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Deep infection after hip hemiarthroplasty: risk factors for infection and outcome of treatments

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Aims

Deep surgical site infection (SSI) remains an unsolved problem after hip fracture. Debridement, antibiotic, and implant retention (DAIR) has become a mainstream treatment in elective periprosthetic joint infection; however, evidence for DAIR after infected hip hemiarthroplasty is limited.

Methods

Patients who underwent a hemiarthroplasty between March 2007 and August 2018 were reviewed. Multivariable binary logistic regression was performed to identify and adjust for risk factors for SSI, and to identify factors predicting a successful DAIR at one year.

Results

A total of 3,966 patients were identified. The overall rate of SSI was 1.7% (51 patients (1.3%) with deep SSI, and 18 (0.45%) with superficial SSI). In all, 50 patients underwent revision surgery for infection (43 with DAIR, and seven with excision arthroplasty). After adjustment for other variables, only concurrent urinary tract infection (odds ratio (OR) 2.78, 95% confidence interval (CI) 1.57 to 4.92; $p < 0.001$) and increasing delay to theatre for treatment of the fracture (OR 1.31 per day, 95% CI 1.12 to 1.52; $p < 0.001$) were predictors of developing a SSI, while a cemented arthroplasty was protective (OR 0.54, 95% CI 0.31 to 0.96; $p = 0.031$). In all, nine patients (20.9%) were alive at one year with a functioning hemiarthroplasty following DAIR, 20 (46.5%) required multiple surgical debridements after an initial DAIR, and 18 were converted to an excision arthroplasty due to persistent infection, with six were alive at one year. The culture of any gram-negative organism reduced success rates to 12.5% (no cases were successful with methicillin-resistant *Staphylococcus aureus* or *Pseudomonas* infection). Favourable organisms included *Citrobacter* and *Proteus* (100% cure rate). The all-cause mortality at one year after deep SSI was 55.87% versus 24.9% without deep infection.

Conclusion

Deep infection remains a devastating complication regardless of the treatment strategy employed. Success rates of DAIR are poor compared to total hip arthroplasty, and should be reserved for favourable organisms in patients able to tolerate multiple surgical procedures.

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Introduction

Deep surgical site infection (SSI) after hip hemiarthroplasty is a devastating complication with high morbidity and mortality.^{1,2} Debridement, antibiotic therapy and implant retention (DAIR) has become a mainstay in the initial treatment of deep periprosthetic joint infection (PJI). There is a growing body of evidence to support DAIR for deep infection after an elective total hip arthroplasty

(THA), with studies demonstrating implant survival of 75% to 90%.³ When DAIR fails to eradicate infection, patients may require a single or two-stage revision, and both approaches have been shown to have relatively high rates of success.⁴

Hemiarthroplasty is the most common treatment for elderly patients with displaced femoral neck fractures.⁵ Approximately 19,000 hemiarthroplasties are performed

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for hip fracture in England, Wales, and Northern Ireland each year.⁶ Rates of deep infection are high at up to 4.9% when compared to elective THA at 0.5%.⁷⁻⁹ Despite the high prevalence, there is paucity in quality evidence on the management of SSI after hemiarthroplasty. Prompt debridement and implant removal or excision arthroplasty has historically been a standard practice.¹⁰ In contrast to THA, many hemiarthroplasty stems are of a monoblock design, limiting options for bearing exchange.¹¹ With widespread use of a tapered polished stem as an implant of choice for hip hemiarthroplasty, the stem exchange is also accepted as a part of thorough debridement. Hip fracture patients are often frailer than elective patients, and have the added insult of their injury further complicating their recovery.

The purpose of this study was to assess outcomes in patients undergoing treatment for deep SSI after hip hemiarthroplasty. We also aim to report the risk factors for developing SSI after hemiarthroplasty, and factors influencing success with treatment for deep SSI.

