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Eligibility for One-Stage Exchange Arthroplasty for Hip Periprosthetic Joint Infection Predicts Survivorship: A Retrospective Review of 368 Cases

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ABSTRACT

Background: A two-stage exchange arthroplasty is the standard treatment for chronic periprosthetic joint infection (PJI) of total hip arthroplasty (THA), though one-stage exchange arthroplasty is gaining interest. The proportion of THA PJIs eligible for one-stage exchange arthroplasty remains unclear. We aimed to determine what proportion of patients undergoing two-stage exchange arthroplasty for THA PJI met one-stage criteria and how eligibility impacted outcomes.

Methods: Between 2000 and 2020, there were 368 two-stage exchange arthroplasties for THA PJI at our institution. The mean age was 65 years, the mean body mass index (BMI) was 32, and 60% were men. The one-stage exchange arthroplasty eligibility criteria included unilateral PJI with preoperatively identified susceptible, nonfungal, and non–multi-resistant bacteria; McPherson A host status; no prior two-stage exchange arthroplasty; minimal bone or soft-tissue loss; and absence of sepsis. Cumulative incidences of reoperation for infection, re-revision for infection, any reoperation, and any re-revision were compared utilizing a competing risk model. The mean follow-up was five years.

Results: Overall, 23% met the eligibility criteria for one-stage exchange arthroplasty. The most common reasons for ineligibility were host grade (52%) and unidentified organism (25%). At two years, cumulative incidences of reoperation for infection for ineligible and eligible patients were 11 and 11%, respectively. At two years, the cumulative incidences of re-revision for infection for ineligible and eligible patients were 6 and 2%, respectively. Ineligible patients had a significantly higher 2-year cumulative incidence of any re-revision compared to eligible patients (12 versus 5%, respectively; HR [hazard ratio] = 2.5). There was no significant difference in the 2-year cumulative incidence of any reoperation between ineligible and eligible patients (18 versus 15%, respectively).

Conclusions: Only 23% of two-stage exchange arthroplasties for hip PJIs met the published eligibility criteria for one-stage exchange arthroplasty. The 2.5-fold increased hazard of any re-revision among ineligible patients must be considered when evaluating data comparing the two surgical strategies.

Level of Evidence: III (retrospective).

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A two-stage exchange arthroplasty remains the standard treatment for chronic periprosthetic joint infection (PJI) following total hip arthroplasty (THA), with studies consistently documenting good postoperative outcomes [1–5]. Recently, one-stage exchange arthroplasty has garnered major attention in the United States [6]. Despite the reported successful outcomes for one-stage exchange arthroplasty for the treatment of chronic PJI, there are insufficient data to definitively favor one approach over the other [7–12].

Investigation performed at Mayo Clinic, Rochester, MN.

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Table 1
Demographics of Eligible and Ineligible Cohorts.

Number of Hips	All (n = 368)	Ineligible (n = 284)	Eligible (n = 84)	*P*-Value[a]
Age at surgery (years)				
Mean (SD)	65 (11)	65 (12)	63 (9)	**0.042**[b]
Sex, N (%)				
Men	218 (60)	161 (57)	57 (68)	0.067[c]
Women	150 (40)	123 (43)	27 (32)	
Body mass index				
Mean (SD)	32 (8)	32 (8)	33 (7)	0.80[b]
McPherson Host Grade, N (%)				
A = no compromising factors	177 (48)	93 (33)	84 (100)	**<0.001**[c]
B = 1-2 compromising factors	181 (49)	181 (64)	0 (0)	
C = >2 compromising factors	10 (3)	10 (4)	0 (0)	

SD, standard deviation.
[a] *P* value for comparing between ineligible and eligible cohorts.
[b] Unequal variance two sample *t*-test.
[c] *Chi*-square *P* value.

