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The outcomes of acute periprosthetic joint infection following unicompartmental knee replacement managed with early debridement, Antibiotics, and implant retention

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ABSTRACT

Background: Periprosthetic joint infection (PJI) following unicompartmental knee replacement (UKR) is an uncommon, yet serious, complication. There is a paucity of evidence regarding the effectiveness of Debridement-Antibiotics-and-Implant-Retention (DAIR) in this setting. The aim of this study is to investigate the effectiveness of DAIR for acute UKR PJI.

Method: Between 2006 and 2019, 5195 UKR were performed at our institution. Over this period, sixteen patients underwent DAIR for early, acute PJI. All patients met MSIS PJI diagnostic criteria. The median age at DAIR was 67 years (range 40–73) and 12 patients were male (75.0%). The median time to DAIR was 24 days (range 6–60). Patients were followed up for a median of 6.5 years (range1.4–10.5) following DAIR.

Results: 0.3% (16/5195) of UKR in our institution had a DAIR within 3 months. 15 of 16 patients (93.8%) were culture positive, with the most common organism MSSA (n = 8, 50.0%). Patients were treated with an organism-specific intravenous antibiotic regime for a median of 6 weeks, followed by oral antibiotics for a median duration of 6 months. The Kaplan-Meier survivor estimate for revision for PJI was 57% (95%CI: 28–78%) at five years, and survivor estimate for all cause revision 52% (95%CI: 25–74%).The median Oxford Knee Score for patients with a viable implant at final follow-up was 45 points (range 39–46).

Conclusion: Early, acute PJI after UKR is rare. DAIR had a moderate success rate, with infection-free survivorship of 57% at 5 years. Those successfully treated with DAIR had excellent functional outcome and implant survival.

1. Introduction

Periprosthetic joint infection (PJI) is a serious complication following joint replacement [1–3]. Accepted surgical management strategies in the management of PJI, include debridement-antibiotics-and-implant-retention (DAIR), single-stage or

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two-stage revision surgery [4]. Although there is ample evidence regarding the outcome of PJI following TKR, there is limited information available on the management of infected UKRs [5–8].

DAIR is an attractive option in the surgical management of PJI due to several advantages [9,10]. Compared to formal revision surgery, advantages of DAIR include lower morbidity and quicker recovery as there is no loss of bone stock and reduced soft tissue destruction [11]. There is, however, a degree of uncertainty regarding its success in terms of PJI eradication, with a reported rate ranging from 11.1% to 100% [12].

Our specialist tertiary orthopaedic centre is a national reference centre for bone and joint infections. Our routine treatment for early (within three months) PJI following UKR is DAIR. The purpose of the study was to estimate the incidence of early PJI after UKR and to investigate the outcome of DAIR in this situation in our unit. The outcomes we assessed were: (1) The success rate of DAIR in terms of PJI eradication, (2) The implant survival following DAIR and (3) The functional outcome following successful DAIR.

2. Patients and methods

Institutional review board approval was obtained for this study. Between 2006 and 2019, 5195 UKRs were performed at our tertiary referral orthopaedic centre with routine review at 6 weeks and 3 months. The inclusion criteria for the study were patients with infected UKR who met the Musculoskeletal Infection Society (MSIS) PJI diagnostic criteria and underwent DAIR for postoperative infection within 3 months of surgery. [13] We excluded arthroscopic washouts (n = 1), cases where the "surgical washout" was superficial to the fascia (n = 2), open procedures with no debridement performed (n = 1), or MSIS criteria was not met (n = 3).

Sixteen patients met the inclusion (Table 1). All cases were managed within a multidisciplinary team, which included physiotherapists, occupational therapists, specialist nurses, infectious disease physicians, plastics, and orthopaedic surgeons. All DAIR procedures were carried out by experienced arthroplasty consultants. Tissue sampling for microbiology and histopathology were obtained before antibiotic administration using a strict protocol previously described by our group [14]. The femoral and tibia components were assessed for the integrity of the interface, using manual pressure and instrumented probing. DAIR was only performed if the implants were found to be stable. Meticulous debridement and a full synovectomy was followed by 5–9 litres of saline irrigation. Replacement of meniscal bearing took place in all but one case, where a fixed-bearing lateral unicompartmental knee replacement was in situ.

