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Complications - Infection

One- or Two-Stage Hip Revision? High Mortality in One-Stage Challenges Its Growing Popularity: A Registry Study

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ABSTRACT

Background: Periprosthetic joint infection is a severe complication after hip arthroplasty. While one-stage revision is increasingly used in Germany and other countries, the two-stage procedure remains the gold standard in much of the world. Meta-analyses report comparable or superior success rates for one-stage procedures, but it is unclear whether results from large orthopaedic centers can be reproduced in registry data reflecting broader clinical practice.

Methods: This observational cohort study used German Endoprosthesis Registry data (2013 to 2023) to compare re-revision and mortality rates between one-stage and two-stage revision total hip arthroplasty (RTHA). Cases included first-time RTHA (one-stage: n = 12,418; two-stage: n = 1,000) and multiple RTHA (one-stage: n = 2,459; two-stage: n = 810). Kaplan-Meier estimates were applied for analysis.

Results: Re-revision rates after first-time RTHA were similar at five years (21.1% one-stage versus 19.9% two-stage, $P = 0.068$), though slightly higher at one year for one-stage (16.1% versus 14.1%, $P = 0.022$). In multiple revisions, one-stage showed higher re-revision rates (one year: 26.5 versus 21.0%; five years: 32.2 versus 26.5%, $P = 0.001$). Mortality after first-time RTHA was higher for one-stage at one year (9.9 versus 6.3%, $P = 0.014$), but not significant at five years (26.5 versus 23.9%, $P = 0.077$). In multiple RTHA, mortality remained higher in the one-stage group (one year: 12.8 versus 5.5%, $P < 0.001$; five years: 31.9 versus 23.7%, $P = 0.008$).

Conclusions: Despite the excellent results reported for one-stage RTHA by individual large centers, nationwide data show significantly higher mortality rates in this procedure. This discrepancy raises concerns about broader implementation outside of specialized centers. Significant differences within the first year indicate an increased perioperative mortality for one-stage revision. While the re-revision rates are comparable, the increased mortality risk suggests that the one-stage approach cannot be recommended for wide use.

Periprosthetic joint infection (PJI) following total hip arthroplasty is a serious complication that significantly affects patient outcomes and poses substantial challenges to health care systems. Managing PJI effectively requires careful consideration of the two primary surgical strategies: one- and two-stage revision arthroplasty. The two-stage revision has long been regarded as the gold standard, particularly in complex cases involving resistant organisms or compromised immunity, as it allows for the removal of the infected prosthesis, a period of targeted antibiotic therapy, and subsequent reimplantation [1].

In recent years, however, the one-stage revision approach has gained attention as a viable alternative, particularly in selected patient populations. In one-stage revision, the infected prosthesis is removed and replaced in a single surgical procedure, offering the benefits of shorter hospital stays and quicker recovery times. Furthermore, the one-stage exchange provides faster functional recovery and pain relief, which is reflected in patient satisfaction,

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as well as better cost-effectiveness [2]. Recent studies, such as those by Patel et al., [3] and Saul et al., [4] have demonstrated that one-stage revisions can achieve comparable, if not superior, outcomes to two-stage revisions in terms of reinfection rates, operative times, and patient satisfaction. Kunutsor et al. also showed that the reinfection rate of the one-stage procedure (8.2%) with 2,536 included patients did not differ widely from the two-stage revision (7.9%) with 3,288 patients [5]. These findings suggest that one-stage revisions may be particularly advantageous in patients who have well-contained infections and favorable microbiological profiles.

Despite these promising results, the adoption of one-stage revision remains controversial. Critics argue that its success is heavily dependent on careful patient selection, with strict criteria required for indications such as stable soft tissue, minimal bone loss, and infections caused by susceptible organisms [6].

The controversy in the literature largely stems from the variability in study designs and patient populations, leading to conflicting results. For instance, a meta-analysis by Zhao et al. [7] found no significant difference in the reinfection or reoperation rates between one- and two-stage revisions across a broad cohort of patients, highlighting the need for more robust, prospective studies to clarify these findings. In addition, while one-stage revision may reduce the economic burden on health care systems due to fewer surgeries and shorter hospitalizations, its long-term success in complex cases remains uncertain, and the potential risks of recurrence may outweigh these benefits in certain patient groups.