Proper patient selection is often cited as an important factor for successful one-stage exchange arthroplasty for the treatment of chronic PJI [7,9,13]. Although eligibility criteria for one-stage exchange vary widely in the literature, it is generally considered appropriate for healthy patients who present with a known, susceptible, low-virulence organism, with an adequate soft-tissue envelope and minimal bone loss. This strict criterion that used to determine eligibility for one-stage exchange arthroplasty creates selection bias, making it difficult to directly compare between the outcomes of one-stage and two-stage exchange arthroplasty procedures [9,13–16]. As such, interpreting existing data comparing these two surgical strategies may be inaccurate and misleading.

As the adoption of one-stage exchange arthroplasty increases, estimating the proportion of patients eligible for one-stage exchange arthroplasty in the treatment of chronic hip PJI could provide valuable insights into its feasibility, application, and whether it should be widely adopted. Moreover, evaluating whether the eligibility for one-stage exchange arthroplasty influences surgical outcomes may provide important context when analyzing the emerging data on one-stage exchange arthroplasty [6]. There are two prior reports that have evaluated the eligibility for one-stage exchange arthroplasty among patients who underwent two-stage exchange arthroplasty for chronic hip and knee PJI [17,18]. Overall, they found that only 12 to 19% would have been eligible for one-stage exchange arthroplasty based on the published eligibility criteria. However, both studies were limited by the small cohort size, short-term follow-up, and combining both hip and knee PJI cases in the same series [17,18].

Therefore, the aim of this study is to assess how many hip PJI patients who underwent two-stage exchange arthroplasty at our institution would have met the published eligibility criteria for one-stage exchange arthroplasty. Additionally, we sought to determine whether eligibility for one-stage exchange arthroplasty impacted the cumulative incidences of reoperation for infection, re-revision for infection, any reoperation, and any re-revision.

Materials and Methods

From January 1, 2000, to December 31, 2020, 368 two-stage exchange arthroplasties for PJI following THA were performed at our institution. All patients underwent both stages of the two-stage exchange arthroplasty for hip PJI and were prospectively captured by our total joint registry. Patients were followed at three months, one year, two years, five years following surgery, and every five years thereafter [19]. The mean age of patients at the time of the two-stage exchange arthroplasty was 65 years (range, 28 to 89), and 60% of patients were men. The mean body mass index (BMI) was 32 (range, 17 to 55) (Table 1). Of the 368 two-stage exchange arthroplasties, 36 were revised within two years, 16 died within two years, and 41 had less than two years of follow-up. The mean follow-up for the remaining 275 patients was five years (range, 2 to 13). Institutional review board approval was obtained before beginning this study.

Eligibility Criteria for One-Stage Exchange Arthroplasty

All 368 two-stage exchange arthroplasties for hip PJI were assessed for eligibility for one-stage exchange arthroplasty using the criteria proposed by Haddad et al. [13]. Patients were considered candidates for one-stage exchange arthroplasty if they had met the following criteria: (1) unilateral PJI; (2) identification of a susceptible pathogen preoperatively, excluding multi–drug-resistant organisms (*methicillin-resistant Staphylococcus aureus* (MRSA), *methicillin-resistant Staphylococcus epidermidis* (MRSE)), or fungal pathogens; (3) McPherson A host status; (4) no prior two-stage exchange arthroplasty of the index joint; (5) absence of severe bone loss; (6) absence of severe soft-tissue loss; (7) absence of severe peripheral arterial disease (PAD); and (8) no sepsis.

McPherson's host grade was defined according to the established criteria [20]. Severe acetabular bone loss was defined as Paprosky type IIIA or IIIB [21], or the utilization of a custom acetabular component, cup-cage construct, or porous metal augments. Severe femoral bone loss was defined as Paprosky type IIIB or IV [22], or the utilization of proximal femoral replacement (PFR), or allograft prosthetic composite (APC). Severe soft-tissue loss was defined by the need for flap coverage by a plastic surgeon, and severe peripheral arterial disease was defined by the presence of lower-limb skin ulcerations due to ischemia or the need for vascular intervention before undergoing the index two-stage exchange arthroplasty.