The type and duration of antibiotics were selected under the supervision of Infectious Disease physicians. The typical antibiotic regime included intravenous vancomycin and meropenem following specimen sampling. Meropenem was discontinued at 48 hours if no Gram-negative organisms had been cultured, and treatment adjusted based on the causative organism and the sensitivity profile.

All patients who had a DAIR were contacted to ascertain whether they had recurrence of infection or additional surgeries elsewhere.

The primary outcome measure was infection control with no continued antibiotic therapy (MSIS Tier 1) at five years [15]. Secondary outcome measures included infection control with no continued antibiotic therapy (MSIS Tier 1) at one year and all cause revision arthroplasty (MSIS Tier 3) at one and five years. Functional outcome was assessed at last follow up by the Oxford Knee Score [10,16]. Revision was defined as any operation where tibial or femoral components were explanted,

Table 1
Patients characteristics who underwent DAIR for prosthetic infection after UKA.

Number	Age & Gender	BMI kg/m^2	Charlson Index	Interval between index UKA and DAIR (days)	Side	UKA Type	MSIS Criteria met	Revision
1	73M	32.0	4	44	Right	medial	MSIS B	Aseptic revision for loosening (5.9y)
2	48M	30.0	0	29	Left	medial	MSIS A	Two stage revision for infection (2.6y)
3	73M	22.3	5	8	Right	medial	MSIS A	Two stage revision for infection (2.5y)
4	54F	32.6	1	43	Right	medial	MSIS A	Aseptic revision for disease progression (2.1y)
5	68F	36.3	2	30	Right	lateral	MSIS A	Two stage revision for infection (0.2y)
6	71M	42.3	4	22	Left	medial	MSIS A	Single stage revision for infection (1.4y)
7	73F	N/A	4	60	Right	lateral	MSIS B	No
8	68F	40.8	5	18	Right	medial	MSIS A	No
9	55M	24.6	1	27	Left	medial	MSIS A	No
10	69M	34.4	4	10	Left	medial	MSIS A	No
11	57M	34.0	1	25	Right	medial	MSIS A	Two stage revision for infection (0.3y)
12	40M	31.1	0	19	Right	medial	MSIS A	No
13	66M	28.2	2	30	Right	medial	MSIS A	No
14	61M	31.4	2	21	Left	lateral	MSIS A	Two stage revision for infection (2.5y)
15	71M	N/A	0	14	Right	medial	MSIS A	No
16	63M	N/A	0	6	Left	medial	MSIS A	No

M – Male, F – Female; N/A – Not available. MSIS A: x2 positive intraoperative culture. MSIS B: Sinus tract.

meniscal bearing exchanged or a new component added to a further compartment of the knee [11]. Where there was persistent wound discharge or wound dehiscence requiring surgical intervention in the first 30 days of index DAIR and the index of suspicion for PJI was high a first stage revision was performed and this was considered treatment failure. Where there was persistent wound discharge or wound dehiscence requiring surgical intervention in the first 30 days of index DAIR and the suspicion for PJI was low it is our units protocol to perform repeat DAIR with deep sampling and modular exchange. These DAIR were not considered treatment failure provided the intraoperative sampling was negative as the index of suspicion for infection was low.

Functional outcome at final follow-up was assessed using the Oxford Knee Score (OKS) as a joint specific measure in which 0 is the worst possible score and 48 the best [17].

2.1. Statistical analysis

Statistical analysis was performed using Stata (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.) and R version 3.6.2. Data were not normally distributed and so were presented as medians and range. Kaplan-Meier survival analysis was performed for primary and secondary outcome measures. A p-level of less than 0.05 was considered statistically significant.

3. Results

There were 16 patients of 5195 UKR (0.3%) during the study period that underwent DAIR for early, acute PJI following UKR. The median interval between the primary UKA and DAIR was 24 days (range 6–60). 12 were male and four female. The median age at DAIR was 67 years (range 40–73). Median body mass index was 32.3 kg/m^2 (range 22.3–42.3). 13 patients had a medial UKR, and three had a lateral UKR. Table 1 outlines the cohort of patients in the study.