Methods

Data source and collection. A local prospective registry data of all hip fracture admissions to our institution formed the population for this study. All trauma patients admitted to our institution (Queen's Medical Centre, Nottingham, UK) are included within the registry, which monitors the process of care, return to theatre and outcomes; these records are maintained by the admitting clinical team with data entry supported by audit personnel.

Consecutive patients who underwent a primary hip hemiarthroplasty between August 2007 and August 2018 were identified. Patients were eligible to be included in the study if they had undergone a primary hemiarthroplasty for hip fracture. Patients were excluded if they were undergoing revision surgery for periprosthetic fracture or dislocation. Patients who subsequently underwent surgery for deep infection were analyzed to assess success rates after DAIR or primary excision arthroplasty.

Demographic information, including age, sex, and medical comorbidities, were assessed to identify potential predictors of developing a SSI. Urinary tract infection (UTI) and pressure sores diagnosed either preoperatively or during the inpatient stay post-surgery were recorded. Variables within the paper were prospectively recorded within the registry during the index admission.

Each case of SSI that had been prospectively recorded was manually checked retrospectively by the authors (SC, JN) against the electronic patient record, microbiology laboratory results, and available radiological investigations to ensure data fidelity. Mortality data was cross-validated with data from the Office of National Statistics.¹² Patient records were reviewed for readmission or revision

surgery and mortality within one year of their index procedure.

Diagnosis of infection. Infection surveillance is prospective and conducted on a rolling basis, with each patient monitored for 12 months to document development of an infection. In addition to prospectively monitoring readmission and return to theatre data, surveillance is carried out in partnership with the microbiology team, who provide orthopaedics with a monthly line-listing of all positive microbiology samples that have occurred either within the trust or community settings. This line-listing is linked to the orthopaedic registry, and matched cases indicate an orthopaedic admission and a positive sample. Readmissions are prospectively reviewed by the audit team for evidence of SSI. Infection is defined and classified as deep or superficial as per the Centre for Disease Control (CDC) criteria.¹³ The pre-2013 criteria were used as the post-2013 criteria has been shown to exclude up to 10% of orthopaedic SSI.¹⁴ Our hospital (Queen's Medical Centre) is the only facility providing emergency care for our catchment population of approximately 750,000 people; infections presenting after discharge will present back to our unit and be collected in the database.

Bacteriology. Wound swabs were processed using a variety of selective media to identify aerobic and anaerobic pathogens. Samples of pus or tissue obtained during surgery were plated on non-selective agar for aerobic and anaerobic incubation, and also suspended in an enrichment broth culture. All microbiological samples were cultured for seven days.

Surgical technique. The majority of patients undergoing a hemiarthroplasty at our institution receive a cemented monoblock implant with gentamicin containing cement. It is our practice to use uncemented hip hemiarthroplasty in patients otherwise considered at high risk of developing cement implantation syndrome, or with other significant medical comorbidities. Since 2015, stem exchange without removal of the cement mantle has been advocated as part of DAIR, although this is still ultimately left to the discretion of the treating surgeon. This is a local unit policy and is based on anecdotal, rather than published, evidence.

Statistical analysis. Demographic differences between patients with and without SSI, and for patients undergoing DAIR and excision arthroplasty, were compared using Pearson's chi-squared test and independent-samples Student's *t*-test. Due to the large sample size, parametric tests were preferred, regardless of data skew. Binary multivariate logistic regression was used to adjust for potential confounders between the two groups when comparing risk factors for developing SSI and predictors of a successful DAIR at one year. A successful DAIR was defined as a retained implant in an alive patient, without the use of suppressive antibiotics, at one year post-surgery. Variables previously thought to potentially influence

Table I. Demographics in patients with and without surgical site infection.