Data Analyses

Descriptive statistics were employed to summarize both discrete and continuous variables. All cases were included in the statistical analyses, regardless of their follow-up duration or time to reoperation or re-revision. The cumulative incidences of reoperation for infection, re-revision for infection, any reoperation, and any re-revision were calculated with death as a competing risk. Comparisons were made between patients eligible and ineligible for one-stage exchange arthroplasty. Reoperation was defined as any return to the operating room for the index hip, while re-

Table 2
Reasons for Ineligibility for One-Stage Exchange Arthroplasty.

Criteria for Ineligibility	Number of Hips	Percent of Overall Cohort (n = 368)	Percent of Ineligible Cohort (n = 284)
McPherson host grade B/C	191	52	67
Diabetes	64	17	23
Malignancy (history or active)	54	15	19
Current nicotine usage	40	11	14
Inflammatory diseases (systemic lupus, rheumatoid arthritis)	32	9	11
Immunosuppressive drugs	31	8	11
Age ≥80 years	30	8	11
Alcohol abuse	7	2	2
Liver cirrhosis	7	2	2
Chronic malnutrition (albumin ≤3)	4	1	1
Chronic dermatitis or cellulitis	3	1	1
Systemic immune compromise	3	1	1
Chronic indwelling catheter	0	0	0
Renal failure requiring dialysis	0	0	0
Pulmonary insufficiency	0	0	0
Failure to identify organism preoperatively	93	25	33
Severe bone loss	71	19	25
Prior two-stage on infected joint	36	10	13
MRSA infection	26	7	9
MRSE infection	19	5	7
Bilateral PJI	16	4	6
Sepsis at presentation	16	4	6
Severe PAD	5	1	2
Fungal infection	3	1	1
Severe soft tissue loss	2	1	1

PJI, periprosthetic joint infection; PAD, peripheral arterial disease; MRSA, methicillin-resistant *Staphylococcus aureus*; MRSE, methicillin-resistant *Staphylococcus epidermidis*.

revision was defined as any subsequent surgery involving revision of a component of the prosthesis. Cox proportional hazards regression, adjusted for age, sex, and BMI, was used to assess the association between eligibility for one-stage exchange for hip PJI and time-to-event outcomes.

Results

Eligibility for One-Stage Exchange Arthroplasty for Hip PJI

Out of 368 two-stage exchange arthroplasties for hip PJIs, only 23% (n = 84) met eligibility criteria for one-stage exchange arthroplasty based on the above criteria. The most common reasons for ineligibility were McPherson host grade (52%, n = 191), failure to isolate causative organism preoperatively (25%, n = 93), and severe acetabular and/or femoral bone loss (19%, n = 71) (Table 2). Of the 284 patients who were ineligible for one-stage exchange arthroplasty, 41% (n = 116) met one ineligibility criterion and 59% met two or more ineligibility criteria (96 met two criteria, 49 met three criteria, and 23 met four or more ineligibility criteria).

Reoperations and Re-Revisions Based on Eligibility for One-Stage Exchange Arthroplasty

The 2-, 5-, and 10-year cumulative incidences of reoperation for infection were 11, 13, and 15% for hips ineligible for one-stage exchange arthroplasty and 11, 13, and 13% for hips eligible for one-stage exchange arthroplasty, respectively (Figure 1). The 2-, 5-, and 10-year cumulative incidences of re-revision for infection were 6, 8, and 11% for hips ineligible for one-stage exchange arthroplasty and 2, 4, and 4% for hips eligible for one-stage exchange arthroplasty, respectively (Figure 2).

The 2-, 5-, and 10-year cumulative incidences of any reoperation were 18, 23, and 25% for hips ineligible for one-stage exchange arthroplasty and 15, 18, and 18% for hips eligible for one-stage exchange arthroplasty, respectively (Figure 3). The 2-, 5-, and 10-year cumulative incidences of any re-revision were 12, 17, and 21% for hips ineligible for one-stage exchange arthroplasty and 5, 8, and 8% for hips eligible for one-stage exchange arthroplasty, respectively (Figure 4).