15 out of 16 patients (93.8%) were culture positive, with the most common organism methicillin-sensitive Staphylococcus aureus (n = 8, 50.0%). Table 2 summarises the organism profile of this series. Following DAIR All patients initially received broad spectrum intravenous antibiotics. In 9 patients this was followed by organism specific intravenous antibiotics (8 patient for 6 weeks and 1 patient for 12 weeks) and then oral antibiotics until 6 months (1 case for 3 months and 1 case for 12 months). In 7 patients organism specific oral antibiotics were used, commenced within the first two weeks of DAIR when cultures and sensitivities were available. Oral antibiotics were then continued until 6 months following DAIR. The variation in antibiotic duration changed over time and was in part due to the OVIVA trial conducted at our unit [1]. No chronic antibiotic suppression was administered. Patients were contacted at a median of 6.5 years (range 1.4–10.5) following DAIR.

With respect to our primary outcome at five years following DAIR there were six septic revisions for recurrence of PJI. One revision was single-stage and five were two-stage. The 5 years Kaplan-Meier survivor estimates for revision for PJI (MSIS Tier 1) was 57% (95% CI: 28–78%) (Figure 2).

With respect to our secondary outcomes the 1 year Kaplan-Meier survivor estimates for revision for PJI (MSIS Tier 1) was 88% (92–97%). Figure 1. In addition to septic revisions there were two aseptic revisions. One was for tibial component loosening and one for lateral compartment disease progression. In both cases the microbiology and histology was negative for infection. The Kaplan-Meier survivor estimates for revision for any reason (MSIS Tier 3) were: 88% (92–97%) at 1 year and 52% at 5 years (95% CI: 25–74%) (Figure 3).

Repeat DAIR within 30 days was required in 4 cases (median 14 days (range 5–20). In all cases the index of suspicion for infection was low and microbiology cultures negative. Ultimately two of these four patients were subsequently revised, one at 2.6 years and one at 2.5 years. Both underwent two-stage revision due to history of infection, and were considered as septic failures for our analysis, but at revision microbiology and histology were negative. Aside from one arthroscopic assessment and biopsy for persistent pain (negative for infection) no other operations were conducted. The median Oxford Knee Score for patients with a viable implant at final follow-up was 45 points (range 39–46).

Following DAIR one patient had an acute postoperative kidney injury, which recovered uneventfully. There was one postoperative urinary retention managed with catheterisation. There were no cases of symptomatic DVT/PE. Four patients were intolerant of their antibiotics requiring a change of regime. One patient died after 5.4 years for an unrelated reason.

Table 2
Summary of organisms grown from intraoperative samples.

Bacteria	Number (%)
Methicillin sensitive staphylococcus aureus	8 (50%)
Coagulase negative staphylococcus	3 (19%)
Enterococcus spp.	1 (6%)
Multi-organism	3 (19%)
Negative culture	1 (6%)