Variable	No infection, n = 3,897, n (%)	Any SSI, n = 69, n (%)	p-value	Deep SSI only, n = 51, n (%)	p-value
Urinary tract infection	427 (10.96)	17 (24.64)	< 0.001*	11 (21.57)	0.017†
Pressure sore	40 (1.03)	3 (4.41%)	0.008†	2 (3.92)	0.039†
Cemented hemiarthroplasty	2,940 (75.44)	44 (63.77)	0.026†	33 (64.7)	0.077†
Days delayed before surgery, mean (SD)	0.52 (1.01)	0.96 (1.50)	0.019*	0.75 (1.26)	0.213*
Age, yrs, mean (SD)	82.45 (8.89)	82.20 (10.06)	0.816*	82.26 (10.83)	0.900*
Admission from institution	808 (20.85)	17 (24.6)	0.443†	13 (25.49)	0.418†
Female sex	2,779 (71.01)	49 (71.31)	0.957†	34 (66.67)	0.467†
Renal disease	495 (12.7)	8 (11.59)	0.784†	7 (13.73)	0.827†
Diabetes	601 (15.42)	16 (23.19)	0.078†	12 (23.53)	0.112†
Rheumatoid arthritis	117 (3.0)	1 (1.45)	0.452†	1 (1.96)	0.664†
Smoker	358 (9.19)	8 (11.59)	0.493†	6 (11.76)	0.527†
Steroids	125 (3.21)	0 (0.0)	0.131†	0 (0.0)	0.194†
Warfarin	225 (5.77)	5 (7.25)	0.604#	4 (7.84)	0.530†
Clopidogrel	144 (3.61)	3 (4.35)	0.776†	1 (1.96)	0.513†
Operative duration, mins, mean (SD)	94.89 (33.85)	92.20 (30.35)	0.469*	95.53 (30.51)	0.882*
Pathological fracture	45 (1.16)	1 (1.45)	0.821†	1 (1.96)	0.594†
AMT less than 7	1,373 (35.6)	25 (36.23)	0.913†	18 (35.39)	0.953†
ASA grade, mean (SD)	2.93 (0.71)	2.96 (0.65)	0.939*	2.94 (0.583)	0.889*

*Pearson's independent-samples chi-squared test.

†Students *t*-test.

AMT, Abbreviated Mental Test; ASA, American Society of Anaesthesiology; SD, standard deviation; SSI, surgical site infection.

success of DAIR that were analyzed included time from index case to DAIR, cementation and organism, and stem exchange.¹⁵

Significance was defined as *p*-value < 0.05. Endpoints of both SSI and success of DAIR were used, along with mortality at one year. Regression analysis and multiple imputation was performed using SPSS version 24.0 (SPSS, USA). Kaplan-Meier curve estimators were produced using GraphPad Prism version 8 (GraphPad, USA).

Results

Sample. A total of 3,966 eligible patients were identified. The overall rate of SSI within the cohort was 1.74%; 51 patients (1.29%) were diagnosed with a deep infection, while 18 (0.45%) were treated for a superficial SSI. More patients with SSI also had a urinary tract infection (UTI) (427 (10.96%) vs 17 (24.64%); *p* < 0.001, chi-squared test), pressure sores (40 (1.03%) vs three (4.41%); *p* = 0.008, chi-squared test), and were less likely to have had a cemented hemiarthroplasty (2,940 (75.44%) vs 44 (63.77%); *p* = 0.026, chi-squared test) than patients without SSI. Demographics are shown in Table I.

Missing data. American Society of Anaesthesiology (ASA) grade had a high level of missing data (1,304 cases; 32.87%). Due to the likelihood of collinearity with other medical comorbidities, ASA was not used in the regression model.

Missing data for other variables was in general low; 49 patients (1.24%) had at least one missing variable. Data was missing for admission source (22 cases; 0.56%), AMT (40 cases; 1.01%), and presence of a pressure sore

(nine cases; 0.23%). Due to the low level of missing data for these variables, complete case analysis was performed rather than imputation.¹⁶ A complete dataset was available for all other covariables.