All these factors, such as cost-effectiveness, higher patient satisfaction, less numbers of surgeries, shorter recovery time, and comparable results between one- and two-stage procedures, encourage an ever-increasing number of surgeons to decide on the one-stage revision. The aim of this study was to assess whether the comparable results in the literature on re-revision rate and mortality between one- and two-stage procedures in revision total hip arthroplasty (RTHA) are also reflected in the results of registry data, and therefore whether a recommendation for the operative treatment of PJI can be given.

Materials and Methods

Data Source

The German Endoprosthesis Registry (EPRD) has compiled data from nearly 2.5 million hip and knee arthroplasty surgeries since its inception in 2012, representing about 70% of the total arthroplasty and revision arthroplasty surgeries performed annually in Germany. This dataset is one of the largest national registries worldwide, combining documentation from 747 participating clinics, a product database from implant suppliers, and routine data from health insurance companies. By linking these three data sources, the registry provides an almost complete follow-up mechanism for patients, capturing data even if revision surgeries are performed at different clinics within Germany. The Elixhauser Comorbidity Index, which has been shown to outperform the American Society of Anesthesiologists score in predicting mortality, was utilized to classify patient comorbidities based on their association with mortality [8,9].

In the context of this study, revision arthroplasty is defined within the EPRD as any surgery involving the exchange of components in a hip arthroplasty, including the head and liner. Each subsequent surgery that includes the exchange or removal of components following reimplantation is classified as a re-revision. For total hip arthroplasties undergoing re-revision, the initial event is defined as the date of the most recent one-stage RTHA or the reimplantation date in two-stage RTHA. The EPRD categorizes a revision arthroplasty as septic when the International Statistical Classification of Diseases and Related Health Problems code T84.5 “infection and inflammatory reaction due to joint arthroplasty” is recorded or when “infection” is explicitly mentioned as the reason for surgery in the operative report. In cases where multiple revision arthroplasties have been performed on a single patient, the classification of the revisions as septic or aseptic is determined by the reason for the most recent revision. This study received general institutional review board approval under approval number D 473/11.

Patient Cohort

For this study, the EPRD provided data on 12,418 one-stage RTHA and 1,000 two-stage RTHA procedures performed between March 2013 and September 2023. In addition, data on patients who had undergone multiple revisions were included, comprising 2,459 one-stage RTHA cases and 810 two-stage RTHA cases. Details of the cohorts are given in Table 1.

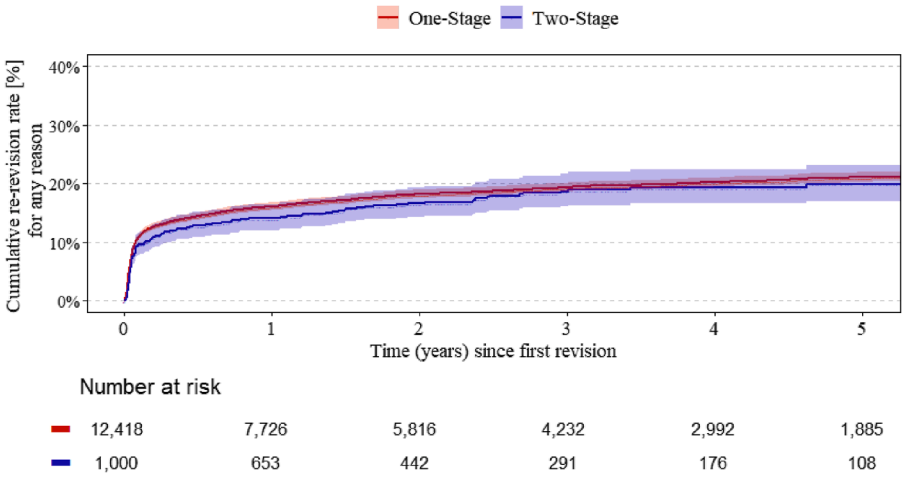

Figure 1. Cumulative re-revision rate for any reason after primary revision total hip arthroplasties.

