA (Figure 4a).

Mobility, including the use of a prosthesis, was evaluated using the medical database after rehabilitation (Figure 5). Mortality differed within the different mobility groups, with higher mortality in bedridden patients and patients only mobilizing using a wheelchair. Accordingly, comparing arthrodesis and AKA, 32/52 patients (61.5%) after arthrodesis and 18/46 patients (39.1%) after AKA were able to walk after rehabilitation (p = 0.001, chi-squared test). Walking distance was also significantly different, with 19 patients (36.5%) after arthrodesis and nine patients (19.6%) after amputation being able to walk > 500 metres (0.31 miles) after rehabilitation (p = 0.002, Mann-Whitney U test).

Of the surviving patients with follow-up after arthrodesis and AKA, 31 and 24 completed the survey, respectively. Activity levels after surgery showed significant differences, with higher activity levels after arthrodesis compared to AKA when evaluated with the WOMAC activity score (p = 0.017) and Function Score (p = 0.019). The WOMAC cumulative score showed a significant difference between the groups (p = 0.020). QoL was evaluated comparing arthrodesis and AKA using SF-12, showing higher scores after arthrodesis in physical health (p = 0.016) but almost no difference in mental health (p = 0.617) (Figures 4b to 4d).

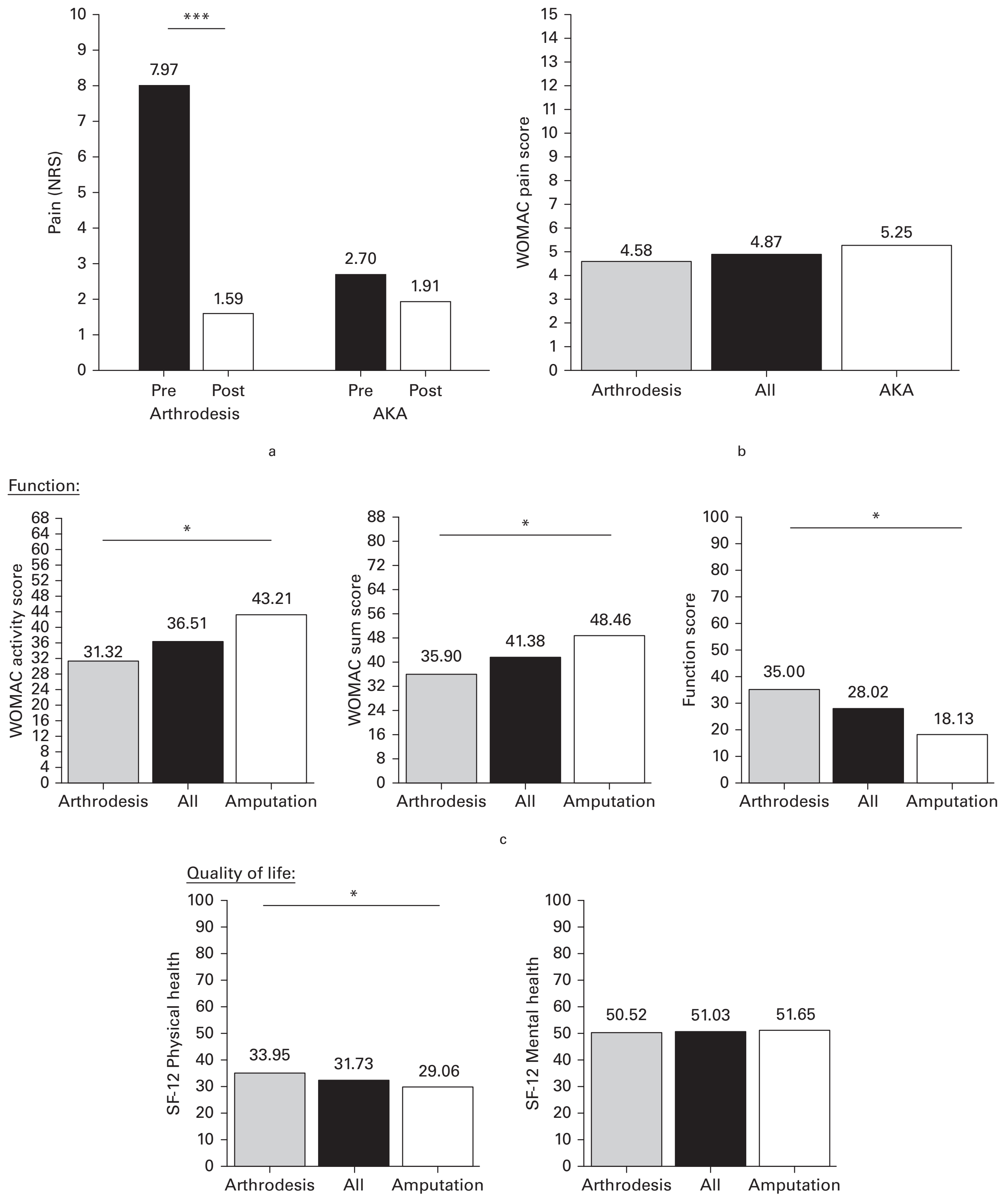

Fig. 4

a) Pain levels before and after arthrodesis (n = 52) or above-knee amputation (AKA) (n = 46). b) to d) Follow-up scores including Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score, function score, and 12-Item Short-Form Health Survey (SF-12) questionnaire score for patients after arthrodesis (n = 31) and AKA (n = 24). WOMAC sum score (range 0 to 88) was calculated using WOMAC pain (range 0 to 20) and WOMAC activity score only (range 0 to 68), with higher scores indicating worse results.

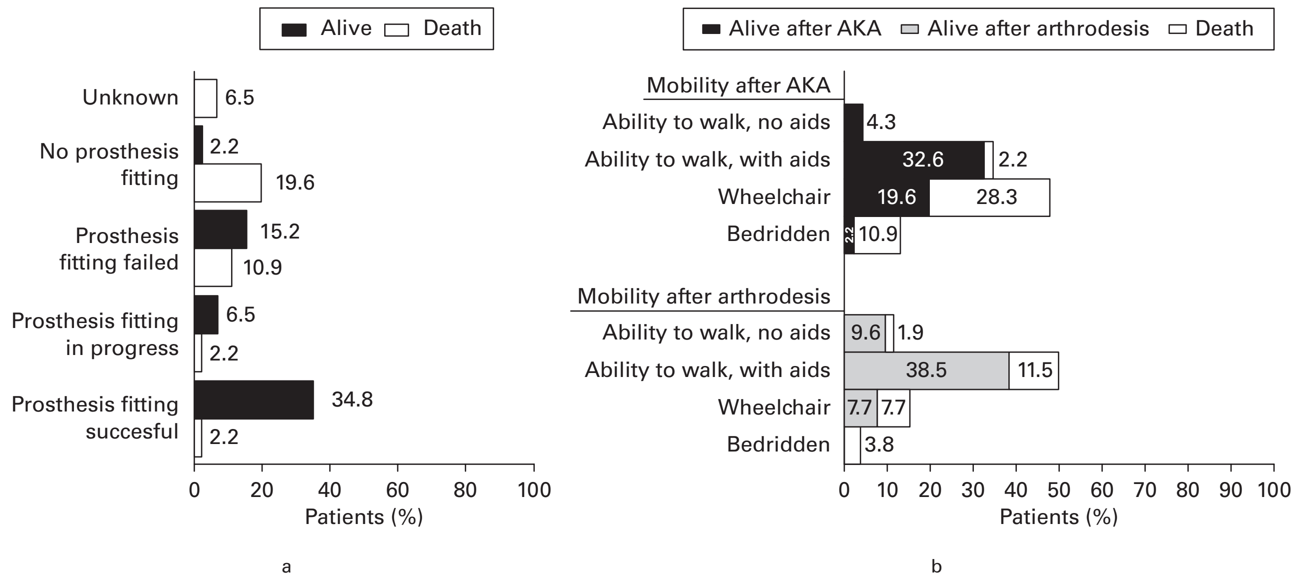

Fig. 5

a) Status of prosthesis-fitting after above-knee amputation (AKA) (n = 46) after rehabilitation. b) Mobility of patients after arthrodesis (n = 52) or AKA (n = 46) after rehabilitation with proportion of deceased patients during follow-up with regard to status of prosthesis-fitting and mobility. Mobility after arthrodesis was unknown in ten (19.2%) cases.