Risk factors for SSI. Delay in time to surgery (OR 1.32, 95% CI 1.13 to 1.54; *p* < 0.001), (OR 2.83, 95% CI 1.60 to 5.01; *p* < 0.001, multivariable logistic regression), presence of pressure sores (OR 3.49, 95% CI 1.00 to 12.17; *p* = 0.050, multivariable logistic regression), and UTI were predictors of SSI. Only 4/17 patients with SSI and UTI (23.53%) cultured the same organism in their urine as in their wound. A cemented arthroplasty was protective when compared to an uncemented implant (OR 0.55 95% CI 0.32 to 0.97; *p* = 0.037, multivariable logistic regression). Risk factors for SSI are summarized in Table II.

Management of deep infection. One patient died with a clinically diagnosed deep SSI before a formal debridement was undertaken, leaving 50 patients available for full analysis. In all, 43 patients had a DAIR procedure to treat their SSI; eight of these patients underwent a stem exchange as part of the DAIR.

Seven patients underwent a primary excision arthroplasty. Patients selected by their operating surgeon to undergo an excision arthroplasty were older (mean age 86.14 years (SD 6.07) vs 81.54 years (SD 11.28)), and more likely to have undergone an initial uncemented hemiarthroplasty (OR 6.46, 95% CI 1.10 to 37.92; *p* = 0.390, binary logistic regression). The details of these two groups is shown in Table III.

Implant survival. Overall, DAIR with or without stem exchange as an initial strategy for infection clearance had a

Table II. Multiple logistic regression for variables influencing development of a surgical site infection.

Variable	Unadjusted odds ratio (95% CI)	p-value*	Adjusted odds ratio (95% CI)	p-value*
Cemented hemiarthroplasty	0.57 (0.35 to 0.94)	0.028	0.55 (0.32 to 0.97)	0.037
Days before surgery	1.29 (1.16 to 1.50)	0.001	1.32 (1.13 to 1.54)	< 0.001
Pressure sore	4.44 (1.34 to 14.72)	0.015	3.49 (1.00 to 12.17)	0.050
Urinary tract infection	2.71 (1.55 to 4.73)	< 0.001	2.83 (1.60 to 5.01)	< 0.001
Age, yrs	1.00 (0.97 to 1.02)	0.816	0.99 (0.99 to 1.02)	0.508
Admission from an institution	1.24 (0.71 to 2.16)	0.444	1.37 (0.70 to 2.65)	0.357
Female sex	0.99 (0.58 to 1.67)	0.957	0.96 (0.56 to 1.67)	0.895
Renal disease	1.11 (0.53 to 2.33)	0.784	0.74 (0.35 to 1.64)	0.475
Diabetes	1.66 (0.94 to 2.92)	0.081	1.74 (0.97 to 3.12)	0.063
Rheumatoid arthritis	0.48 (0.065 to 3.45)	0.462	0.63 (0.086 to 4.67)	0.653
Smoker	1.30 (0.62 to 2.73)	0.495	1.07 (0.47 to 2.46)	0.865
Steroids	29,551,390.99 (0 to 99,999,999)	1.00	0 (0 to 99,999,999)	0.996
Warfarin	1.28 (0.51 to 3.20)	0.601	1.31 (0.50 to 3.48)	0.584
Clopidogrel	0.84 (0.26 to 2.72)	0.776	1.27 (0.39 to 4.15)	0.694
Operation duration, mins	1.00 (0.99 to 1.01)	0.51	1.00 (0.99 to 1.01)	0.929
Pathological fracture	1.26 (0.17 to 9.27)	0.821	1.29 (0.17 to 9.99)	0.807
AMT less than 7	1.03 (0.63 to 1.67)	0.913	1.29 (0.71 to 2.35)	0.412

*OR calculated using binary logistic regression.

AMT, Abbreviated Mental Test; CI, confidence interval.

Table III. Patient characteristics treated with Debridement, antibiotic, and implant retention (DAIR) and excision arthroplasty.