On univariate analyses, ineligibility for one-stage exchange arthroplasty was not associated with a higher risk of reoperation for infection (HR [hazard ratio] 1, 95% CI [confidence interval] 0.5

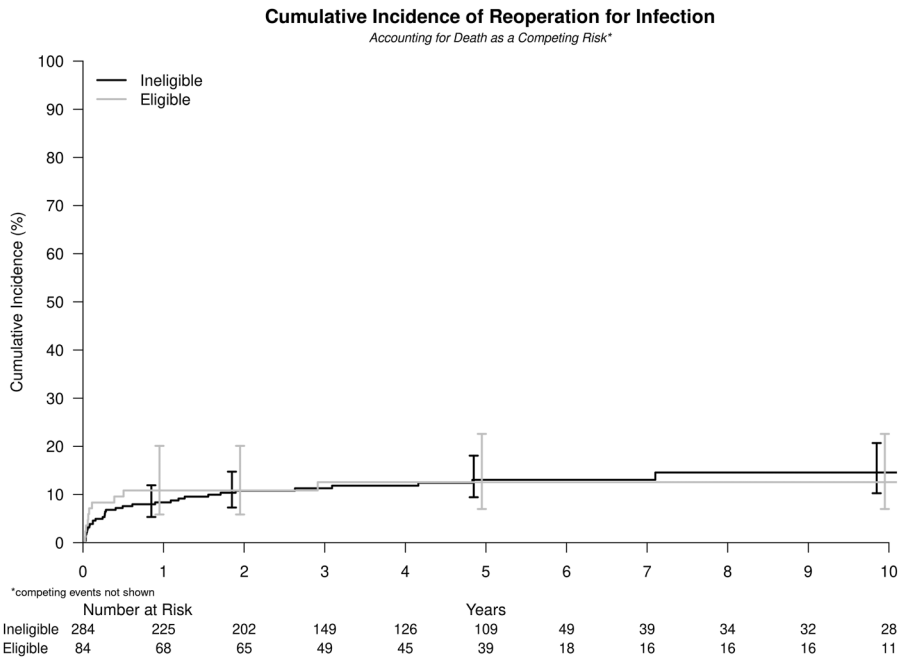


Figure 1. Cumulative incidence curves for reoperation of infection for eligible and ineligible patients. PJI, periprosthetic joint infection.

