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Clinical Outcomes following Primary Hip Replacement Arthroplasties in Patients with Solid Organ Transplantation: A Systematic Review and Meta-Analysis

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There is still controversy regarding clinical outcomes following primary hip arthroplasty after solid organ transplantation (SOT). The aim of this study was to determine whether clinical outcomes after hip arthroplasty differ between previous SOT recipients and control subjects with no history of undergoing SOT. We conducted a systematic search of MEDLINE, Embase, and the Cochrane Library for studies comparing the clinical outcomes after hip arthroplasty following SOT published up to January 5, 2022. A comparison of medical and surgery-related complications, as well as the readmission rate and 90-day mortality rate between previous SOT recipients and control subjects was performed. Subgroup analyses of the SOT types, liver transplantation (LT) and kidney transplantation (KT), were also performed. Ten studies that included 3,631,861 cases of primary hip arthroplasty were included; among these, 14,996 patients had previously undergone SOT and 3,616,865 patients had not. Significantly higher incidences of cardiac complications, pneumonia, and acute kidney injury were observed in the SOT group compared with the control group. Regarding surgical complications, a higher transfusion rate was observed in the SOT group. The readmission rate and 90-day mortality rate were also significantly higher in the SOT group. A significantly higher incidence of deep vein thrombosis was observed in the KT subgroup compared with the control group. A higher risk of medical and surgical complications, as well as higher readmission and mortality rates after hip arthroplasty was observed for previous SOT recipients compared to patients with no history of SOT.

Key Words: Transplantation, Arthroplasty, Hip, Meta-analysis

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Hip Pelvis 34(3): 127-139, 2022

INTRODUCTION

With the continuing improvement of survival rates among solid organ transplantation (SOT) recipients, patients are living longer, and the demand for hip joint arthroplasty procedures is increasing due to the development of age-related osteoarthritis (OA), hip fractures, or immunosuppressive medication-induced osteonecrosis of the femoral head (ONFH)[1-3].

Clinical outcomes following primary hip arthroplasty after various types of SOT have been investigated in several published studies. However, different outcomes have been reported, with significant variation in terms of sample size, making it difficult for surgeons to draw conclusions. Indeed, some studies have reported significantly higher postoperative complications after hip arthroplasty among patients in the SOT recipients group compared with control subjects[4,5]. In contrast, other studies reported that there were no differences in clinical outcomes after hip arthroplasty between SOT and control groups[2,6]. Furthermore, most of these studies were limited by small sample sizes, limited follow-up time, or even included patients who underwent total joint arthroplasty (TJA) before SOT.

Most recently, one meta-analysis examining the complication profiles after total hip and knee arthroplasty among liver transplantation (LT) recipients has been reported[7]. The authors reported that previous LT recipients had an increased risk of postoperative infection, revision/reoperation, short-term mortality, and medical complications following hip and knee arthroplasty compared with control subjects. However, the analysis only included LT; in addition, it was a single-arm analysis, thus there is greater potential for bias compared with double-arm studies that make direct comparisons.

Therefore, in this systematic review and meta-analysis, our aim was to determine whether clinical outcomes after hip arthroplasty differ between SOT recipients and control subjects, with a particular focus on medical complications, surgical complications, readmission rate, and short-term mortality. An overall SOT group, as well as subgroups of patients who underwent different types of SOT, were included in our double-arm analyses.

MATERIALS AND METHODS

This systematic review and meta-analysis were conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines[8,9]. While this analysis involved human participants, all data were based on previously published studies and were analyzed anonymously without any potential harm to the participants; therefore, both ethical approval and acquisition of informed consent from participants were not required.

1. Literature Search

In compliance with the referenced guidelines, a search of MEDLINE, Embase, and the Cochrane Library was conducted in order to identify studies examining clinical outcomes after hip arthroplasty following SOT. Articles published up to January 5, 2022, were identified using an *a priori* search strategy. Search terms included synonyms and terms related to hip arthroplasty and SOT. The full search strategies and results for all databases are shown in Appendix 1. There were no restrictions on language or year of publication. After the initial electronic search, a manual search for relevant articles and their bibliographies was conducted.

