Ghosh A, Madanipour S, Stammers J, Mitchell P, Alazzawi S. Long-term outcomes of single-stage versus two-stage revision for prosthetic joint infection: a retrospective, observational cohort study. *Orthopedic Reviews*. 2025;17. doi:10.52965/001c.147165. PMID:41306377

General

Long-term outcomes of single-stage versus two-stage revision for prosthetic joint infection: a retrospective, observational cohort study

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Keywords: Prosthetic joint infection, one-stage exchange, two-stage exchange, total hip arthroplasty, total knee arthroplasty

https://doi.org/10.52965/001c.147165

Orthopedic Reviews

Vol. 17, 2025

Background & objective

To compare long-term outcomes of single-stage and two-stage revision procedures for prosthetic joint infection (PJI) in total joint arthroplasty, with a focus on infection clearance and treatment failure rates in demographically similar patient cohorts.

Methods

A retrospective cohort study was conducted at a tertiary referral centre between 2011 and 2021. Patients who underwent either single-stage or two-stage revision for PJI and completed a minimum of two years of follow-up were included. They were identified from electronic health records and hospital databases. Infection clearance at final follow-up was the primary outcome. Treatment failure was defined as need for further revision or long-term suppressive antibiotics.

Results

A total of 75 patients were included, with 50 undergoing single-stage revision and 25 undergoing two-stage revision. The groups were similar for age, joint type and MacPherson host grade. Mean follow-up was 4.2 years (range 2–9). Infection clearance was achieved in 48 patients (96%) in the single-stage group and 23 patients (92%) in the two-stage group (p = 0.624). Treatment failure occurred in two patients (4%) in the single-stage group and in two patients (8%) in the two-stage group. Patients in the single-stage group received significantly longer courses of post-operative antibiotics (mean 6.2 weeks vs 4.8 weeks; p= 0.0058). All-cause 5-year and 10-year mortality was similar between groups (p=0.85).

Conclusion

In patients with chronic PJI and similar demographic profiles, selected patients undergoing single-stage revision demonstrated comparable infection clearance and mortality compared with two-stage revision. These findings support the increasing use of single-stage revision in appropriately selected patients.

1 INTRODUCTION

Prosthetic joint infection (PJI) remains one of the most devastating complications following total joint arthroplasty, with a reported incidence of 1% to 2% in primary procedures and a significant impact on patient quality of life and survival.[1-3] The optimal surgical strategy for managing chronic PJI remains controversial. While two-stage revision has traditionally been considered the gold standard, recent studies suggest that single-stage revision may achieve comparable outcomes with fewer procedures, and lower costs.[4-9] Single stage surgery has subsequently become more prevalent globally over the last decade with high rates of reported infection clearance,[10,11] so much so that at the 2025 International Consensus Meeting in Istanbul it was determined that there should be no absolute contraindication to single stage revision for PJI.

In the United Kingdom, the adoption of single-stage revision has been increasing, particularly in tertiary centres with multidisciplinary expertise.[4,12] However, the literature remains limited by heterogeneous patient selection, variation in surgical technique, and short-term follow-up.

This retrospective, observational study aims to evaluate outcomes of single-stage versus two-stage revision for PJI

in demographically matched patient cohorts, treated at a single tertiary centre over a mid to long-term period.

2 MATERIALS AND METHODS

2.1. ETHICAL CONSIDERATIONS

This study was approved by the local institutional review board, with consent waived due to its retrospective nature

2.2. STUDY DESIGN AND PATIENT SELECTION

This retrospective, observational cohort study included patients treated for chronic PJI between January 2011 and December 2021 at a UK tertiary referral centre. Eligible patients underwent either single-stage or two-stage revision and had a minimum of two years of follow-up. Patients with incomplete records, less than two years follow-up, or revisions for aseptic failure were excluded.

Chronic PJI patients were selected and identified using the Outpatient Parenteral Antibiotic Therapy (OPAT) service archive. Demographic and clinical data were extracted, including age at time of surgery, sex, joint involved, infective organism, antibiotic duration, and clinical outcomes. Clinical data from patient records was extracted to calculate the McPherson classification for systemic host grade.[13] Compromising patient factors affecting the McPherson host grading included age>80, immunosuppressive drugs, alcohol excess, long term urinary catheter, renal failure (requiring dialysis), malnutrition, systemic inflammatory disease, smoking, systemic immune compromise, diabetes mellitus and hepatic insufficiency.

