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INFECTION

Mortality and re-revision following single-stage and two-stage revision surgery for the management of infected primary hip arthroplasty in England and Wales

DATA FROM THE NATIONAL JOINT REGISTRY

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Aims

We compared the risks of re-revision and mortality between two-stage and single-stage revision surgeries among patients with infected primary hip arthroplasty.

Methods

Patients with a periprosthetic joint infection (PJI) of their primary arthroplasty revised with single-stage or two-stage procedure in England and Wales between 2003 and 2014 were identified from the National Joint Registry. We used Poisson regression with restricted cubic splines to compute hazard ratios (HRs) at different postoperative periods. The total number of revisions and re-revisions undergone by patients was compared between the two strategies.

Results

In total, 535 primary hip arthroplasties were revised with single-stage procedure (1,525 person-years) and 1,605 with two-stage procedure (5,885 person-years). All-cause re-revision was higher following single-stage revision, especially in the first three months (HR at 3 months = 1.98 (95% confidence interval (CI) 1.14 to 3.43), p = 0.009). The risks were comparable thereafter. Re-revision for PJI was higher in the first three postoperative months for single-stage revision and waned with time (HR at 3 months = 1.81 (95% CI 1.22 to 2.68), p = 0.003; HR at 6 months = 1.25 (95% CI 0.71 to 2.21), p = 0.441; HR at 12 months = 0.94 (95% CI 0.54 to 1.63), p = 0.819). Patients initially managed with a single-stage revision received fewer revision operations (mean 1.3 (SD 0.7) vs 2.2 (SD 0.6), p < 0.001). Mortality rates were comparable between these two procedures (29/10,000 person-years vs 33/10,000).

Conclusion

The risk of unplanned re-revision was lower following two-stage revision, but only in the early postoperative period. The lower overall number of revision procedures associated with a single-stage revision strategy and the equivalent mortality rates to two-stage revision are reassuring. With appropriate counselling, single-stage revision is a viable option for the treatment of hip PJI.

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Article focus

- The two-stage revision strategy has traditionally been considered the gold standard, but there has been an increasing interest in the use of the single-stage revision strategy, as the patient only requires

one surgical procedure with potentially better patient outcomes such as shorter overall hospital stay, quicker recovery, and notable cost benefits.
- Meta-analyses have shown conflicting evidence, but they suffer from data scarcity on one-stage periprosthetic joint infection (PJI) revision, heterogeneity between pooled studies, and small sample sizes.
- No study has compared mortality outcomes between the two PJI revision strategies.

Key messages

- The risk of re-revision for PJI was higher following single-stage revision but only in the first three months following surgery and comparable to two-stage revision thereafter, and patients treated with single-stage revision underwent fewer planned and unplanned operations in total.
- The mortality following both PJI revision approaches was comparable, but higher than the mortality following primary hip arthroplasty and non-septic revision.

Strengths and limitations

- These results are based on observational data and are therefore subject to potential biases contrary to findings from the INFORM trial.
- They are based on the National Joint Registry data from all orthopaedic units in England and Wales, providing findings that can be directly generalizable to any orthopaedic practices in the NHS.

Introduction

Although total hip arthroplasty is a highly successful treatment with implants lasting on average more than 25 years,[1] periprosthetic joint infection (PJI) is a serious adverse event affecting about 1% of patients,[2,3] reported worldwide,[4,5] who face complex and protracted treatments.

The use of antibiotics can reduce the risk of infection.[6,7] Accurate diagnoses are required to ascertain the presence of an infection,[8-10] but when infection affects the joint replacement or the host tissue immediately around it, surgical treatment is required if the intention is to eradicate the PJI. Antibiotic treatment alone merely suppresses the PJI due to the rapid development of biofilms on implants.[11] Around half of patients diagnosed with PJI subsequently undergo revision surgery.[12] Debridement, antibiotic treatment, and implant retention with exchange of modular components (DAIR) can successfully eradicate infection in about 60% of cases.[13] As DAIR cannot eradicate biofilm once it is formed on the implant interfaces, the outcomes are different from revision surgery where all implants are replaced. The majority of patients undergoing revision for PJI require either single- or two-stage revision.[11]

In the more commonly used two-stage revision strategy, patients require two planned surgeries and an interim period during which they experience limited hip function, as well as pain, disability, and uncertainty.[14] The alternate single-stage strategy with implant removal and re-implantation in a single operation (under a single anaesthetic) has been used extensively at the EndoKlinik in Germany,[15,16] and increasingly in the USA. In England and Wales, one-third of the revisions for PJI are performed with this strategy. This proportion is increasing.[2]

Previously there had been no randomized controlled trial (RCT) published comparing single- and two-stage revision for PJI of the hip, but a multicentre RCT has since been completed and the outcomes published.[17] Systematic reviews have shown comparable risk of reinfection, but are based on small studies with major methodological limitations.[18–22] Recent larger registry and cohort studies are conflicting, showing higher[23,24] or similar[25] risk of revision for PJI for single-stage revision compared to two-stage revision. Most surgical practices throughout the world are not following the advocated criteria,[26] leading to uncertainty in the choice of the best management strategy.[20]

Patients undergoing revision for PJI also have a higher risk of mortality compared with patients undergoing primary arthroplasty or aseptic revision.[27–31] However, no study has compared mortality outcomes between the two PJI revision strategies.