Variable	DAIR, n = 43, n (%)	Excision arthroplasty, n = 7, n (%)	p-value
Cemented hemiarthroplasty	31 (72.01)	2 (28.57)	0.024[†]
Age, yrs, mean (SD)	81.54 (11.28)	86.14 (6.07)	0.130*
Admission from an institution	9 (20.93)	3 (43.86)	0.208 [†]
ASA grade, mean (SD)	2.84 (0.58)	3.25 (0.50)	0.202*
Female sex	29 (67.44)	5 (71.43)	0.834 [†]
Renal disease	5 (11.63)	2 (11.63)	0.231 [†]
Diabetes	9 (20.93)	2 (28.57)	0.651 [†]
Rheumatoid arthritis	1 (2.33)	0 (0.0)	0.684 [†]
Smoker	6 (13.95)	0 (0.0)	0.292 [†]
Steroids	0 (0.0)	0 (0.0)	N/A
Warfarin	3 (6.98)	1 (14.29)	0.509 [†]
Clopidogrel	1 (2.33)	0 (0.0)	0.684 [†]
Urinary tract infection	10 (23.26)	1 (14.28)	0.576 [†]
Pressure sore	2 (4.76)	0 (0.0)	0.556 [†]
Pathological fracture	1 (2.33)	0 (0.0)	0.684 [†]
AMT less than 7	14 (32.56)	4 (57.14)	0.209 [†]
Time from index case to infection diagnosis, mean (SD)	21.89 (27.37)	24.29 (10.92)	0.731*

Significant differences are shown in bold.

*Pearson's independent-samples chi-squared test.

[†]Students t-test.

AMT, Abbreviated Mental Test; DAIR, debridement, antibiotic, and implant retention; SD, standard deviation.

success rate of 20.93% (nine patients still alive and with a hemiarthroplasty in situ at one year). Only seven patients (16.28%) survived to one year with their original implant in situ (two patients of the nine DAIR successes had undergone a stem exchange). Of the original 43 DAIRs, 15 patients (34.88%) subsequently underwent an excision arthroplasty due to persistent infection after DAIR. Three of these patients (7.3%) were subsequently revised to either a THA (two patients) and cemented hemiarthroplasty (one patient). Overall, 8/43 DAIR patients underwent a stem exchange as part of their treatment, of which

six patients (75%) had continuing infection requiring an eventual excision arthroplasty. Stem exchange was not significantly more successful in clearing infection than debridement alone (2/8 (25%) vs 7/35 (20%; $p = 0.754$, chi-squared test).

No patient who underwent an excision arthroplasty as the first revision surgery underwent re-insertion of an arthroplasty. The mean number of procedures for infection in the excision arthroplasty group was 1.14 (SD 0.380) compared to 1.74 (SD 0.93) in the DAIR group.

Table IV. Outcomes after treatment by organism. The total number of organisms are greater than the number of patients with infection to the presence of polymicrobial infection.

Organism	n	Success of DAIR, Alive at one year, n (%)	
DAIR	43		
Gram-positive organisms			
Methicillin-sensitive <i>Staphylococcus aureus</i> (MSSA)	13	3 (23.07)	6 (46.15)
Methicillin-resistant <i>Staphylococcus aureus</i> (MRSA)	4	0 (0.0)	2 (50.0)
Coagulase negative staphylococci	13	5 (38.46)	7 (53.85)
<i>Streptococcus</i>	6	1 (16.67)	2 (33.33)
<i>Citrobacter</i>	1	1 (100)	1 (100)
<i>Corynebacterium</i>	3	1 (33.33)	1 (33.33)
<i>Proteus</i>	2	2 (100)	2 (100)
Diphtheroid	7	1 (14.29)	4 (57.14)
<i>Enterococcus</i>	7	2 (28.57)	4 (57.14)
<i>Clostridium</i>	1	0 (0.0)	0 (0.0)
Gram-negative organisms			
<i>Pseudomonas</i>	5	0 (0.0)	2 (40.0)
Coliform	7	2 (28.57)	5 (71.42)
<i>Klebsiella</i>	1	0 (0.0)	0 (0.0)
<i>Enterobacter</i>	4	0 (0.0)	0 (0.0)
No growth	2	0 (0.0)	1 (50.0)
Gram-positive organisms only	27	8 (29.63)	12 (44.44)
Gram-positive only, excluding MRSA	24	8 (33.33)	11 (45.83)
Gram-negative organisms only	5	0 (0.0)	2 (40.0)
Mixed gram-positive and gram-negative	11	2 (18.18)	6 (54.54)
Infection with any gram-negative organism (gram-negative or mixed)	16	2 (12.50)	8 (50.0)
Excision arthroplasty			
MRSA	2	N/A	0 (0.0)
MSSA	2	N/A	0 (0.0)
Group B <i>Streptococcus</i>	1	N/A	1 (100)
<i>Klebsiella</i>	1	N/A	1 (100)
<i>Corynebacterium</i>	1	N/A	0 (0.0)
<i>Proteus</i>	1	N/A	0 (0.0)
<i>Pseudomonas</i>	1	N/A	0 (0.0)