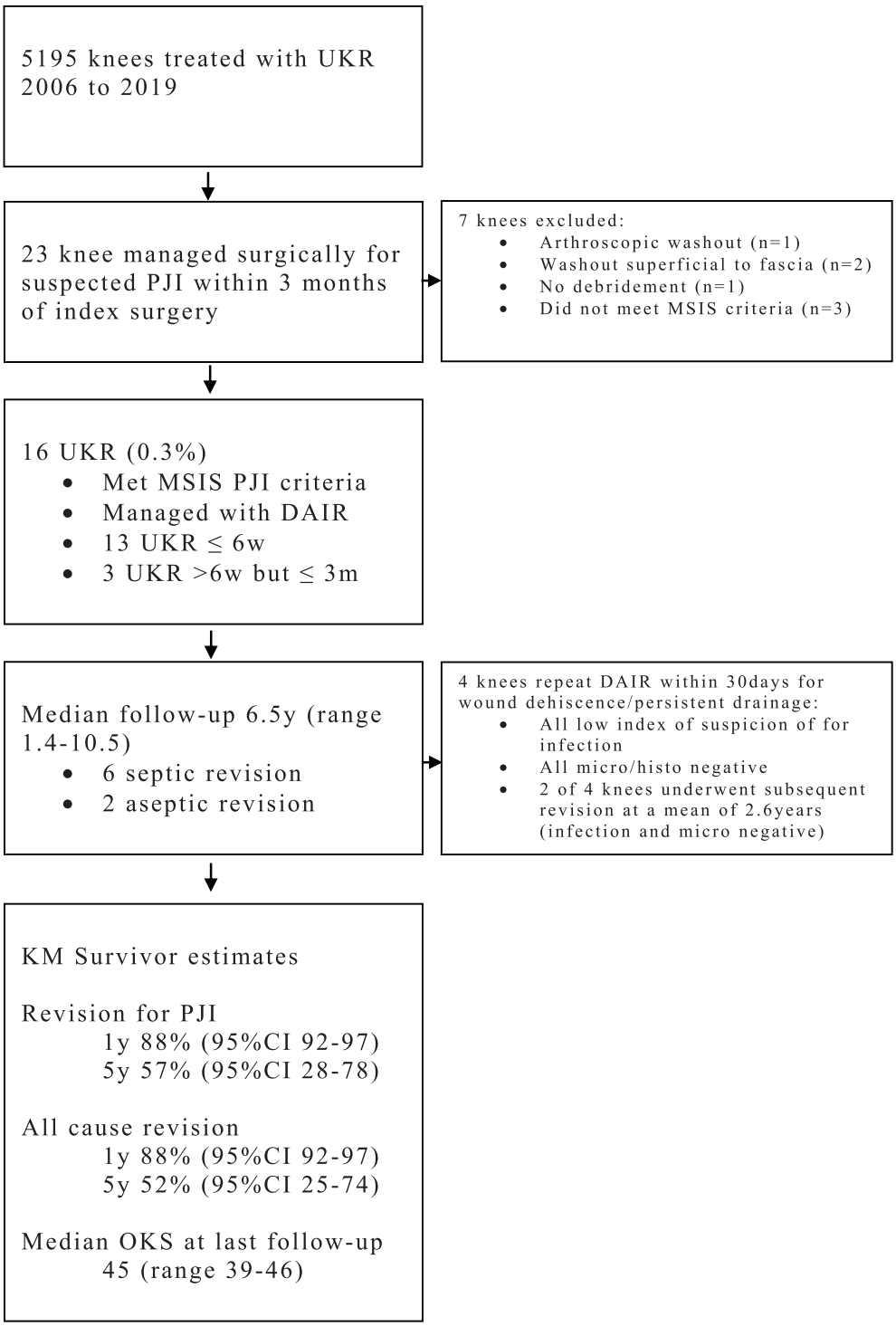

Figure 1. Patient Flow.

4. Discussion

This study identified low rate of PJI following UKR. DAIR is our first-line treatment for early, acute PJI and we identified a rate of DAIR of 0.3% among our cohort of 5195 UKRs performed over the past fifteen years. The rate of infection eradication