It is also unclear whether patients managed with a single-stage revision are undergoing a larger number of additional re-revision procedures to manage their infection and any further complications than those treated with a two-stage revision.

Given the current evidence gaps, we analyzed the cohort of all 2,140 infected primary hip arthroplasties revised with single-stage or two-stage surgeries in England and Wales to compare their all-cause risk and PJI-specific risk of re-revision, their overall revision burden, and risk of mortality.

Methods

Study design and data sources. In this retrospective analysis of prospectively collected data, we used information for England and Wales from the National Joint Registry for England, Wales, Northern Ireland, the Isle of Man, and the States of Guernsey (NJR). Linked data included the Personal Demographics Service of the Office for National Statistics (ONS), to obtain date of death where patients had died following treatment. This output was part of the National Institute for Health and Care Research (NIHR) Programme Grants for Applied Research Programme 'Infection after total joint replacement of the hip and knee', which was granted NJR scientific committee permission to analyze the data reported in this manuscript. Patient consent was obtained for data collection and linkage by the NJR. According to the NHS Health Research Authority, separate consent and ethical approval were not required for this study.

Procedures and outcomes. We included patients with a primary hip arthroplasty, subsequently reported to be revised for PJI with a single- or two-stage procedure by the

Table I. Characteristics and outcomes of initial revision procedures for periprosthetic joint infection.

Characteristic	Single-stage					Two-stage					p-value
	n	Person-years	Cases	Rate*	95% CI	n	Person-years	Cases	Rate*	95% CI	
Total, n	535					1,605					
Sex (male), n (%)	272 (50.8)					881 (54.9)					0.102¶
Mean age, yrs (SD)	68 (11.0)					66 (11.0)					< 0.001**
Age (yrs), n (%)											
< 60	105 (19.6)					359 (22.4)					0.001¶
60 to 69	163 (30.5)					575 (35.8)					
70 to 79	186 (34.8)					516 (32.2)					
≥ 80	81 (15.1)					155 (9.7)					
ASA grade, n (%)											
1	55 (10.3)					168 (10.5)					0.458¶
2	339 (63.4)					971 (60.5)					
3 to 5	141 (26.4)					466 (29.0)					
Re-revised (all-cause), n (%)											
Total	535	1,525	88 (100)	57.7	46.3 to 71.1	1,605	5,885	223 (100)	37.9	33.1 to 43.2	0.003††
with single-stage			45 (51.2)					109 (48.9)			
with two-stage†			42 (47.7)					67 (30.0)			
with repeated Stage 1‡			N/A					35 (15.7)			
with other			1 (1.1)					12 (5.4)			
Re-revised (PJI only), n (%)											
Total	535	1,525	54 (100)	35.4	26.6 to 46.2	1,605	5,885	133 (100)	22.6	18.9 to 26.8	0.031††
with single-stage			18 (33.3)					28 (21.1)			
with two-stage			35 (64.8)					60 (45.1)			
with repeated Stage 1			N/A					35 (26.3)			
with other			1 (1.9)					10 (7.5)			
Deceased, n											
Total	535	1,789	52	29.1	21.7 to 38.1	1,959§	7,608	252	33.1	29.2 to 37.5	0.593††
≤ 90 days	535	1,789	5	2.8	0.9 to 6.5	1,959	7608	19	2.5	1.5 to 3.9	

*Per 10,000 person-years.
†A total of 53 (24/42 and 29/67) of the 109 (42 + 67) two-stage re-revision procedures had no stage 1 operation recorded in the NJR.
‡A total of 24 patients received an additional stage 1 procedure prior to stage 2, and 11 patients received multiple stage 1 procedures but no stage 2.
§N = 1,959 two-stage procedures including 1,047 procedures with both one stage 1 and one stage 2 operations recorded in the NJR, 35 procedures with multiple stage 1 prior to stage 2 (the repeated stage 1 procedure is counted as a re-revision), 523 procedures with only stage 2 operations recorded (1047 + 35 + 523 = 1605), and 354 procedures for which only the stage 1 procedure was performed.
¶Chi-squared test.
**Independent-samples *t*-test.
††Wald test.
ASA, American Society of Anesthesiologists; CI, confidence interval; N/A, not applicable; NJR, National Joint Registry; PJI, periprosthetic joint infection; SD, standard deviation.

operating team. Those revised with DAIR procedures and excision arthroplasties were excluded (Supplementary Figure a).