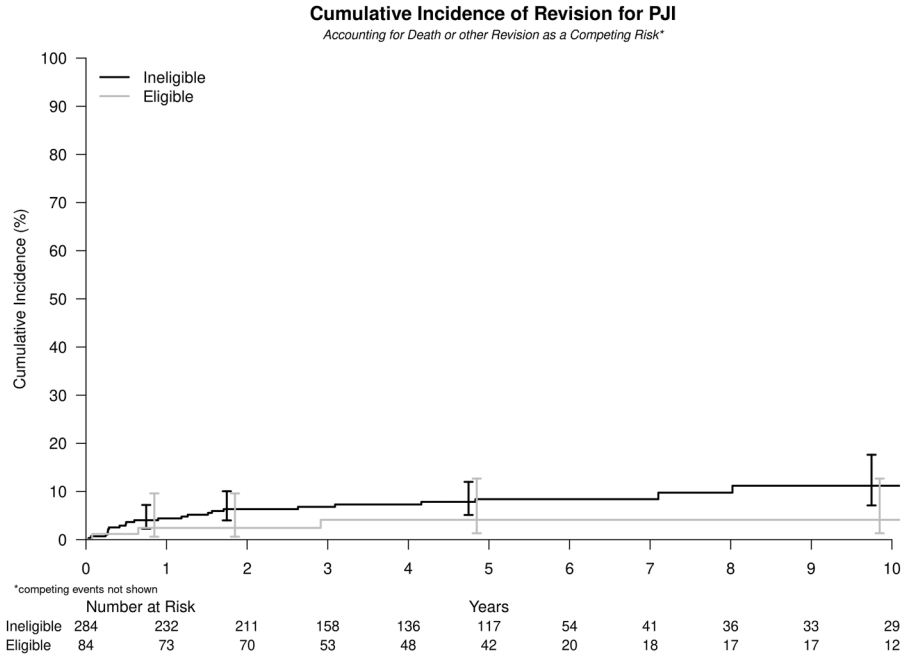


Figure 2. Cumulative incidence curves for re-revision of infection for eligible and ineligible patients. PJI, periprosthetic joint infection.

to 2.1, $P = 0.8$), re-revision for infection (HR 2.6, 95% CI 0.8 to 8.7, $P = 0.1$), or any reoperation (HR 1.4, 95% CI 0.8 to 2.4, $P = 0.2$). However, there was a significant association between ineligibility for one-stage exchange arthroplasty and risk of any re-revision (HR 2.5, 95% CI 1.1 to 6, $P = 0.02$).

After adjusting for age, sex, and BMI on multivariate analyses, ineligibility for one-stage exchange arthroplasty was not associated with a higher risk of reoperation for infection (HR 1, 95% CI 0.5 to 2, $P = 0.9$), re-revision for infection (HR 2.4, 95% CI 0.7 to 8.2, $P = 0.1$), or any reoperation (HR 1.3, 95% CI 0.7 to 2.3, $P = 0.3$). However, ineligibility for one-stage exchange arthroplasty remained associated with a higher risk of any re-revision (HR 2.5, 95% CI 1 to 5.9, $P = 0.03$).

Discussion

While two-stage exchange arthroplasty remains the most common treatment for chronic hip PJI, one-stage exchange arthroplasty has recently gained popularity. However, it is unknown how many patients who have chronic hip PJI would be deemed eligible to undergo one-stage exchange arthroplasty. Furthermore, the inherent selection bias in one-stage exchange

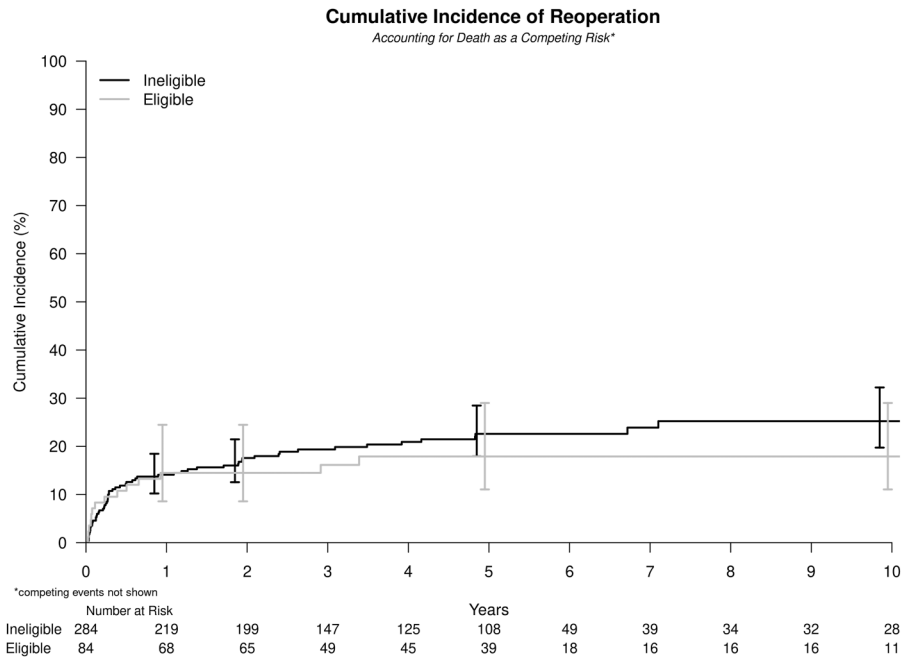


Figure 3. Cumulative incidence curves for any reoperation of eligible and ineligible patients.