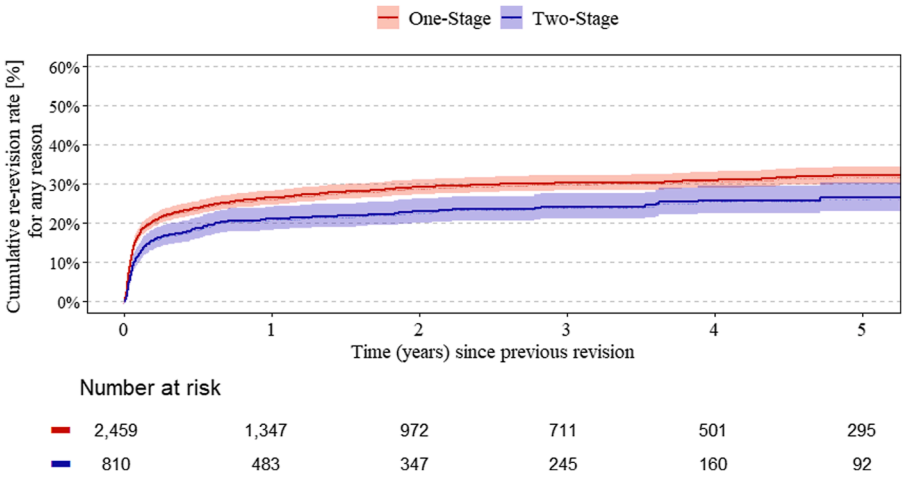

Figure 2. Cumulative re-revision rate for any reason in multiple revision total hip arthroplasties.

Data Analyses

The Elixhauser Comorbidity Index was computed using the "comorbidity" package in R, which provides a comprehensive score reflecting the presence of 29 different comorbidities that may influence patient outcomes [8]. We analyzed re-revision and mortality rates across both initial and multiple hip revision cases. Kaplan-Meier survival estimates were employed to assess the cumulative probability of re-revision and mortality over time. The mortality rate was determined by calculating the survival time, defined as the interval between the date of the revision surgery and the date of death. Group differences were evaluated by multivariate regression analysis, adjusting for age, sex, BMI and Elixhauser-Score. A P value < 0.05 was considered statistically significant. A follow-up of five years is given due to small sample sizes in the groups with > five years of follow-up.

Results

Re-Revision Rate

In this study, we compared the outcomes of 12,418 one-stage and 1,000 two-stage RTHAs performed between 2015 and 2023. The re-revision rates of one- and two-stage first-time revisions showed slight differences; after 1 year, 16.1% of the one-stage revisions required further surgery compared to 14.1% of the two-stage revisions (hazard ratio (HR) 1.23 (95% confidence-interval 1.03 to 1.46), $P = 0.022$). By the 5-year mark, these rates had nearly equalized, with 21.1% of one-stage and 19.9% of two-stage revisions requiring re-revision (HR 1.16 (0.99 to 1.36), $P = 0.068$) (Figure 1).

The study also evaluated outcomes for patients undergoing multiple RTHAs, with 2,459 cases in the one-stage group and 810 cases in the two-stage group. The re-revision rates in multiple RTHA followed a similar pattern, with 26.5% of one-stage multiple revisions requiring further surgery within one year, compared to 21.0% in the two-stage group (HR 1.32 (1.10 to 1.57), $P = 0.002$). It is noteworthy that 82% of all re-revisions following one-stage procedures occurred within the first year, comparable to 79% in the two-stage group. By five years, these rates had increased to 32.2% for one-stage and 26.5% for two-stage multiple revisions (HR 1.31 (1.11 to 1.54), $P = 0.001$) (Figure 2).