Table III. Questions about patient independence and mobility after above-knee amputation during follow-up (n = 24).

Variable	Before AKA	After AKA
Living situation, n (%)		
Own house, without assistance	9 (37.5)	2 (8.3)
Own house, with outside assistance	0	17 (70.8)
Assisted living facility	13 (54.2)	3 (12.5)
Nursing home	2 (8.3)	2 (8.3)
Mobility, n (%)		
Walk outside the house, unlimited distance	5 (20.8)	6 (25.0)
Walk outside the house, < 5 blocks	8 (33.3)	3 (12.5)
Walk around the house only	3 (12.5)	3 (12.5)
Use legs to get in and out of bed/chair/bathroom	5 (20.8)	2 (8.3)
Not able to walk at all	2 (8.3)	6 (25.0)
Not answered	1 (4.2)	4 (16.7)

AKA, above-knee amputation.

In the AKA group, functional outcome was assessed using AAS and PPMS. A mean AAS of -48.92 (SD 36.53) and PPMS of 2.46 (SD 3.00) was reported. For the EQ-5D-5L, a mean index value of 0.449 (SD 0.42) was obtained. Limiting aspects were mobility, self-care, and usual activities, with 16 (66.7%), ten (42.7%), and ten (42.7%) patients reporting scores of ≥ 4, respectively (range 0 to 5; higher scores represent worse health status). For pain/discomfort and anxiety/depression, only three (12.5%) and five (20.8%) patients reported scores of ≥ 4, respectively.

The individual questionnaire was used and reported by 24 patients. In the AKA cohort, 20 patients (83.3%) of the remaining 24 patients during the follow-up period were fitted with a prosthesis, with four patients (16.7%) never wearing it, five patients (20.8%) wearing it < one hour/day, and 11 patients (45.8%) wearing it > one hour/day. However, only 12 patients (50.0%) were able to walk using the prosthesis, with only two (8.3%) being able to walk without any aid. A total of 14 patients (58.3%) reported additional problems with the non-amputated leg, inhibiting them from ambulating. In the AKA cohort, patients required more assistance after surgery (Table III).

Discussion

Knee amputation in PJI results in high complication and mortality rates, in line with poorer functional outcomes compared to arthrodesis. Mortality rates after AKA depend on patient age and mobility after AKA, with most patients not able to be fitted with a prosthesis after AKA. To our knowledge, this is the largest study comparing the complications and mortality of arthrodesis and AKA after PJI of the knee. Furthermore, the use of established clinical scoring systems to evaluate clinical and functional outcomes enables comparison with future reports and studies. Prosthetic limb-fitting after AKA was achieved in only 45.7% (n = 21) of our patients, with higher mortality rates associated with failed prosthesis-fitting in patients who were bedridden, wheelchair-reliant, or had a considerable restriction in everyday life.

Several studies report complication rates after arthrodesis ranging from 20% to 50% and AKA ranging from 10% to 40%;[7,9,20,21] however, few have compared both treatment options.[20,22,23] Hungerer et al[23] reported similar complication rates after arthrodesis and AKA of approximately 35%, with recurrence of infection as the most common complication. We report similar results for AKA, but significantly lower complication rates for KA. Equal or even higher complication rates after AKA compared to arthrodesis are of particular interest concerning the potential for recurrent PJI after arthrodesis and the intended single-surgery treatment pursued with AKA. There are several options to treat PJI after KA, including DAIR, multistage revision, a permanent draining infected sinus, or AKA. After AKA, sufficient wound healing is required to facilitate prosthesis-fitting and treatment options are limited to wound and stump revisions. Positive intraoperative tissue cultures during AKA were strongly associated with the need for further surgical revision (OR 10.113). In our study, microbiological isolates from patients during AKA were identical in 60% (n = 12/20) of patients but, when new bacterial isolates were found, only skin flora were cultured. We advise taking tissue samples during AKA, continuing antibiotic treatment until negative results are obtained, and, in case of positive results, closely monitoring wound healing and infection parameters.