We used the NJR component level data to identify which implants were recorded as being removed and/or implanted, and therefore to identify the precise type of revision procedure. We considered an initial revision for PJI as re-revised if there was a record in the NJR between 1 April 2003 and 31 December 2014 of a subsequent procedure that was in addition to the planned one (single-stage) or two (two-stage) procedures where an implant was added, changed, or removed. The individual and distinct procedures of a two-stage revision are labelled 'stage 1' and 'stage 2'. We also considered two-stage revision to have undergone an additional revision if the patient underwent repeated stage 1 procedures before a stage 2 procedure. We consider single-stage revisions and complete two-stage revisions (after a stage 2 of 2 revision was performed) re-revised if the planned revision procedures were followed by any further revision episode where implants were changed as defined above.

We considered all-cause re-revision and re-revision specifically for PJI. The indication for surgery was recorded by the surgical team at the time of the procedure.

Primary arthroplasties not revised, or revised for a non-septic indication, were used as comparators in the mortality analysis, excluding from the 'non-septic revision' comparator group primary procedures initially revised for a non-septic indication prior to a re-revision for PJI.

Incomplete two-stage revisions, where patients only received a single stage 1 but no stage 2 of a two-stage revision procedure or no further stage 1 reoperation, were excluded from the re-revision analyses but included in the mortality analysis.