DAIR, debridement, antibiotics, and implant retention; N/A, not applicable.

Infection with methicillin-resistant *Staphylococcus aureus* (MRSA), *Pseudomonas*, or *Enterobacter* also had unfavourable outcome. Certain gram-positive organisms appeared to be more favourable; *Citrobacter* and *Proteus* infections both had cure rates of 100% following DAIR. The causative organisms and resulting success rates of DAIR and excision arthroplasty are shown in Table IV.

Staphylococcus aureus was the most common organism cultured in patients undergoing a primary excision arthroplasty (4/9; 44.44%). MRSA and *Pseudomonas* had a poor outcome, with 100% mortality at one year despite implant removal.

We were unable to identify a statically significant predictor of DAIR success. No DAIR was successful if performed over 32 days from the index procedure. Analyzed variables are reported in Table V.

Mortality. The overall mortality at one year after a deep SSI was 55.87%, compared to 24.9% for patients without infection ($p < 0.0001$, log rank test). Overall, 21/43 patients (48.84%) were alive at one year after an attempted DAIR compared to 2/7 (28.57%) after a primary excision arthroplasty ($p = 0.0081$, log rank test). Differences in survivorship of patients with no infection, DAIR and excision arthroplasty over one year following their index procedure are shown in Figure 1.

Discussion

The most appropriate treatment of an infected hemiarthroplasty remains controversial.¹⁷ Overall, success rates for DAIR were lower in this study than those reported after elective hip arthroplasty.³ Success rates in the few small studies on DAIR after hemiarthroplasty range from 22% to 82%.¹⁷⁻¹⁹ This wide range of success rates may be due to variations in study design. Kazimoglou et al²⁰ reported a success rate of 41% in 39 patients at one year, but counted death deemed not due to infection as a successful DAIR. The highest success rate (82%)

Table V. Multiple logistic regression for potential predictors of debridement, antibiotic, and implant retention (DAIR) success.

Variable	Unadjusted odds ratio (95% CI)	p-value*	Adjusted odds ratio (95% CI)	p-value*
Stem exchange	1.33 (0.22 to 8.08)	0.750	2.04 (0.26 to 16.33)	0.501
Time between index procedure and DAIR, days	0.97 (0.90 to 1.04)	0.331	0.97 (0.90 to 1.05)	0.487
Cemented hemiarthroplasty	4.00 (0.44 to 36.15)	0.217	3.62 (0.36 to 36.07)	0.272
Not multi-resistant or gram-negative organism	5.60 (0.63 to 49.95)	0.123	6.16 (0.65 to 58.84)	0.114

*Binary logistic regression.

CI, confidence interval.