Mortality Rate

The mortality rate within one year was significantly higher in the one-stage group at 9.9% compared to 6.3% in the two-stage group after first-time RTHA (HR 1.39 (1.07 to 1.81) $P = 0.014$). Over a 5-year follow-up period the mortality rate was 26.5% in the one-stage RTHA group versus 23.9% in the two-stage group (HR 1.17 (0.98 to 1.40), $P = 0.077$). These findings suggest that while one-stage revisions are associated with higher early mortality, the long-term mortality rates are comparable to those seen with two-stage procedures (Figure 3).

In patients undergoing multiple RTHA, the mortality rate was markedly higher for the one-stage approach, with 12.8% of patients dying within one year compared to 5.5% in the two-stage group (HR 1.88 (1.35 to 2.61), $P < 0.001$). This difference in mortality persisted over time, with 5-year mortality rates reaching 31.9% for one-stage revisions and 23.7% for two-stage revisions (HR 1.33 (1.08 to 1.63), $P = 0.008$) (Figure 4).

Discussion

A one-stage procedure showed similar results for re-revision rate in first-time RTHA within the first year (16.1%) compared to two-stage revision (14.1%). While the re-revision rate remained higher for the one-stage procedure over the entire follow-up period, the rates actually converged somewhat. In multiple RTHA, differences were seen with a higher re-revision rate for one-stage re-revision rate of 26.5% compared to two-stage revision with 21.0%. These differences persisted over the follow-up period. Within the first year, mortality after primary one-stage revision (9.9%) was higher compared to two-stage revision (6.3%), whereas in multiple RTHA, the one-stage procedure (12.8%) shows even a 2.2-fold higher mortality than the two-stage procedure (5.5%). These results contradict the previous findings that a single-stage procedure is superior in the management of acute infections. Contrary to the increasing popularity of the one-stage revision procedure, the results of the present study do not validate the success rate in terms of mortality and re-revision rate for multiple revisions in comparison to the two-stage procedure.

The Re-Revision Rate for One-/Two-Stage Is Higher Than in the Literature

In the literature, re-revision rates after one- and two-stage revisions of 15 to 26% have been reported, which is significantly

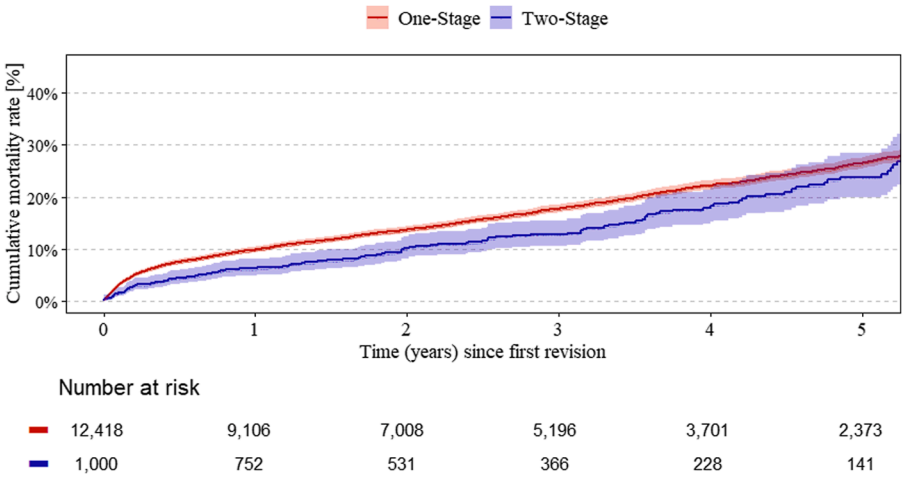

Figure 3. Cumulative mortality after primary revision total hip arthroplasties.