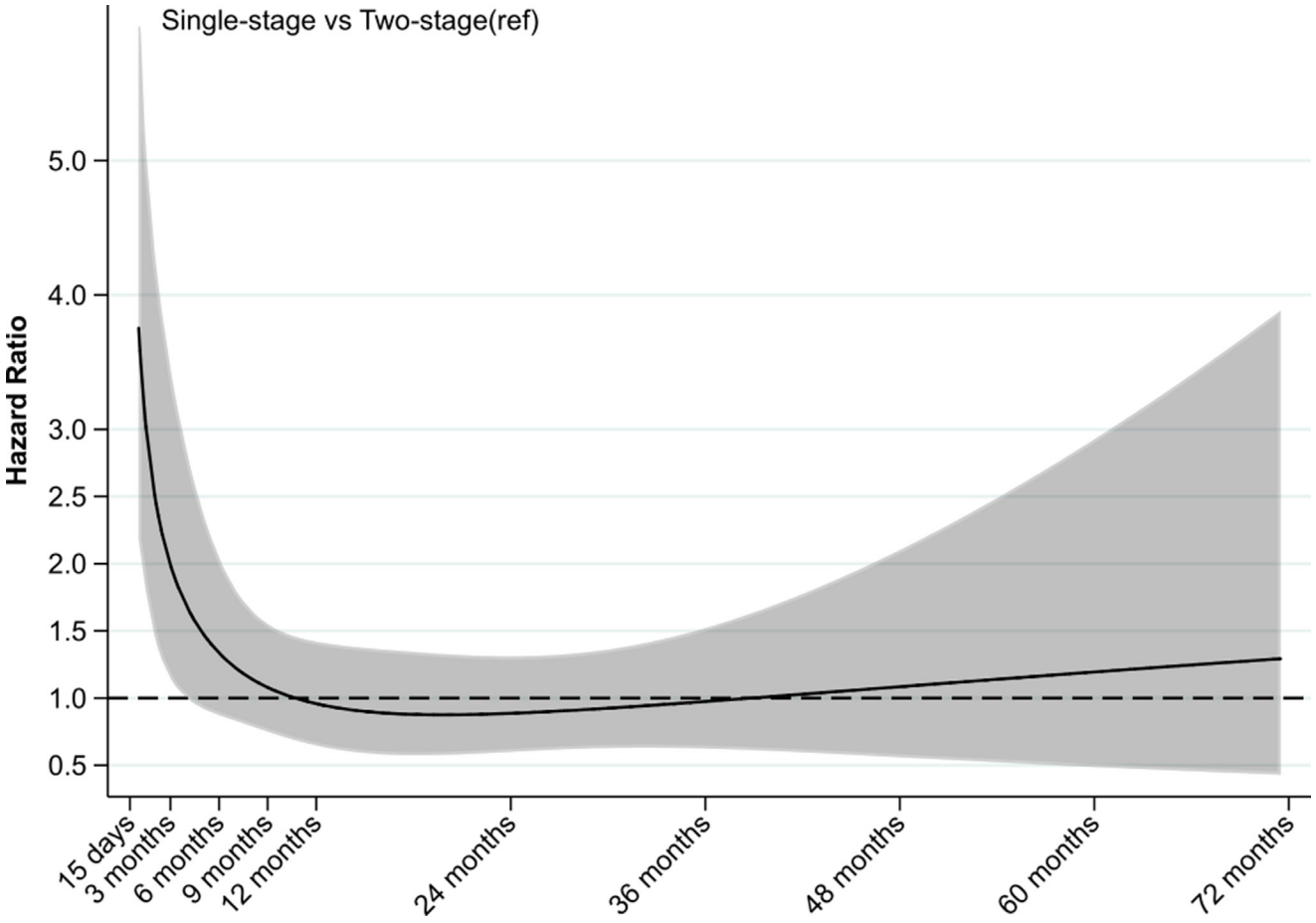

Fig. 1

Hazard ratios (HRs) (95% confidence interval) of all-cause re-revision between revision procedures performed to manage infected primary hip arthroplasty. HRs are adjusted for age, sex, and American Society of Anesthesiologists grade. The HRs are reported between one and 72 months (six years) postoperative due to a small number of reoperations and/or person-years observed thereafter.

Statistical analysis. Kaplan-Meier analyses were performed to assess the cumulative re-revision incidence for any cause, for PJI, and mortality incidence by study group. The derivation of the time at risk is detailed in the Supplementary Material. We used Cox shared frailty models to account for within-hospital correlation and compute overall hazard ratios (HRs) of re-revision/mortality for the first two years following the single-stage revision and for the first five years (two-stage used as the reference).

We then produced time-dependent HRs using Poisson regression, modelling the baseline hazard function with restricted cubic splines,[32] to capture time-specific disparities throughout the postoperative period between the two PJI revision procedures (Supplementary Table i). These regressions were adjusted for age, sex, and American Society of Anesthesiologists (ASA) grade.[33] Further details are provided in the Supplementary Material. Patients with a primary procedure not revised or revised for a non-septic indication were used as comparator groups in the mortality analysis.

We performed sensitivity analysis for each of the above models without patients with incomplete two-stage revision, i.e. no stage 1 recorded and only a stage 2 procedure recorded for their first PJI revision following the primary hip arthroplasty.

We compared the revision burden by type of PJI revision (single- or two-stage) using zero-truncated Poisson model. The revision burden included all procedures recorded in the NJR from the first single-stage or first stage 1 of two-stage procedure for PJI following the primary procedure to the last recorded re-revision procedures.

We conducted the analyses with Stata 15.1 (StataCorp, USA). The level of significance was set at $p < 0.05$. Independent-samples *t*-test and chi-squared test were used to compare means and proportions, respectively. Wald test was used to investigate the regression coefficients.

Results

Between 2003 and 2014, 2,140 primary hip arthroplasties were subsequently revised for PJI, 535 with a single-stage