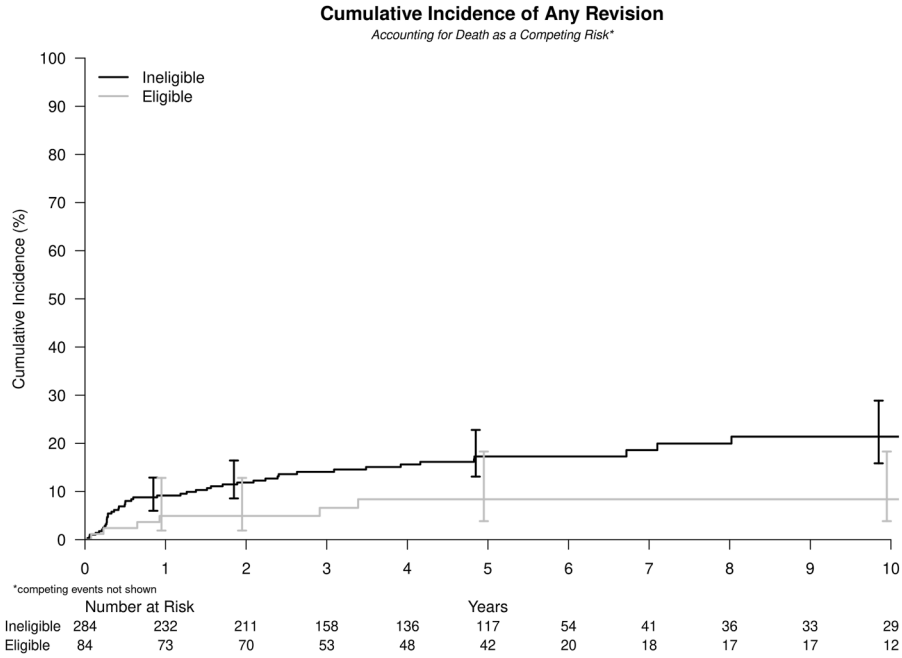


Figure 4. Cumulative incidence curves for any re-revision of eligible and ineligible patients.

arthroplasty confounds its comparison to the standard two-stage exchange arthroplasty, particularly in retrospective studies comparing outcomes between these surgical strategies. In our analysis of 368 hip PJI, only 23% were found eligible to undergo one-stage exchange arthroplasty based on the published eligibility criteria. Moreover, approximately two-thirds of hip PJIs had more than one reason for ineligibility. The most prevalent ineligibility reasons were McPherson host grade (52%), failure to identify the organism preoperatively (25%), and severe bone loss (19%). Additionally, ineligible patients had 2.5 times the risk of any re-revision than those eligible for one-stage exchange arthroplasty.

Previous reports investigating eligibility for one-stage exchange arthroplasty have demonstrated similar findings to our study. Kheir et al. [17] and Dombrowski et al. [18] evaluated eligibility for one-stage exchange arthroplasty in patients who underwent two-stage exchange arthroplasties for either hip or knee PJI. In their studies, only 12 to 19% of hip and knee PJIs were found to be eligible to undergo one-stage exchange arthroplasty based on the International Consensus Meeting (ICM) criteria [23,24]. While both studies found lower infection-free survivorship at two years for ineligible patients, this was not statistically significant [17,18]. However, these studies were limited by the small cohort size, short length of follow-up, and the inclusion of total hip and knee PJIs in the same series. In our study, patients ineligible for one-stage exchange arthroplasty had higher rates of re-revision for infection than eligible patients at two years (6 versus 2%, respectively), five years (8 versus 4%, respectively), and 10 years (11 versus 4%, respectively), but this was not statistically significant. Furthermore, ineligible patients had 2.5 times the risk of undergoing any re-revision than eligible patients. Notably, we did not find significant differences in the risk of reoperation and re-revision for infection between patients ineligible and eligible for one-stage exchange arthroplasty, which may be attributable to sample size. Additionally, 59% of patients ineligible for one-stage exchange arthroplasty met two or more exclusion criteria, suggesting that despite variation in selection protocols, the presence of multiple risk factors would likely render most patients ineligible across different selection criteria for one-stage exchange arthroplasty. Our findings, combined with the existing evidence, demonstrate that a relatively small proportion of patients who have chronic PJI is eligible for one-stage exchange arthroplasty based on the current criteria. Additionally, these data highlight the need to consider the restrictive selection criteria when evaluating the literature on both one- and two-stage exchange arthroplasty outcomes, particularly studies reporting long-term implant survivorship.