lower than in our present results from the German Arthroplasty Registry. Engesæter et al. used data from the Norwegian arthroplasty registry and found 2-years re-revision rates of 12% in the one-stage and 8% in the two-stage exchange procedures, which equals a 1.4-fold increase in the re-revision rate [10]. A 5-year re-revision rate after RTHA of 19% was published by Ong et al., using health care data from the US, and 15% by Petis et al. after a two-stage exchange due to PJI [11,12]. Zahar et al. showed a comparatively high re-revision rate of 24.1% after 10 years, with a reinfection rate of 6% in a one-stage exchange procedure after septic RTHA [13]. The highest re-revision rate was reported by Lie et al. with data from the Norwegian Arthroplasty registry, which was 26% after 10 years [14]. In comparison to these results from the literature, our 5-year re-revision rates in primary RTHA for one-stage (21.1%) and two-stage (19.9%) revision procedures are higher than most of the published results. In multiple RTHA, our registry data exceed the re-revision rates of the literature by far, with 31.0% for one-stage and 25.8% for two-stage exchange revision after five years. These differences in re-revision rates might be explained by the fact that most of the studies on RTHA are published by a few orthopaedic centers with high case numbers. The published results from these centers are not comparable to the standard of hospitals in the rest of the country and are therefore too early for transferability to a broad application. Furthermore, single-center studies have varying inclusion or exclusion criteria, which modify the patient cohort and therefore the results. The EPRD has no inclusion or exclusion criteria, which ensures a broad spectrum of patients who have more comorbidities and more complex cases.

One-Stage Revision Is Not Recommended for General Usage in the First Revision

An increasing share of authors is promoting the usage of one-stage revision in primary RTHA, such as Riemer et al., who reported that the cementless one-stage revision is an adequate alternative in early PJI with potentially lower reinfection rates [15]. Other authors, such as Negus et al., also reported on the increasing implementation of one-stage revisions due to superiority in infection control, decreased mortality, and cost-effectiveness compared to two-stage revision [16]. An analysis of the Swedish Hip Arthroplasty Registry from 1979 to 2015 by Svensson et al. showed that there was no significant difference in the re-revision rate and reinfection rate between single-stage and two-stage exchange revision, but it is remarkable that 80% of all RTHA have been two-stage revisions [17]. The literature supporting the utilization of one-stage revisions in primary RTHA is contrary to our results in terms of mortality. In primary RTHA, one-stage revision

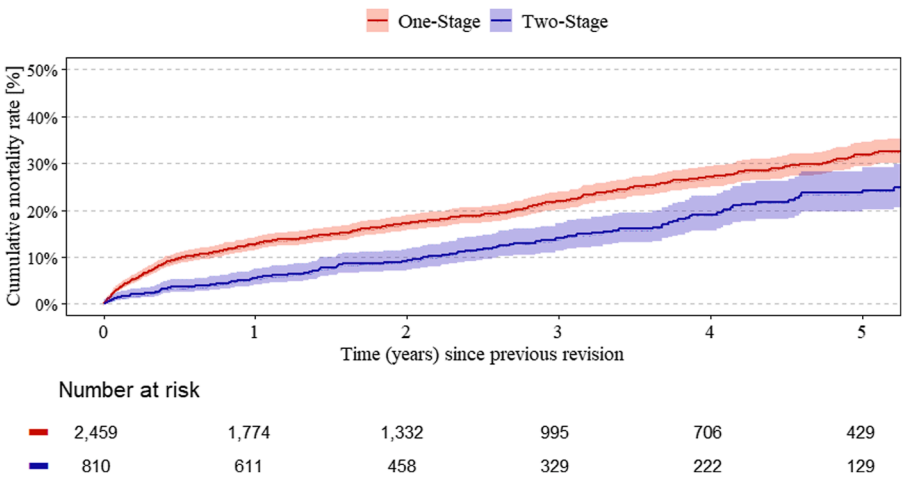

Figure 4. Cumulative mortality rate in multiple revision total hip arthroplasties.

Table 1
Demographics, BMI, and Elixhauser Scores of the Cohorts.