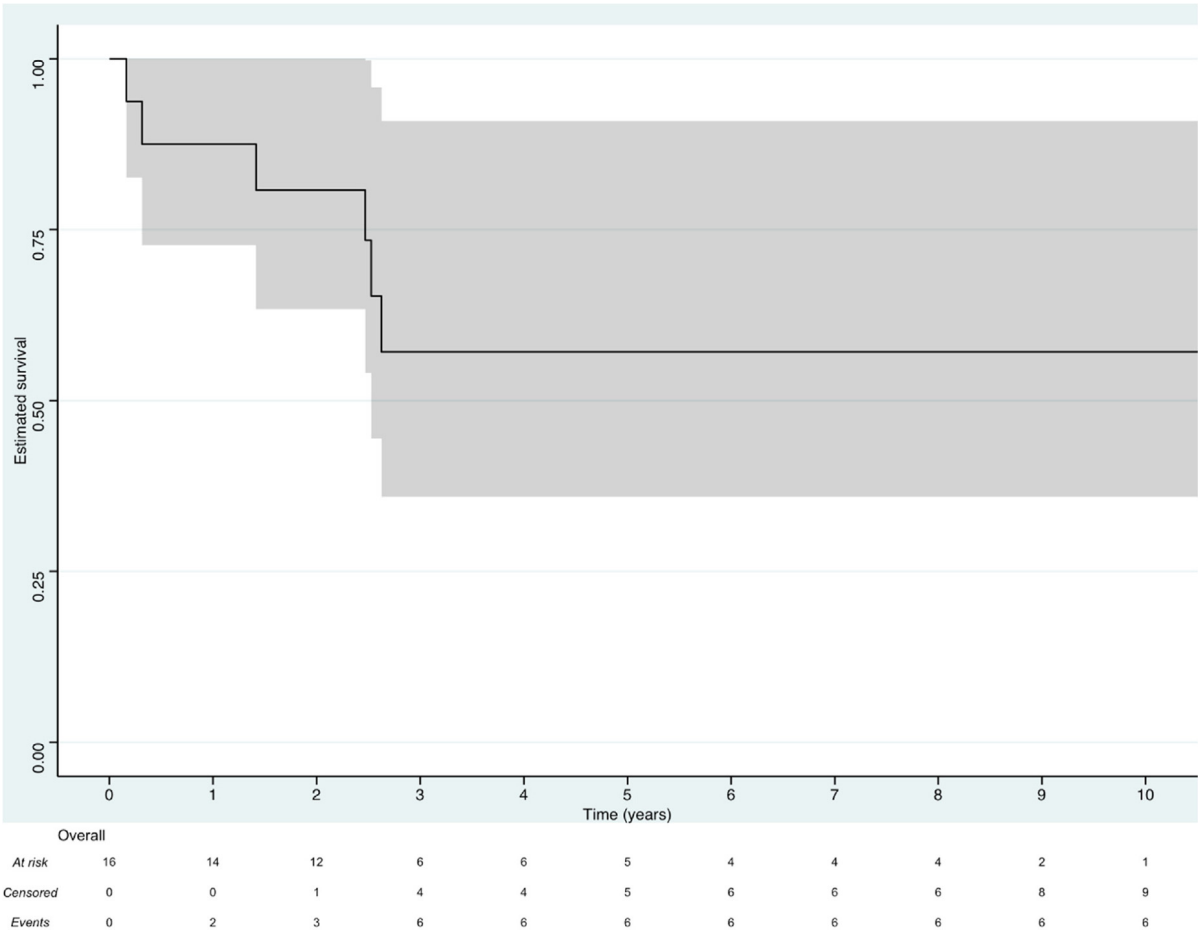

Figure 2. Kaplan Meier survival curve for PJI revision arthroplasty following DAIR.

following our DAIR protocol was 57% at 5 years. The overall revision-free survivorship at 5 years was 52% due to some patients being revised for aseptic indications.

We have performed approximately 400 UKRs a year in our tertiary referral orthopaedic centre over the last 14 years and about 60% of the primary knee replacements performed in our institution are UKR. Due to the rare occurrence of early infection after UKR, the ideal treatment and prognosis for this have not previously been well studied [5–7]. Labruyère et al. reported a high success rate of a one-stage conversion to TKR in eight patients with chronic UKA PJI [7]. Hernandez et al. reported the result of 15 patients who either had a DAIR or two-stage knee arthroplasty and showed lower infection-free survivorship at five years after DAIR compared with two-stage revision surgery (61% versus 100%) [5]. Recently Chalmers et al. reported survivorship of 55% at five years in 13 patients who underwent DAIR for acute UKR postoperative infections [6] which is similar to the 57% survivorship at five years in the current study. Finally Brivio et al. have reported an 79% survivorship at a mean 32.5 month follow up for 19 UKR performed at three specialist centres [18]. These figures are similar to the average 52.6% in TKR PJI eradication following DAIR in a recent meta-analysis [12] but lower than a previously reported 69% success rate in our centre [19].

There are several factors implicated in the success of a DAIR procedure including debridement technique, irrigation solution, exchange of modular components, type of microorganism, and symptoms duration [4,9,11,14]. Performing DAIR in the setting of UKR has some exclusive features that might contribute to its low success rate in comparison to TKR. Inadequate debridement of the knee through the small original medial incision could be a contributing factor. Visualising lateral compartment, lateral gutter and posterior capsule is suboptimal using the UKR incision. We suggest performing a meticulous debridement and thorough irrigation by extending the old incision proximally and everting the patella to obtain a complete exposure of the knee. The existing native articular cartilage is not debrided at the time of DAIR, however a complete soft tissue debridement of the three compartments is undertaken. An incomplete full knee debridement may potentially contribute to the higher failure rate due to residual potential infection [7].