Factors influencing success of DAIR. The majority of causative organisms grown from deep tissue samples were gram-positive (77.8% of organisms cultured); 40.5% of infections were caused by a single gram-positive organism ($n = 17$; 27.8% success rate of DAIR). Isolated gram-negative infections were relatively uncommon ($n = 5$; 11.9%), but had a 100% failure rate.

was reported by Mellner et al,¹⁸ who also reported a high rate of deep SSI (4.5%). The onset of infection was earlier following the index surgery than in our study, with 26/28 patients treated with DAIR within seven days of the index procedure, whereas the average time to treatment for infection in our series was 22 days. This study also

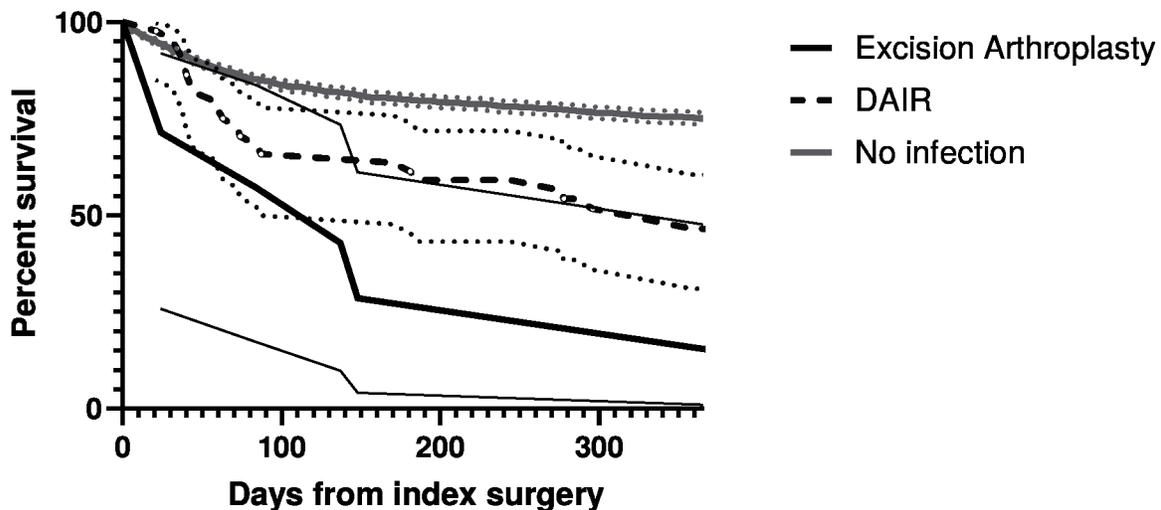


Fig. 1

Patient survival at one year, with 95% confidence interval, following debridement, antibiotic, and implant retention (DAIR), excision arthroplasty, or no infection.

reported on hemiarthroplasty and THA, whereas we report on hemiarthroplasty alone.

Over the last decade, improvements in hip fracture care have led to improved outcomes.²¹ Disappointingly, outcomes after deep SSI do not appear to have improved over the same time.^{1,2} We found that deep infection significantly reduced survival at one year, with mortality rates after infection essentially unchanged in our unit since 2004.² Mortality after an excision arthroplasty was higher than after DAIR; however, the excision arthroplasty patients were older and were more likely to have undergone an initial uncemented hemiarthroplasty, suggesting greater frailty.

We did not collect patient-reported outcomes in this study. Previous studies of deep SSI in THA have shown that patients who retain a functioning hip arthroplasty have higher patient-reported outcome scores.^{22,23} Following excision arthroplasty, patients report lower health status than after lower limb amputation or myocardial infarction.²²

Factors influencing success of DAIR. Several factors, including time from index procedure to onset of infection, have previously been shown to influence success rates of DAIR within elective arthroplasty.²⁴ We were unable to identify statistically significant predictors of a successful DAIR, perhaps partially due to the smaller sized cohort of deep infections available within our dataset. Stem exchange, leaving the cement mantle intact where present, demonstrated a marginally greater success rate compared to debridement and antibiotics alone; this difference was not statistically significant (7/34 (20.59%) vs 2/9 (22.22%); $p = 0.915$, chi-squared test). Multi-drug resistant organisms and polymicrobial infections have been shown to significantly reduce the rates of successful infection clearance, either by DAIR or two-stage revision.²⁵ We found that

success rates of DAIR after hip fracture may be influenced by the causative organism. Patients with certain gram-positive organisms had more favourable success rates of over 60% compared to patients with any gram-negative organism; in these cases, rates of success were around 12%. None of the patients with MRSA or *Pseudomonas* SSI had an implant at one year post-surgery.