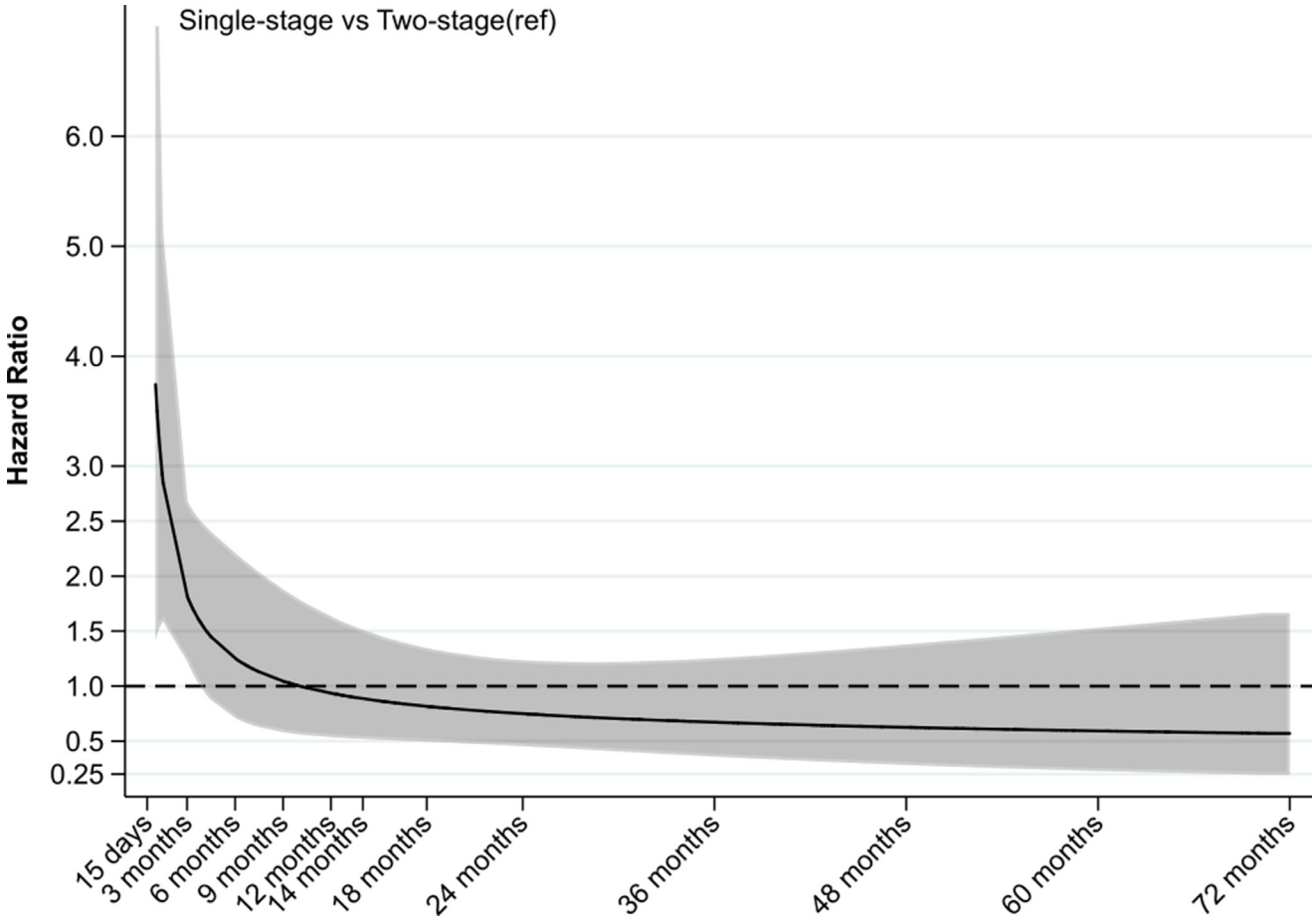

Fig. 2

Hazard ratios (95% confidence interval) of re-revision for periprosthetic joint infection between revision procedures performed to manage infected primary hip arthroplasty. Hazard ratios (HRs) are adjusted for age, sex, and American Society of Anesthesiologists grade. HRs are reported between one and 72 months (six years) postoperative due to a small number of reoperations and/or person-years observed thereafter.

procedure and 1,605 with a two-stage procedure (Supplementary Figure a). Patients revised with a single-stage procedure were older than patients revised with a two-stage procedure (Table I).

All-cause re-revision. Of the 2,140 primary hip arthroplasties revised for PJI, 311 revisions for PJI subsequently underwent re-revision for any cause (Table I). The incidence rate of all-cause re-revision following single-stage revision was 58/10,000 person-years (95% confidence interval (CI) 46 to 71) compared with 38/10,000 (95% CI 33 to 43) following two-stage revision (p = 0.006, Wald test). The adjusted risk of re-revision for the first two postoperative years was higher following single-stage revision than two-stage revision (HR overall 2 years = 1.54 (95% CI 1.15 to 2.07), p = 0.004, Wald test); the risk was also higher for the first five postoperative years (HR overall 5 years = 1.52 (95% CI 1.17 to 1.97), p = 0.002, Wald test). These overall differences are driven by the early postoperative period as shown by the time-specific differences in failure (Supplementary Figure b); compared with two-stage revision for hip PJI (Figure 1), the adjusted risk of all-cause re-revision was higher in the single-stage group in the first three postoperative months (HR at 3 months = 1.98 (95% CI 1.14 to 3.43), p = 0.009, Wald test). The risks were comparable thereafter (Supplementary Table ii).

PJI re-revision. A total of 187 (60%) re-revisions were performed for an indication of PJI (Table I). The incidence rate of PJI re-revision following single-stage revision was 35/10,000 person-years (95% CI 27 to 46) and 23/10,000 (95% CI 19 to 27) following two-stage revision (p = 0.004, Wald test). The adjusted risk of PJI re-revision for the first two years and first five years postoperatively was higher following single-stage revision than two-stage revision (HR overall 2 years = 1.70 (95% CI 1.19 to 2.44), p = 0.004, Wald test; HR overall 5 years = 1.49 (95% CI 1.07 to 2.08), p = 0.022, Wald test). Again, these differences were driven by the early postoperative period (Supplementary Figure c); the incidence of re-revision for PJI was higher for single-stage revision in the first three postoperative months (HR at 3 months = 1.81 (95% CI 1.22 to 2.68), p = 0.003, Wald test; Supplementary Table iii) compared with two-stage revision, but no difference was observed thereafter (Figure 2).