The intra-operative irrigation solution is also an important factor [20,21]. Specifically, in the UKR setting, surgeons should consider the risk of chondrotoxicity with a recent in vitro study has shown chlorhexidine is highly toxic to the chondrocytes

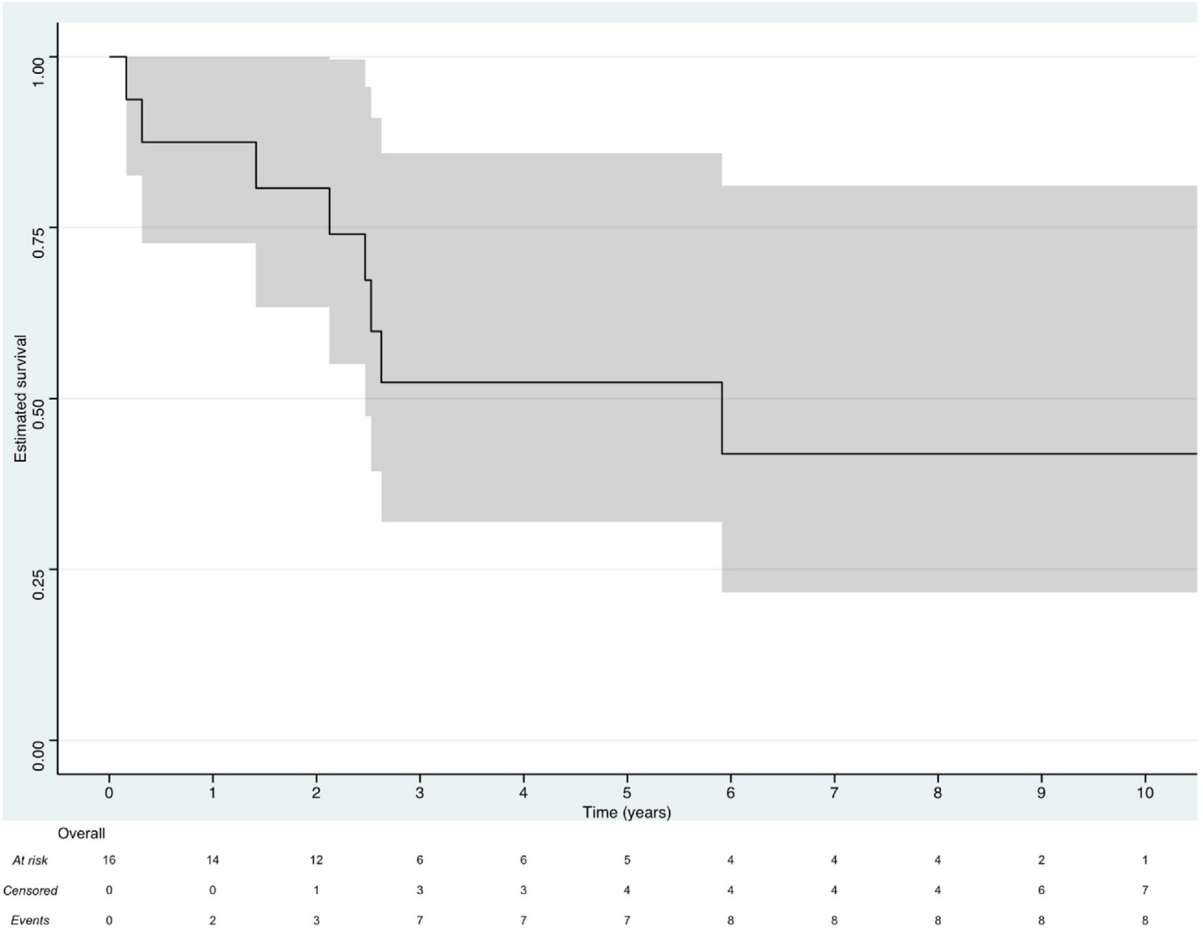

Figure 3. Kaplan Meier survival curve for all-cause revision arthroplasty following DAIR.

[22]. Whilst diluted Povidone-iodine has been reported to be less toxic to chondrocytes yet still effective against Staph aureus, we routinely use normal saline during DAIR of UKR [22].