Mortality after AKA was significantly higher compared to arthrodesis, even though comorbidity scores were higher in the arthrodesis group. Higher mortality after AKA compared to arthrodesis was also reported by Hungerer et al[23] and Son et al.[24] The five-year survival rate after AKA has also been reported to be 51.7%, with a two-year mortality rate of 28.4%,[10] similar to our results. Advancing age is a risk factor for mortality after AKA, as is renal failure.[10] In our study, neither CCI nor any single disease contributing to CCI was significantly associated with an increased mortality after AKA. This might be explained by differences in the patient cohorts (34.9% chronic renal failure vs 8.7% in our study)[10] and different variables used in the multivariable logistic regression model. Notably, 90% of patients with no prosthesis-fitting, 59.1% of patients mobile only using a wheelchair, and 83.3% of patients bedridden after rehabilitation died during follow-up. Corroborating increased age as a risk factor for mortality after AKA, our study adds to the literature by highlighting the importance of prosthesis-fitting and mobilization after AKA.

Comparisons of functional outcomes are difficult due to fundamentally different treatment methods. Functional outcomes after arthrodesis using the WOMAC activity score and function score were significantly better compared to AKA. Comparisons of SF-12 scores showed significant differences in physical health, but not mental health. Similarly, EQ-5D-5L dimensions of mobility, self-care, and usual activities in the AKA cohort were poor, with higher scores reported in the dimensions of pain/discomfort and anxiety/depression. While functional outcome and mobility were limited, mental health and pain were comparable to patients after arthrodesis or TKA. In our study, PPMS was reported with a mean of 2.46 points after AKA, meaning that patients were only mobile to perform everyday tasks with help from another person. Our score is lower compared to a study by Trouillez et al,[20] reporting a mean of 5.2 points in a small study of 15 patients after AKA. However, those patients were younger and had fewer comorbidities compared to our study population. Previously, a mean WOMAC combined score (excluding stiffness score) of 61.7 points was reported in a series of 11 patients after AKA.[8] Compared to our study, functional results were worse, but patient numbers were lower and only two patients were fitted with a prosthesis,[8] highlighting the importance of prosthesis-fitting for functional outcome.

Few studies compare functional outcomes after arthrodesis and AKA. Chen et al[22] reported a higher SF-12 physical component score (PCS) and mental component score (MCS) after arthrodesis compared to AKA. Higher but comparable SF-12 PCS and SF-12 MCS after AKA compared to arthrodesis were reported by Hungerer et al.[23] In our study, SF-12 PCS was significantly higher after arthrodesis compared to AKA, and SF-12 MCS was almost identical, when comparing the groups. This is similar to previously reported results. Higher functional scores after AKA in patients fitted with a prosthesis were also reported in our study, corroborating previously published results,[22] and explaining differences between studies. One review reported better functional outcomes after arthrodesis compared to AKA, attributed to only a small percentage of patients fitted with a prosthesis after AKA,[25] concluding that arthrodesis should be the treatment of choice whenever possible. As per our results, other studies report rates of prosthesis-fitting after AKA of approximately 30%,[21,22] with only one reporting a higher rate of 80%.[23] Poor functional outcomes do not seem to result in equally poorer mental health. Despite the poor functional outcome after AKA, studies report general patient satisfaction after AKA for PJI of the knee and retrospectively would have made an earlier decision for AKA,[26,27] which is in line with our results.

Comparisons of functional outcomes after AKA are hampered by heterogenous reporting, using mostly individual questionnaires.[9,10,21] Ryan et al[10] argue that standardized surveys are not specific to patients with AKA after septic failure of TKA. Although individual questionnaires add important information regarding the functional outcome, we recommend using standardized scores to not only allow comparison between studies, but also enable comparisons of functional outcomes for AKA for different surgical indications. This is of particular importance for physicians and patients regarding treatment decisions. Functional outcomes after AKA also depend upon regional differences regarding costs and insurance cover or funding for prosthesis-fitting, which should be considered when comparing studies. In our study, prosthesis-fitting would have been possible for all patients without additional costs, but was only successful in 42% of patients, and mortality was significantly associated with failed prothesis-fitting.