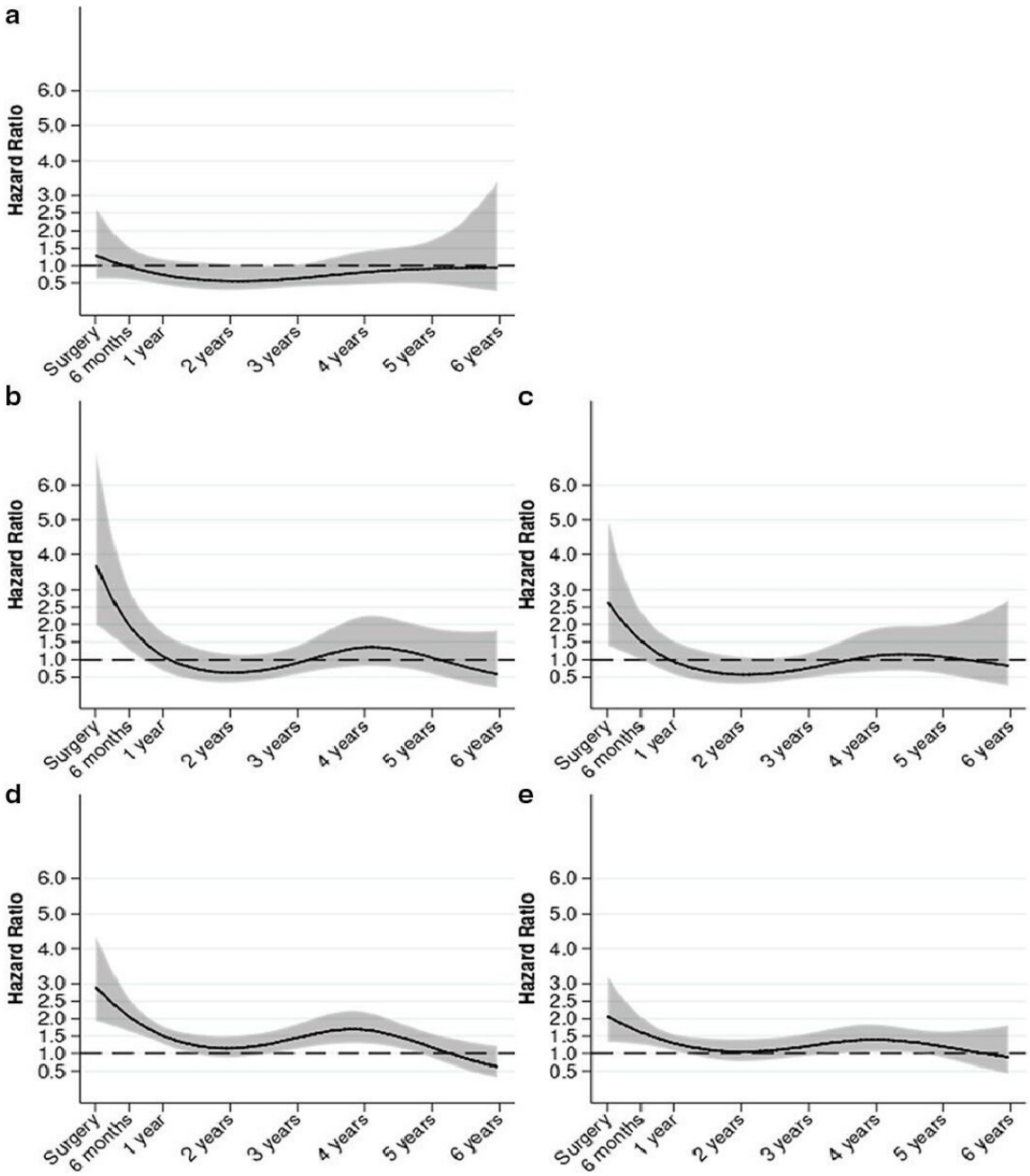

Fig. 3

Mortality hazard ratios (HRs) between revision procedures performed to manage infected primary hip arthroplasty and other arthroplasty procedures. a) Single-stage versus two-stage (reference). b) Single-stage versus primary (reference). c) Single-stage versus non-septic revision (reference). d) Two-stage versus primary (reference). e) Two-stage versus non-septic revision (reference). HRs are adjusted for age, sex, and American Society of Anesthesiologists grade. HRs are reported between one and 72 months (six years) postoperative due to a small number of reoperations and/or person-years observed thereafter. Non-septic revisions are primary hip arthroplasty revised for any indication other than periprosthetic joint infection.

Mortality. A total of 304 patients who underwent revision for hip PJI died (Table I). The mortality rates for patients revised with single- and two-stage procedures were 29/10,000 person-years (95% CI 22 to 38) and 33/10,000 person-years (95% CI 29 to 38), respectively (p = 0.953, Wald test).

The adjusted risks of mortality in the first two years and first five years postoperatively for PJI were comparable (HR single-stage (ref) vs two-stage 2 years = 1.05 (95% CI 0.68 to 1.62), p = 0.814; HR 5 years = 1.15 (95% CI 0.84 to 1.58), p = 0.392, all Wald test), and no time-specific difference was identified (Figure 3a, Supplementary Table iv). The Kaplan-Meier mortality function curves are shown in Supplementary Figure d.