Developing arthritis in the retained compartments is another distinct complication of UKR PJI [6,7]. Activation of proteolytic enzymes can lead to early destruction of the intra-articular cartilage. Of the two aseptic revisions in this study one was for progression of arthritis in the lateral compartment and one for aseptic loosening.

Finally, whether or not to perform DAIR for an infected UKR continues to be a topic of debate. We have shown DAIR for infected UKRs has a success rate of about one in two, however, in cases of successful infection eradication and implant survival, the mean OKS was 43.7 [23]. This is similar to what would be expected following an uncomplicated UKR at our unit (mean 10 year OKS 40) [24–26], and better than what would be expected following a one or two stage revision to a TKR [27]. As infection is rare following UKR there is a paucity of data to guide clinical decision making. It is likely in acute PJI DAIR will have the lowest costs and likely provides the best function but, at the cost of an increased failure rate. Single-stage revision will have intermediate costs, intermediate function and likely a failure rate better than DAIR but marginally worse than two-stage. Two-stage will have the highest costs, worst function but likely the lowest failure rate. Thus the optimum treatment strategy will need to be tailored to individual patients and the likelihood of success of each of these treatment strategies. On the basis of our results we continue to use DAIR as our treatment of choice for acute early infection following UKR as when successful functional outcomes are excellent and there is no evidence to suggest that early DAIR compromised the outcome of subsequent revision if required [28].

We acknowledge several limitations of the present study. This is a small, yet complete, retrospective series with no comparison group. Due to the limited numbers and average follow up of 5 years we cannot make long term predictions about the effectiveness of DAIR for longer than 5 years. As our routine treatment for early PJI after UKR is DAIR we have concluded that the incidence of early PJI after UKR matches this however some infection may be acquired at the time of index surgery but present later and therefore be classified as chronic PJI and as such this may under estimate the incidence but does not change the interpretation of the results as DAIR is not an appropriate treatment for chronic PJI. Finally, whilst we are confident that patients did not receive any further operations than those listed and did not receive chronic antibiotic suppression we cannot

be sure that patients have not received additional short courses of antibiotics from other sources although believe initiation of suppressive antibiotics which consulting our specialist service to be unlikely. To our knowledge, this is the largest series available in the literature reporting the success and functional outcome of DAIR for UKR PJI with mid-term follow up.

In conclusion, early (<3 months) deep infection after UKR is rare (approximately 0.3%). DAIR was successful in eradicating the infection in just over half of the cases. Despite the relatively low success rate, as the functional outcome in successful cases was excellent, we would recommend DAIR as the first line treatment for acute early infection following UKR.

CRediT authorship contribution statement

S. Asadollahi: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **T.W. Hamilton:** . **S. Sabah:** Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **M. Scarborough:** Conceptualization, Data curation, Writing – review & editing. **A.J. Price:** . **C.L.M.H. Gibbons:** Conceptualization, Data curation, Investigation, Supervision, Writing – original draft, Writing – review & editing. **DW. Murray:** . **A. Alvand:** Conceptualization, Data curation, Formal analysis, Investigation, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The author or one or more of the authors have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article. In addition, benefits have been or will be directed to a research fund, foundation, educational institution, or other non-profit organisation with which one or more of the authors are associated.