Variable	First Time Revision		Multiple Revision	
	One-Stage N = 12,418[a]	Two-Stage N = 1,000[a]	One-Stage N = 2,459[a]	Two-Stage N = 810[a]
Age	74 (64, 81)	71 (62, 78)	74 (65, 81)	70 (62, 78)
Sex (%)				
Women	7,790 (63)	538 (54)	1,493 (61)	436 (54)
Men	4,628 (37)	462 (46)	966 (39)	374 (46)
BMI (%)				
Underweight [<18.5]	170 (1.4)	6 (0.6)	28 (1.1)	5 (0.6)
Normal [18.5 to 24.99]	3,069 (25)	211 (21)	563 (23)	147 (18)
Preobese [25.0 to 29.99]	3,534 (28)	300 (30)	695 (28)	204 (25)
Obese 1 [30.0 to 34.99]	2,177 (18)	211 (21)	422 (17)	180 (22)
Obese 2 [35.0 to 39.99]	941 (7.6)	100 (10)	235 (9.6)	96 (12)
Obese 3 [≥40]	517 (4.2)	55 (5.5)	141 (5.7)	80 (9.9)
Missing	2,010 (16)	117 (12)	375 (15)	98 (12)
Elixhauser score (%)				
<0	1,622 (13)	165 (17)	309 (13)	128 (16)
0	4,185 (34)	274 (27)	550 (22)	175 (22)
1 to 4	1,237 (10.0)	123 (12)	261 (11)	124 (15)
5+	5,374 (43)	438 (44)	1,339 (54)	383 (47)

[a] Median (IQR); n (%). IQR, interquartile range.

showed a significantly increased mortality within the first year compared to two-stage revision, and in multiple RTHA, even 2.2-fold higher mortality. These results may partially be attributed to the higher age structure of the one-stage revision group. However, patients undergoing one-stage revision show significantly increased perioperative mortality, while in the following years, a consistent increase in mortality of 3 to 6% is observed in both groups. Our results with registry data clearly contradict the current literature and do not support the utilization of a one-staged revision procedure, especially when considering the rapidly rising mortality within the first year. The increased perioperative mortality for one-stage revision might be explained by longer surgery duration, blood loss, and patient selection, as well as more cautious debridement for one-stage revision. The narrow applicability of one-stage revision limits its use in more complex cases, where the two-stage approach may still be necessary to ensure thorough debridement and effective infection control. The two-stage revision's ability to allow for a more controlled and phased treatment of the infection is seen as a significant advantage, particularly in cases where the infection is aggressive or the patient's health is compromised.

In Re-Revisions, One-Stage Exchange Should Be Done in Specialized Centers

While the two-staged procedure in RTHA has been the gold standard for chronic PJI in the last decades, a one-stage revision with extensive wound debridement and usage of antibiotics is becoming more and more popular in acute infection due to its cost-effectiveness, reduced number of surgeries, and quicker recovery [2,18]. Furthermore, studies showed the advantages of one-stage revision over two-stage revision in terms of eradication of acute infections and patient satisfaction [19]. In one-staged revision arthroplasty, there are some essential principals that must be observed to ensure the success of the therapy. In principle, single-staged procedures tend to be used for patients in good general health who have fewer comorbidities and in cases with identified pathogens in chronic infections. These criteria are mainly a preselection of the patient cohort and therefore already limit the scope of application. Intraoperatively, it is important to ensure an adequate wound debridement and to choose the right implants to assure good anchoring. In addition, a targeted selection of the preoperative and postoperative antibiotic therapy needs to be done. In contrast to the two-staged revision, one-staged revision enables earlier mobilization due to fact that only one surgery was performed. All these factors, which are decisive for all septic revisions and especially for one-staged revision, require a multidisciplinary approach. Therefore, one-staged procedures in re-revision THA should only be performed in highly specialized centers with extensive experience in revision arthroplasty with appropriate technical capabilities [20].

Potential Limitations

One minor limitation of this study is that EPRD covers approximately 70% of all primary and revision THA performed in Germany annually, but it is mentionable that almost all hospitals with high case numbers are included. The inclusion of high-volume centers increases the significance of this study due to the wide spectrum of patients including those who have undergone multiple revisions. The EPRD is collecting its data independently from the register documentation of hospitals, the product database of implant manufacturer, and the health insurance companies. The surgeon- and institution-independent entry of diagnosis and complete collection of data is one major strength of this study. Due to the three independent and complementary data sources, EPRD can ensure an almost 100% follow-up of 16,687 RTHA from 2015 to 2023. Because the data presented originate from a register, it is not possible to evaluate the individual decision-making process for the one-stage revision compared to the two-stage revision. As a result, it is not possible to present any individual risk factors that could explain a higher mortality in addition to the demographic data and the Elixhauser score.