Chronic PJI was diagnosed using the criteria defined by the Musculoskeletal Infection Society (MSIS 2018).[14]

Choice of revision was dependent at the time of presentation with the following criteria used. Single stage revision was performed only in cases of a recorded antibiotic sensitivity to an established organism and immunocompetent patients without soft-tissue compromise. Single stage revision was not performed in the presence of systemic sepsis or draining sinus. The decision to go ahead with single or two-stage revision was made in conjunction with a multidisciplinary team (MDT) meeting setting with sub-specialist microbiologists with an interest in musculoskeletal infection. Soft tissue compromise included inability to adequately restore soft tissue coverage following debridement and extensor mechanism loss. Fungal infections underwent two-stage revision.

2.3. SURGICAL TECHNIQUE

In both procedures, radical debridement and synovectomy was performed with removal of all infected material and lavage. In single-stage revisions, reimplantation was performed at the same sitting following re-preparation and re-draping of the surgical field, and re-gowning of surgeons and scrub staff. In two stage revisions, the preference was for an articulating spacer. In the knee, a posterior stabilised femoral component and all-polyethylene tibial component were loosely cemented, whilst the 'Kiwi' technique (custom-made antibiotic-coated, articulating spacer i.e. Kiwi Prostalac) was used in the hip to loosely cement articulating primary components, facilitating mobility and delivering high doses of antibiotics to infected bone.[15] If an articulating spacer was not able to be used due to bone loss, soft tissue compromise or concern for instability, a static antibiotic eluting cement spacer was utilised in the tibiofemoral and acetabular dead space. Systemic and local antibiotic composition and duration was determined in conjunction with microbiology colleagues in the MDT meeting on a per case basis. Second stage surgery was embarked upon following normalisation of inflammatory markers and negative aspiration. Repeat debridement, synovectomy, washout and sampling was performed in the second stage.

2.4. OUTCOME MEASURES

The primary outcome measure was infection clearance, defined as absence of clinical, laboratory, or radiographic signs of infection at final follow-up without further surgery for infection or the need for suppressive antibiotics. This aligned with the Musculoskeletal Infection Society Outcome Reporting Tool.[16] Secondary outcome measures included duration of antibiotic therapy, microbiological profile and all-cause patient survivorship.

2.5. STATISTICAL ANALYSIS

Continuous variables were compared using independent-samples t-tests. Categorical data were analysed using chi-squared tests or Fisher's exact test where appropriate. A p-value < 0.05 was considered statistically significant. Survival analysis was performed using the Kaplan-Meier technique (95% confidence intervals) for all patients, with all-cause mortality as the endpoint.

3. RESULTS

3.1. PATIENT DEMOGRAPHICS

A total of 75 patients were included: 50 in the single-stage group and 25 in the two-stage group. There was a normal distribution of single and two-stage patients between 2011 and 2021, with around 50% of patients in the two-stage group presenting between 2015 and 2017. The mean age was 67 and 56% were female. 26 patients were McPherson host grade A, 27 were grade B and 21 were grade C. There were 48 THA and 27 TKA. The groups were similar in age, sex distribution, McPherson host grading, joint type (hip/knee), and infective organism (predominantly Staphylococcus aureus and coagulase-negative staphylococci). TABLE 1

3.2. CLINICAL OUTCOMES

At a mean follow-up of 4.2 years (range 2–9), infection clearance was achieved in 96% (48/50) of single-stage patients and 92% (23/25) of two-stage patients ($p = 0.624$). Treatment failure occurred in two patients in each group. TABLE 2

Table 1. Baseline demographics: age, sex and co-morbidities

	Single stage (n=50)	Two stage (n=25)	*p-value*	Total (n=75)
Age (years) - Mean ± SD **Range**	69.44 ± 9.36 51-91	62.16 ± 13.11 27-86	*p*= 0.1778	67.01 ± 11.21 27-91
Gender (M:F) • **Males, n (%)** • **Females, n (%)**	1:1.0833 24 (48%) 26 (52%)	1:1.0833 12 (48%) 13 (52%)	*p*= 0.8810	1:1.0833 36 (48.18%) 39 (56.36%)
McPherson[9] *Systemic Host grade (medical + immune status)* A – B - C	A. 20 B. 17 C. 13	A. 6 B. 10 C. 9	*p*= 0.3743 (Chi-square)	A. 26 B. 27 C. 21
Follow up (years) - Mean ± SD **Range**	3.63 ± 1.29 2-8	3.06 ± 1.44 2-9	-	3.35 ± 1.37 2-8.5

Table 2. Breakdown by prosthesis type, intervention and outcome

	Single stage (n=50)		Two-stage (n=25)		*p-value*	Total
Total Hip Replacement (%) (n=48)	30 (60%)		18 (72%)		*p*=0.0153	48 (64%)
Total Knee Replacement (%) (n=27)	20 (40%)		7 (21%)			27 (36%)
Laterality	**Left**	**Right**	**Left**	**Right**		
	16 (32%)	34 (68%)	13 (52%)	12 (48%)	*p*=0.0936	***75***
Failed (%)	2 (4%)		2 (8%)		*p*=0.624	***4***
Total Success (%)	48 (96%)		23 (92%)			71 (94.67%)