Compared with patients who had undergone a primary arthroplasty (23/10,000 (95% CI 22.4 to 22.8)),

Table II. Number of revision procedures performed to manage infected primary hip arthroplasty by recorded type of revision.

Number of surgeries	Single-stage (n = 535)	Two-stage (n = 1,605)	p-value
Median (IQR)	1 (1 to 1)	2 (2 to 2)	< 0.001*
Mean (SD)	1.3 (0.7)	2.2 (0.6)	
One, n (%)	447 (83.6)	0 (0)	< 0.001†
Two, n (%)	44 (8.2)	1,395 (86.9)	
Three, n (%)	38 (7.1)	129 (8.1)	
Four to five, n (%)	6 (1.1)	71 (4.4)	
Six to nine, n (%)	0 (0)	10 (0.6)	

*Zero-truncated Poisson regression.
†Chi-squared test.
IQR, interquartile range; SD, standard deviation.

the mortality was higher following single-stage revision for PJI (HR primary (ref) vs single-stage overall 2 years = 1.40 (95% CI 0.95 to 2.06), p = 0.085; HR overall 5 years = 1.24 (95% CI 0.93 to 1.66), p = 0.139) and particularly following two-stage revision for PJI (HR primary (ref) vs two-stage overall 2 years = 1.48 (95% CI 1.22 to 1.76), p < 0.001; HR overall 5 years = 1.43 (95% CI 1.25 to 1.64), p ≤ 0.001, all Wald test).

Compared with patients who had undergone a revision for a non-septic indication (21/10,000 (95% CI 20 to 23)), the overall mortality rate was not different following single-stage revision for PJI (HR non-septic revision (ref) vs single-stage overall 2 years = 1.30 (95% CI 0.88 to 1.94), p = 0.187; HR overall 5 years = 1.12 (95% CI 0.83 to 1.51), p = 0.444) but was higher following two-stage revision for PJI (HR non-septic revision (ref) vs two-stage overall 2 years = 1.37 (95% CI 1.11 to 1.70), p = 0.003; HR overall 5 years = 1.29 (95% CI 1.11 to 1.50), p = 0.001, all Wald test).

These differences were not constant throughout the postoperative period (Supplementary Table iv). In the first six postoperative months, patients revised for hip PJI with a single-stage procedure were at higher risk of mortality than those who had undergone a primary arthroplasty (Figure 3b; HR at 6 months = 1.96 (95% CI 1.28 to 3.00), p = 0.002) or a revision for non-septic indication (Figure 3c; HR at 6 months = 1.54 (95% CI 1.00 to 2.37), p = 0.049). In the first 12 postoperative months, the mortality was higher following revision for PJI with a two-stage procedure than following primary arthroplasty (Figure 3d; HR at 12 months = 1.50 (95% CI 1.27 to 1.78), p < 0.001) or revision for a non-septic indication (Figure 3e; HR at 12 months = 1.29 (95% CI 1.07 to 1.55), p = 0.007, all Wald test).

Number of revision surgeries performed. The two-stage group underwent more operations than those initially managed with a single-stage procedure (p < 0.001; Table II). A total of 16.3% of single-stage patients required additional revision procedures, i.e. they underwent more than one procedure, with 8.2% re-revised three to five times. Around 13.1% of two-stage patients required additional surgeries, i.e. at least three procedures, but 5% were re-revised four to nine times.

Discussion

Single-stage revision was associated with a higher risk of unplanned re-revision for all-cause as well as further PJI. This increased risk was only evident in the first three postoperative months. Mortality rates were comparable between single-stage and two-stage revisions. The surgical burden to manage the infection and its complications was higher following two-stage revision, with around 13% of infected patients managed with three to nine procedures, compared with 8% in the single-stage group managed with three to five procedures.

These findings appear at odds with systematic reviews reporting similar rates of re-revision for PJI between single- and two-stage revision for hip PJI.[18–22] However, they focused on the risk of reinfection rather than revision for PJI. They are based on small case series, prone to selection bias, representing the experience of specialist academic centres, with few head-to-head comparisons between the two revision strategies. Evidence from registry and observational studies is conflicting, showing similar rates of re-revision[25] or worse risk of re-revision in patients receiving single-stage procedure.[23,24] Our results are aligned with these two studies and provide new insight. To date, no study has compared the surgical journey and mortality outcomes following single-stage and two-stage revisions for PJI. The higher mortality rate following revision for PJI than following primary hip arthroplasty or revision for aseptic failures is consistent with previous reports.[27–31] One study based on a small sample of 11 deaths reported lower mortality following single-stage revision for hip PJI without performing any statistical comparison.[34] It is noteworthy that the mortality rates in our study are comparable between the two groups despite two-stage surgery requiring a second major operation and the functional limitation of having no hip joint for a protracted period, with the associated restrictions in mobility. It is possible that the mortality risk is balanced by the association of single-stage revision with subsequent re-revision or the magnitude of the single surgery.