In conclusion, while the literature suggests that one-stage revision hip arthroplasty offers advantages such as shorter recovery times, fewer surgeries, and comparable re-revision rates to two-stage procedures, our analysis using real-world data from the EPRD reveals a more complex picture. Although the re-revision rates are similar between the two methods over the long term in first-time RTHA, one-stage revision is associated with significantly higher re-revision rates in multiple RTHA and significantly higher mortality rates in first-time as well as multiple RTHA, particularly within the first year postsurgery. This increased mortality risk suggests that, despite the growing popularity of one-stage

procedures, they may not be suitable for widespread application, especially in patients who have more complex cases or higher comorbidities. Instead, one-stage revisions should be limited to specialized centers with significant expertise in revision arthroplasty. The two-stage approach, with its more controlled infection management and lower mortality, remains a safer option for broader patient populations.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT-4o for language editing and refinement to improve clarity and readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Martin Resl: Writing – review & editing, Writing – original draft, Conceptualization. **Luis Becker:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Yinan Wu:** Writing – review & editing, Visualization, Data curation. **Carsten Perka:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

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Appendix

Appendix Table 1
Kaplan-Meier Estimates of Rerevision Rate After Primary One- and Two-Stage Revision

Time (Year)	Group	Estimates	Lower	Upper
1	One-stage	16.1	15.5	16.8
1	Two-stage	14.1	12	16.5
2	One-stage	18.2	17.5	18.9
2	Two-stage	16.6	14.3	19.3
3	One-stage	19.4	18.6	20.1
3	Two-stage	18.7	16.1	21.6
4	One-stage	20.2	19.4	21
4	Two-stage	19.3	16.6	22.4
5	One-stage	21.1	20.3	22
5	Two-stage	19.9	17	23.2

Appendix Table 2
Kaplan-Meier Estimates of Rerevision Rate After Multiple One- and Two-Stage Revision

Time (Year)	Group	Estimates	Lower	Upper
1	One-stage	26.5	24.7	28.3
1	Two-stage	21	18.3	24.1
2	One-stage	29.2	27.3	31.2
2	Two-stage	23	20.1	26.2
3	One-stage	30.3	28.4	32.3
3	Two-stage	24.2	21.2	27.6
4	One-stage	31	29	33.1
4	Two-stage	25.8	22.5	29.5
5	One-stage	32.2	30.1	34.4
5	Two-stage	26.5	23	30.5

Appendix Table 3
Kaplan-Meier Estimates for Mortality After Primary One- and Two-Stage Revision

Time (Year)	Group	Estimates	Lower	Upper
1	One-stage	9.9	9.4	10.5
1	Two-stage	6.3	4.9	8.1
2	One-stage	13.8	13.1	14.4
2	Two-stage	10.1	8.3	12.4
3	One-stage	17.8	17	18.6
3	Two-stage	12.9	10.6	15.6
4	One-stage	22.3	21.4	23.2
4	Two-stage	17.9	14.9	21.4
5	One-stage	26.5	25.4	27.5
5	Two-stage	23.9	19.9	28.5

Appendix Table 4
Kaplan-Meier Estimates for Mortality After Multiple One- and Two-Stage Revision

Time (Year)	Group	Estimates	Lower	Upper
1	One-stage	12.8	11.5	14.2
1	Two-stage	5.5	4.1	7.4
2	One-stage	17.3	15.8	19
2	Two-stage	9.3	7.3	11.8
3	One-stage	21.9	20.1	23.9
3	Two-stage	14	11.4	17.2
4	One-stage	27.2	25.1	29.4
4	Two-stage	19	15.7	23
5	One-stage	31.9	29.5	34.5
5	Two-stage	23.7	19.6	28.3