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References

[1] Li HK et al. Oral versus intravenous antibiotics for bone and joint infection. N Engl J Med 2019;380(5):425–36.
[2] Alvand A, Carrington R. Surgical strategies for management of infection following knee arthroplasty and arthroscopic procedures. Orthopaed Trauma 2019;33(3):166–74.
[3] Gehrke T, Alijanipour P, Parvizi J. The management of an infected total knee arthroplasty. Bone Joint J 2015;97B(10 Suppl A):20–9.
[4] Cochran AR et al. Risk of reinfection after treatment of infected total knee arthroplasty. J Arthroplasty 2016;31(9 Suppl):156–61.
[5] Hernandez NM et al. Infection after unicompartmental knee arthroplasty: a high risk of subsequent complications. Clin Orthop Relat Res 2019;477(1):70–7.
[6] Chalmers BP, Chiu Y-F, Henry M, Miller AO, Carli AV. Treatment and outcome of periprosthetic joint infection in unicompartmental knee arthroplasty. J Arthroplasty 2020.
[7] Labruyere C et al. Chronic infection of unicompartmental knee arthroplasty: one-stage conversion to total knee arthroplasty. Orthop Traumatol Surg Res 2015;101(5):553–7.
[8] Singer J et al. High rate of infection control with one-stage revision of septic knee prostheses excluding MRSA and MRSE. Clin Orthop Relat Res 2012;470(5):1461–71.
[9] Sousa R, Abreu MA. Treatment of prosthetic joint infection with debridement, antibiotics and irrigation with implant retention – a narrative review. J Bone Jt Infect 2018;3(3):108–17.
[10] Wouthuyzen-Bakker M et al. Timing of implant-removal in late acute periprosthetic joint infection: A multicenter observational study. J Infect 2019;79(3):199–205.
[11] Grammatopoulos G et al. Outcome following debridement, antibiotics, and implant retention in hip periprosthetic joint infection-an 18-year experience. J Arthroplasty 2017;32(7):2248–55.
[12] Kunutsor SK et al. Debridement, antibiotics and implant retention for periprosthetic joint infections: A systematic review and meta-analysis of treatment outcomes. J Infect 2018;77(6):479–88.
[13] Parvizi J. New definition for periprosthetic joint infection. Am J Orthop (Belle Mead NJ) 2011;40(12):614–5.
[14] Byren I et al. One hundred and twelve infected arthroplasties treated with 'DAIR' (debridement, antibiotics and implant retention): antibiotic duration and outcome. J Antimicrob Chemother 2009;63(6):1264–71.
[15] Fillingham Y et al. What is the definition of success of surgical treatment of a patient with a periprosthetic joint infection (PJI)? What clinical, operative, microbiological and functional metrics should be considered? 2018.
[16] Qasim SN, Ashford R. The DAIR (debridement, antibiotics and implant retention) procedure for infected total knee replacement – a literature review. SICOT J 2017;3(2).
[17] Murray DW et al. The use of the Oxford hip and knee scores. J Bone Joint Surg Br 2007;89(8):1010–4.
[18] Brivio A et al. Debridement, antibiotics and implant retention (DAIR) is successful in the management of acutely infected unicompartmental knee arthroplasty: a case series. Ann Med 2023;55(1):680–8.
[19] Alvand A, De Vos FH, Scarborough M, Kendrick BJL, Jackson W, Gundle R, et al. Ten-year outcome of debridement, antibiotics, and implant retention in knee periprosthetic joint infection. AAOS annual meeting 2017: San Diego, California, 2017.
[20] Brown NM et al. Dilute betadine lavage before closure for the prevention of acute postoperative deep periprosthetic joint infection. J Arthroplasty 2012;27(1):27–30.
[21] de Jonge SW et al. Systematic review and meta-analysis of randomized controlled trials evaluating prophylactic intra-operative wound irrigation for the prevention of surgical site infections. Surg Infect (Larchmt) 2017;18(4):508–19.
[22] Goswami K et al. Polymyxin and bacitracin in the irrigation solution provide no benefit for bacterial killing in vitro. J Bone Joint Surg Am 2019;101(18):1689–97.
[23] Moonot P et al. Correlation between the Oxford Knee and American Knee Society scores at mid-term follow-up. J Knee Surg 2009;22(3):226–30.

[24] Pandit H et al. The clinical outcome of minimally invasive Phase 3 Oxford unicompartmental knee arthroplasty: a 15-year follow-up of 1000 UKAs. Bone Joint J 2015;97-B(11):1493–500.
[25] Liddle AD et al. Patient-reported outcomes after total and unicompartmental knee arthroplasty: a study of 14,076 matched patients from the National Joint Registry for England and Wales. Bone Joint J 2015;97-B(6):793–801.
[26] Price AJ, Waite JC, Svard U. Long-term clinical results of the medial Oxford unicompartmental knee arthroplasty. Clin Orthop Relat Res 2005;435:171–80.
[27] Baker P et al. Patient reported outcome measures after revision of the infected TKR: comparison of single versus two-stage revision. Knee Surg Sports Traumatol Arthrosc 2013;21(12):2713–20.
[28] Kim K et al. Failed Debridement and Implant Retention Does Not Compromise the Success of Subsequent Staged Revision in Infected Total Knee Arthroplasty. J Arthroplasty 2019;34(6):1214–1220.e1.