One patient in the two-stage group had recurrence of THA PJI less than 4 months post second stage. This patient had a polymicrobial infection with candida albicans, enterococcus faecalis and methicillin sensitive staphylococcus aureus. She did not undergo further reconstruction and was treated with doxycycline suppression and sinus management. The second patient with recurrence in the two-stage group was treated initially for vancomycin resistant enterococcus (VRE) TKA PJI and developed recurrence 3 years after second stage with polymicrobial VRE, alpha haemolytic streptococcus and staphylococcus epidermidis. He was treated with lifelong suppressive doxycycline.

Amongst the single stage group there were two recurrences. One patient underwent revision for staphylococcus aureus TKA PJI and had recurrence of pain and swelling within four months, with persistent raised C-reactive protein, erythrocyte sedimentation rate and raised synovial white cell count on aspirate. The patient declined further surgery due to frailty. She continues to ambulate with two crutches 12 years post operatively. The second patient had revision for THA PJI and periprosthetic fracture to total femoral replacement. Initial treatment was for polymicrobial MSSA, Cutibacterium acnes and proteus mirabilis. She represented 12 months later with sinus formation. She was eventually treated with antibiotic suppression as guided by the microbiology team and died 7 years later.

Patients undergoing single-stage revision received significantly longer courses of antibiotics (mean 75 days vs 55 days; p = 0.0058). TABLE 3

3.3. MORTALITY

There were eleven deaths within the study period. Three out of twenty-five patients died in the two-stage group and eight out of fifty died in the single stage group. Mortality was unrelated to PJI in all three cases in the two stage-group. Four out of eight deaths were not PJI related in the single stage group. The remaining four deaths were of unknown aetiology. 5-year survivorship was 96% (SE3.9%) for the two-stage group and 92% (SE 3.8%) for the single-stage group. 10-year survivorship was 86% (SE 7.6%) for the two-stage group and 86% (SE 4.9%) for the single stage group. The survivorship during the study period between groups was similar (p=0.8, X^2=0.03).

3.4. MICROBIOLOGICAL FINDINGS

100 organisms were grown from the 75 interventions. Gram positive bacteria were the most common causative organisms. Staphylococcus aureus and staphylococcus epidermidis represented 32% of all organisms grown. No significant difference was observed in organism type or resistance patterns between groups. Mixed growth and polymicrobial

Table 3. Length of antibiotics course breakdown by single and two stage interventions (2011-2019)

	Single stage (n=50)	Two stage (n=25)	All (n=75)	*p-value*
Mean course length (days) ± SD **Standard Error** **Range**	75.45 ± 26.05 3.65 34-168	55.44 ± 29.28 5.86 14-126	68.87 ± 28.57 3.28 14-168	***p*= 0.0058**

Table 4. Organisms identified in single and two stage interventions

Single stage (n=50)		Two stage (n=25)		*p-value*
Organism	**Frequency**	**Organism**	**Frequency**	***p*=0.1932 (Chi-square)**
S. aureus (inc MRSA and MSSA)	19	*S. aureus (inc MSSA)*	6	
S. epidermidis	8	*S. epidermidis*	5	
CoNS	4	*B. fragilis*	2	
E. coli	4	*Candida albicans*	2	
Pseudomonas aeruginosa	4	*CoNS*	2	
Strep. oralis	3	*Enterococcus spp*	2	
Diphteroids	2	*S. capitis*	2	
Enterococcus faecalis	2	*Bacillus licheniformis*	1	
Cutibacterium	2	*Diphteroids*	1	
S. dysgalactiae	2	*E. coli*	1	
S. hominis	2	*Enterobacter spp*	1	
Group A streptococcus (GAS)	1	*Enteroccocus faecalis*	1	
Candida albicans	1	*P. mirabilis*	1	
Clostridium perfingens	1	*Parvimonas micra*	1	
Coliforms	1	*Pseudomonas spp*	1	
Enterobacter cloacae	1	*S. mitis*	1	
Enterococcus spp	1	*S. warneri*	1	
Group G streptococcus (GGS)	1	*S. pasteuri*	2	
Klebsiella spp	1	*S. constellatus*	1	
S. lugdunensis	1	*Vancomycin resistant Enterococcus*	1	
S. simulans	1	**TOTAL**	**35**	
Strep. intermedius	1			
Strep. milleri	1			
Strep. sanguinis	1			
TOTAL	**65**			