The criteria for determining eligibility for one-stage exchange arthroplasty are not universally defined, and the findings of this study should be interpreted within that context. For instance, the criteria for identifying an immunocompetent host vary across one-stage exchange arthroplasty reports [9]. Additionally, polymicrobial infections and prior two-stage exchange arthroplasty are not always considered contraindications for one-stage exchange arthroplasty [9]. These variations, coupled with inherent selection bias in one-stage exchange arthroplasty for PJI, complicate meaningful comparisons between one-stage and two-stage exchange arthroplasty approaches. This study does not attempt to determine which surgical strategy is superior but seeks to demonstrate how the eligibility criteria can influence implant survivorship, highlighting the importance of considering such factors when outcomes of both one- and two-stage exchange arthroplasty are compared. Based on the two decades of experience at a high PJI-volume center, our study found that only a small percentage of patients would have met the current eligibility criteria for one-stage exchange arthroplasty for chronic hip PJI. The majority of patients treated for chronic hip PJI at our institution had multiple reasons for ineligibility, and those deemed ineligible faced a 2.5-fold increased hazard of any re-revision, reinforcing the need for standardized selection criteria and careful patient selection.

This study has potential limitations. The findings of this study are influenced by the eligibility criteria for one-stage exchange arthroplasty and may differ from alternative criteria. For example, incorporating additional comorbidities commonly captured by the Charlson Comorbidity Index (CCI) may impact the proportion of patients deemed eligible for one-stage exchange and influence

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implant survivorship outcomes. In addition, our study may not be powered to detect significant differences between eligible and ineligible patients in some of the analyzed end points, particularly for reoperation and re-revision for infection. Also, the retrospective design may introduce data collection biases. Furthermore, our results may not be broadly generalizable, especially for institutions managing fewer PJI cases and those with different patients' demographics and characteristics. Moreover, although all patients had chronic hip PJI, we did not assess the impact of infection duration on outcomes, which may be a limitation. Nevertheless, the study highlights how the selection criteria for one-stage exchange arthroplasty impact surgical outcomes and emphasizes the limited applicability of one-stage exchange arthroplasty for chronic hip PJI based on published eligibility criteria.

In conclusion, only 23% of patients who underwent two-stage exchange arthroplasty for hip PJI at our institution would have met published one-stage exchange arthroplasty eligibility criteria. Furthermore, ineligible patients had a 2.5-fold increased hazard of any re-revision compared to eligible patients. As such, the low proportion of hip PJI patients eligible for one-stage exchange arthroplasty and the heightened re-revision risk should be acknowledged in the context of comparing these two surgical strategies.

CRediT authorship contribution statement

Khaled A. Elmenawi: Writing – original draft, Methodology, Investigation, Data curation. **Benjamin D. Mallinger:** Writing – original draft, Investigation, Data curation. **Hervé Poilvache:** Writing – original draft, Methodology, Investigation, Data curation. **Charles P. Hannon:** Writing – review & editing, Supervision. **Matthew P. Abdel:** Writing – review & editing, Validation, Supervision. **Nicholas A. Bedard:** Writing – review & editing, Validation, Supervision.

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