Risk factors for SSI. Given the overall poor outcomes after deep infection, prevention of SSI remains a priority in hip fracture care. We identified several potential risk factors for the development of SSI.

Pressure sores offer an entry site for bacteria, with a resulting risk of sepsis and haematological spread to the new implant.²⁶ UTI has previously been reported as a risk for infection in elective arthroplasty.²⁷ Cemented arthroplasties had a lower risk of infection; antibiotic eluting bone cement, which is standard in our unit for cemented hemiarthroplasty, has been shown to be protective of SSI.²⁸ We hypothesize that delay to theatre may allow patients to be colonized by resistant organisms, or can reflect times when the surgical case intensity is high. By addressing the identified risk factors, we would hope to be able to reduce rates of infection further.

Limitations. We detected differences in the demographics of patients undergoing DAIR and excision arthroplasty. Selection bias in treatment allocation is always possible in a retrospective and non-randomized study. While deep infection after hemiarthroplasty is devastating, the incidence was low in our cohort. The lower number of DAIRs limited the number of variables that could be included within the regression analysis. Some patients may have moved out of our institution's catchment area during the study period; these patients would be missing from the subsequent analysis if they presented with infection to a different institution. Also, only variables

recorded accurately and with sufficient detail within the prospective registry were available for analysis. It is possible that other variables, not analysis, in this study may be significant predictors of infection. Lastly, it could be argued that our criteria for a “success” as an alive patient with a functioning implant at one year was too ambitious. For many hip fracture patients after deep infection, survival in comfort and discharge from hospital may be sufficient. Cause of death was not available for patients within the study. Using a shorter follow-up period to be infection-free would potentially miss recurrent or persistent infection and artificially inflate the success of DAIR, while longer-term follow-up was limited by the already poor long-term survival after infection.²⁹

Recommendations. Our study suggests that DAIR may best be used for patients with a favourable organism and the physiological reserve to tolerate repeat surgeries. As DAIR does not appear to negatively affect mortality when compared to excision arthroplasty, it would seem reasonable to perform as an initial treatment in the presence of suspected deep SSI. Should the patient fail to respond to the initial DAIR, or an unfavourable organism is cultured (gram-negative or multi-drug resistant), then an excision arthroplasty should be performed rather than recurrent washouts or stem exchange. If infection clearance is achieved, reimplantation may be safely performed in select patients. Patients and relatives should be counselled as to the catastrophic effects of PJI after hemiarthroplasty, and the significant risk of the patient ending up with no implant. Unless otherwise contraindicated, cemented arthroplasty should be preferred to reduce rates of SSI. These recommendations are, however, greatly limited by the relatively low sample size and retrospective nature of the analysis in this study.

In conclusion, DAIR has a low chance of success after an infected hip hemiarthroplasty compared to the rates reported in elective practice. The outcome of PJI deep SSI following a hip hemiarthroplasty is poor at one year, regardless whether implant retention is attempted or not. Should the patient fail to respond to the initial DAIR, or an unfavourable organism is cultured, then an excision arthroplasty should be performed rather than recurrent washouts or stem exchange. Deep infection remains an unsolved problem in this vulnerable patient cohort, and avoidance of infection remains key.



Take home message

- Debridement, antibiotic, and implant retention (DAIR) has a low chance of success after an infected hip hemiarthroplasty.
- In patients failing to respond to the initial DAIR, or an unfavourable organism is cultured, then an excision arthroplasty should be performed, rather than recurrent washouts or stem exchange.
- Deep infection remains an unsolved problem in this vulnerable patient cohort, and avoidance of infection remains key.

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