CoNS - Coagulase-negative staphylococci; MRSA - Methicillin-resistant Staphylococcus aureus; MSSA - Methicillin-sensitive Staphylococcus aureus; GAS - Group A Streptococcus; GGS - Group G Streptococcus; *Enterococcus spp. – Enterococcus species; Spp. - Species (plural); P. mirabilis - Proteus mirabilis; P. micra - Parvimonas micra; S. mitis - Streptococcus mitis; S. sanguinis - Streptococcus sanguinis; S. intermedius - Streptococcus intermedius; S. pasteuri - Streptococcus pasteuri; S. constellatus - Streptococcus constellatus (formerly Streptococcus milleri); S. lugdunensis - Streptococcus lugdunensis; S. simulans - Streptococcus simulans; S. capitis - Staphylococcus capitis; B. fragilis - Bacteroides fragilis; B. licheniformis - Bacillus licheniformis; Diphtheroids - Refers to species within the genus Corynebacterium or related genera (commonly known as diphteroid bacteria); P. aeruginosa - Pseudomonas aeruginosa; S. dysgalactiae - Streptococcus dysgalactiae; S. mitis - Streptococcus mitis; S. warneri - Streptococcus warneri; Enterobacter spp. - Enterobacter species.*

infections were rare and evenly distributed. TABLE 4, TABLE 5.

4. DISCUSSION

Our findings suggest that in our centre, single-stage revision can achieve infection eradication rates comparable to two-stage revision in appropriately selected patients. This is consistent with emerging literature demonstrating equivalence or superiority of single-stage revision in terms of morbidity, cost, and function.[5]

The ten-year mortality between single and two-stage groups was the same in this study (82%, p = 0.8). Matar et al from Nottingham, UK reported 10-year patient survivorship of 72% for single stage and 71% for two-stage exchange for TKA PJI.[4] Yao et al from Mayo, Rochester, USA reported a 10-year mortality rate of 47% for septic revision.[17]

Table 5. Polymicrobial frequency breakdown by single and two stage interventions

Number of organisms grown	0 *(Culture Negative)*	1	2	3	4	5	*Total patients (n=75)*	*p-value*
Single stage (n=50)	0	37	9	1	2	1	50	*p=* 0.5388
Two stage (n=25)	1	17	4	1	2	0	25	

The infection clearance is comparable between single and two stage groups in our study (96% of single stage and 92% of two stage, p = 0.624) .This aligns with multiple similar studies such as Jacobs et al from Hengstdal, the Netherlands, where infection clearance was the same in single and two stage groups (96.9%, p = 1.00).[18]

The longer antibiotic duration in the single-stage group likely reflects clinician preference or microbiological advice and may have contributed to the higher success rate. Antibiotic duration in literature varies between 6 weeks for uncomplicated PJIs (Infectious Diseases Society of America guidelines) to around 12 weeks for complex or polymicrobial infections as described Bernard et al.[19,20]

The study is subject to limitations. Key limitations include the retrospective design, limited sample size, and lack of functional outcomes. The data for this study was obtained from the local outpatient antibiotic service registry, limiting inclusion to patients local to the centre and excluding those from our wide referral network. Despite cohorts being similar demographically, unmeasured confounders such as American society of anaesthesiologists scores may still influence treatment choice, outcomes and mortality. Clearly there is selection bias between groups. Patients with soft tissue compromise and systemic sepsis underwent two-stage exchange. Nevertheless, this study supports the viability of single-stage revision as a definitive treatment in selected cases.

The continued emerging evidence for the favourable outcomes of single stage revision open interesting further possibilities including the use of adjunctive intra-articular antibiotics in more challenging cases and poorer host patients.[21]

5. CONCLUSIONS

In this retrospective cohort of patients with chronic PJI, single-stage revision demonstrated comparable infection clearance and treatment failure rates, in selected patients, to two-stage revision. With the added benefit of fewer procedures and shorter treatment timelines, single-stage revision should be considered in suitable candidates within multidisciplinary PJI management pathways.

ACKNOWLEDGEMENTS

The authors would like to thank Yasmin Toseafa (PA-R) for their assistance with data collection for this study. Their support and contributions were greatly appreciated.

DATA AVAILABILITY

All data generated or analysed during this study are included in this published article

AUTHORS' CONTRIBUTIONS

AG, SM conceived and designed the analysis, collected the data, contributed data or analysis tools, performed the analysis, wrote the paper and provided final approval of version to be published

JS, PM, SA conceived and designed the analysis, read and approved the final manuscript

COMPETING INTERESTS

The authors declare that they have no competing interests

ETHICAL STATEMENT

This study was approved by the local institutional review board, with consent waived due to its retrospective nature.

FUNDING

No external funding was received.

Submitted: October 12, 2025 EST. Accepted: October 19, 2025 EST. Published: November 23, 2025 EST.

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