This study has some limitations. Patients were not prospectively randomized to treatment groups. Randomization was not possible due to ethical prerequisites. While follow-up times to measure clinical scores were comparable between the groups, total follow-up time to mortality differs. The difference can be attributed to the lower case number of AKA in the study and additional follow-up to mortality of patients after arthrodesis. Furthermore, there were significant differences between the groups regarding comorbidities, especially CCI. Interestingly, though median CCI was higher in the arthrodesis group, reported mortality during follow-up was higher in the AKA group. Therefore, comorbidities had no effect on mortality, but increased age and poor mobility after AKA result in high mortality. Patients underwent significantly more surgeries prior to AKA than arthrodesis, which can be attributed to the more restrictive indication for AKA and may cause a bias on outcome. Due to the specialization required in treatment of PJI, there might be a bias to more severe cases. However, comparably high numbers in salvage procedures might result in improved outcomes as a result of increased experience and established infrastructure of our specialist unit. Despite the limitations, this study adds significant information to the literature regarding the risk factors for complications after AKA and mortality after arthrodesis and AKA. Our data can be used to support decision-making for either treatment option. AKA should be one of the last treatment options and, if inevitable, tissue sampling and culture, patient and wound healing surveillance, as well as early mobilization and prosthesis-fitting, are of particular importance. Furthermore, standardized reporting of functional outcome allows for comparison with other studies and, subsequently, systematic reviews, which are of particular importance due to reported low case numbers.

In conclusion, although the gold standard in treatment of late PJIs remains revision TKA, salvage procedures should be considered in cases of reduced life expectancy, several recurrences of the infection, patient preference, or negative host factors. Although AKA might be associated with a promising prospect to treat the infection with a single surgical intervention, high complication rates, high mortality rates, and low functional outcomes hamper the expected outcomes. Where further revision surgery after AKA (37%) is indicated, a mean number of 3.7 revision procedures were necessary. Arthrodesis shows higher one-year IFS rates (89% vs 78%), lower complication rates (23% vs 59%), and lower two-year mortality rates (3.8% vs 28.3%), even though CCI of patients undergoing arthrodesis were higher compared to AKA (CCI 3 vs CCI 2). Overall functional outcome and QoL were significantly better after arthrodesis compared to AKA. Even after AKA with control of infection, AKA patients are not fitted with a prosthesis in 54.3% of cases, which was associated with poor mobility and higher mortality. Arthrodesis should be carried out whenever possible; however, if an AKA is unavoidable, two major risk factors for failure should be considered: positive intraoperative cultures obtained during the AKA procedure, and failed postoperative prothesis-fitting.

Take home message

- Above-knee amputation in periprosthetic joint infection of the knee results in high complication and mortality rates, and poorer functional outcome compared to arthrodesis.
- Mortality rates after above-knee amputation depend on patient age and mobility, with most patients unable to be fitted with a prosthesis.
- Therefore, arthrodesis should be preferred whenever possible if salvage procedures are indicated.

Supplementary material

Details on microbiological specimens obtained prior to, during, and after above-knee amputation, as well as details on the multivariable logistic regression models for risk for surgical revision and mortality after above-knee amputation.

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Author information:
M. Schnetz, MD, BSc, Orthopaedic Surgeon
R. Maluki, Medical Student
L. Ewald, MD, Orthopaedic Surgeon
A. Klug, MD, PhD, Orthopaedic Surgeon, Orthopaedic Consultant
R. Hoffmann, MD, Professor, Orthopaedic Surgeon, Medical Director
Y. Gramlich, MD, PhD, Orthopaedic Surgeon, Orthopaedic Consultant
Department of Trauma and Orthopedic Surgery, Berufsgenossenschaftliche Unfallklinik Frankfurt am Main, Frankfurt, Germany.

Author contributions:
M. Schnetz: Methodology, Validation, Investigation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing, Supervision.
R. Maluki: Investigation, Formal analysis, Visualization, Writing – original draft.
L. Ewald: Investigation, Formal analysis, Visualization, Writing – review & editing.
A. Klug: Methodology, Validation, Formal analysis, Visualization, Writing – review & editing, Supervision.
R. Hoffmann: Conceptualization, Resources, Writing – review & editing, Supervision, Project administration.
Y. Gramlich: Conceptualization, Methodology, Validation, Formal analysis, Visualization, Resources, Writing – review & editing, Supervision, Project administration.

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The study was approved by our institutional review board (IRB approval ID: 2021-2661_1-evBO), and informed consent was obtained from all patients. The study was performed in accordance with the ethical standards outlined in the 1964 Declaration of Helsinki.

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