Treatment of PJI is protracted, and both the infection and treatment have profoundly negative effects on patients and their families, particularly if complications

occur between stages.[11,14,35,36] Over 60% of hip PJIs are managed with the two-stage approach in England and Wales,[2] and its cost is 1.6 to 1.7 times more than for a single-stage revision.[37,38] The two-stage strategy has some transient advantage over the single-stage revision with regard to prevention of the need for re-revision. However, with a two-stage strategy, the treatment burden for patients and families due to the greater number of surgeries, complications associated with the interim period, and prolonged periods of immobility is considerable.[14] Many patients receive a temporary spacer, but these can dislocate or fracture,[39] adding to the uncertainty. There is also a trade-off between the possibility of successful re-revision surgery after failed infection clearance in a single-stage operation and long-term antibiotic treatments between stages before reimplantation in a two-stage strategy, with associated distressing side effects[14] and concerns over antibiotic resistance.[40] Surgeons and patients need to consider the complex balance of risks and benefits of treatment strategies for the treatment of hip PJI.

RCTs are currently underway.[41–43] They are not adequately powered to show which treatment is best at eradicating infection, but will be able to ascertain the most cost-effective treatment and the treatment resulting in the best patient-reported outcomes.

This is the largest study to compare the incidence of re-revision after single-stage and two-stage revision for hip PJI. We used a standardized data collection process, examining component level data to precisely define and group comparable procedures. It is the first to map the time-varying risks throughout the postoperative period, the importance of which is demonstrated by the patterns observed. Only procedures where an implant is added, removed, or modified are captured in the NJR. We are therefore unable to explore the risks for hip PJI treated with antibiotics or incision and drainage alone, but the reoperation outcomes are substantially worse for this strategy.[13,20] This study focused on infected primary arthroplasty initially managed with a single-stage or two-stage revision procedure, and its results are generalizable to NHS patients undergoing the same treatment pathways to eradicate PJI. Like any other observational study, and the entirety of the international literature published so far on hip PJI, our results are subject to selection bias. A comprehensive audit of data quality has recently been conducted across all hospitals, which compares procedures uploaded to the registry with those recorded on the hospitals' administration systems. With around 92% of the hip revisions recorded in the NHS hospital's Patient Administration System and each independent hospital's business administration system up to 2014 captured in the NJR, the studied data have a very high national coverage.[44] It is therefore unlikely that the presented results are subject to selection bias that would restrain their interpretation. However, this study is based on the NJR, capturing most if not all hip revision PJI procedures performed in England and Wales, and such bias is likely to be small. The findings are based on the procedures performed until 2014 and may not entirely reflect the current impact and management of infection; this work remains one of the largest on the topic, with single-stage and two-stage surgeries being the current surgical strategy to manage deep PJIs that have not been controlled with other strategies. We excluded DAIR procedures due to their different indications for the procedure compared with single- or two-stage revision and worse infection control rates seen, which means that they are not equivalent interventions and cannot be directly compared.[13] Data on non-surgical treatment and surgical strategies not recorded in the NJR would have been required to investigate the overall burden of infection. Our findings therefore only provide insight into the revision strategies for infection, but this is the part of infection management considered by patients and surgeons to be very traumatic and distressing.[14,45] Our modelling accounted for the clustering of operations within an orthopaedic unit. The models failed to converge when the clustering at operating surgeon level, with or without further clustering at orthopaedic unit level, was considered; we only modelled the clustering at orthopaedic unit level as operating protocol is set at unit level, with comparable PJI operating and management culture between surgeons in the same unit. We were unable to adjust for all patient and clinical factors and residual confounding cannot be totally ruled out, but we believe the related bias to be minimal if not null. Information on immunocompromised patients, previous surgical management, bony defects, types of organisms, presence of a sinus, and duration of surgery is not captured in the NJR. Therefore, patients with easier-to-treat infections may be selected and assigned to one strategy.[46] Finally, the studied data covered the revision procedures performed until 2014. The difference between single-stage and two-stage revision may have changed over time, especially as surgeons would have become more familiar with the single-stage strategy; the early postoperative differences reported here may suggest the importance of training prior to using single-stage operation.

This study has demonstrated a higher risk of unplanned re-revisions following single-stage revision for hip PJI when compared with two-stage revision. However, despite this, those undergoing one-stage revision still on average undergo fewer operations. Mortality rates are similar between the two groups. When considered alongside the results of recent evidence synthesis, the single-stage revision strategy is a reasonable option with acceptable rates of infection control.

Supplementary material

Further methodological and results details are provided in the supplementary material.

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Data sharing:
- The data used in these analyses cannot be accessed without permission from the NJR scientific committee. Further details are available at https://www.njrcentre.org.uk/research/research-requests/. Once the required permissions are secured, the authors will be able to share the data and analytical approaches used in this manuscript.

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