2. Study Selection

From the titles and abstracts of the studies, articles for full-text review were selected independently by two board-certified orthopedic surgeons, who were faculty members at an academic medical center. If the abstract provided insufficient data for making a decision, a review of the entire article was performed. The following inclusion criteria were used: (1) study: directly compared clinical outcomes after hip arthroplasties between SOT recipients and control subjects (double-arm study); (2) population: patients who underwent hip arthroplasty; (3) intervention: SOT; (4) control subjects: patients who did not undergo SOT before hip arthroplasty; (5) outcomes: medical complications, surgery-related complications, readmission rate, and mortality rate. Only original research articles were included. Studies that (1) examined non-SOT (i.e., bone marrow transplantation); (2) examined revision hip arthroplasty; (3) included patients in the control group who had the same underlying disease as that which led to SOT among patients in the intervention group (i.e., kidney transplantation [KT] group vs dialysis group, with patients who have underlying chronic kidney disease in both groups); (4) did not divide each surgery type, including hip arthroplasty; (5) did not report results that allowed us to obtain or calculate comparative data; and (6) were duplicates from the same study group.

The κ-value was calculated in order to determine inter-

reviewer agreement regarding study selection at each stage of article selection. Agreement between reviewers was correlated *a priori* with κ-values as follows: κ=1 corresponded to "perfect" agreement, 1.0>$\kappa\geq$0.8 to "almost perfect" agreement, 0.8>$\kappa\geq$0.6 to "substantial" agreement, 0.6>$\kappa\geq$0.4 to "moderate" agreement, 0.4>$\kappa\geq$0.2 to "fair" agreement, and κ<0.2 to "slight" agreement. Disagreements at each stage were resolved by discussion between the two investigators in order to reach consensus, or by discussion with a third investigator, who was a board-certified orthopedic surgeon, when a consensus could not be reached.

3. Data Extraction

For synthesis of the qualitative data, the following information and variables were extracted using a standardized form: (1) study design, (2) the country in which the study was conducted, (3) number of patients in each group, (4) mean age of patients, (5) follow-up duration, (6) type of SOT, (7) type of hip arthroplasty (total hip replacement or hemiarthroplasty), (8) reason for hip arthroplasty, and (9) the outcomes investigated.

For synthesis of the quantitative data, we only performed a meta-analysis of variables for which data from three or more trials could be extracted. The following data were extracted from the included studies for the SOT and control groups: (1) medical complications: cardiac complications, pneumonia, pulmonary thromboembolism (PTE), deep vein thrombosis (DVT), and acute kidney injury (AKI); (2) surgery-related complications: transfusion rate, prosthetic joint infection (PJI), dislocation (D/L) rate, aseptic loosening, and rate of revision surgery for any reasons; and (3) the readmission rate and 90-day mortality rate. A meta-analysis was performed for overall SOT; subgroup analyses of the SOT types, LT and KT, were also performed.

4. Risk-of-Bias Assessment

An assessment of the methodological quality of the included studies was performed using the MINORS (methodological index for non-randomized studies)[10], a validated tool for assessing the quality of non-randomized studies. The MINORS checklist, which includes methodological items for non-randomized studies (16 points) and additional criteria in the case of comparative study (8 points) was used. The maximum MINORS checklist score for comparative studies was 24 points. The quality assessments were performed by two independent reviewers. Discussions were conducted for resolution of disagreements.

5. Data Synthesis and Statistical Analyses

The main outcomes of this meta-analysis were the medical and surgical complications, readmission rate, and mortality rate after hip arthroplasty between the SOT group and the control group. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for all comparisons of dichotomous data. Heterogeneity was assessed using the I^2 statistic, considering 25%, 50%, and 75% as low, moderate, and high heterogeneity, respectively. Forest plots were used in presenting the outcomes, pooled estimates of effects, and overall summary effect of each study. The value for statistical significance was set at P<0.05. To avoid overestimation of the study results, particularly in the medical field, all data were pooled using a previously recommended random-effects model[11]. The fixed-effects model starts with the assumption that the true effect size is similar in all included studies, thus we believed that the random-effects model is generally a more plausible match for use in the current study. A test for publication bias was not performed because evaluations for publication bias are recommended only when at least 10 studies are included in a meta-analysis[12]. The Review Manager (RevMan), version 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) was used in performance of all statistical analyses.

RESULTS

1. Article Identification

A summary of the details regarding processes for identification and selection of articles is shown in Fig. 1. The initial search of electronic literature yielded 1,053 articles. After removal before screening as duplicates, ineligible records following an automated tool, and inappropriate research articles, the remaining 598 articles were screened. No additional publications were identified by manual searching. Of these, articles were excluded after screening their titles, abstracts, and full-text reviews. Thus, 10 articles[5,13-21] were eligible for qualitative and quantitative data syntheses. Regarding study selection, the agreement between the two reviewers was almost perfect at the title review and abstract review stages (κ=0.814 and κ=0.849, respectively) as well as the full-text review stage (κ=1.0).

Hip Pelvis 34(3): 127-139, 2022

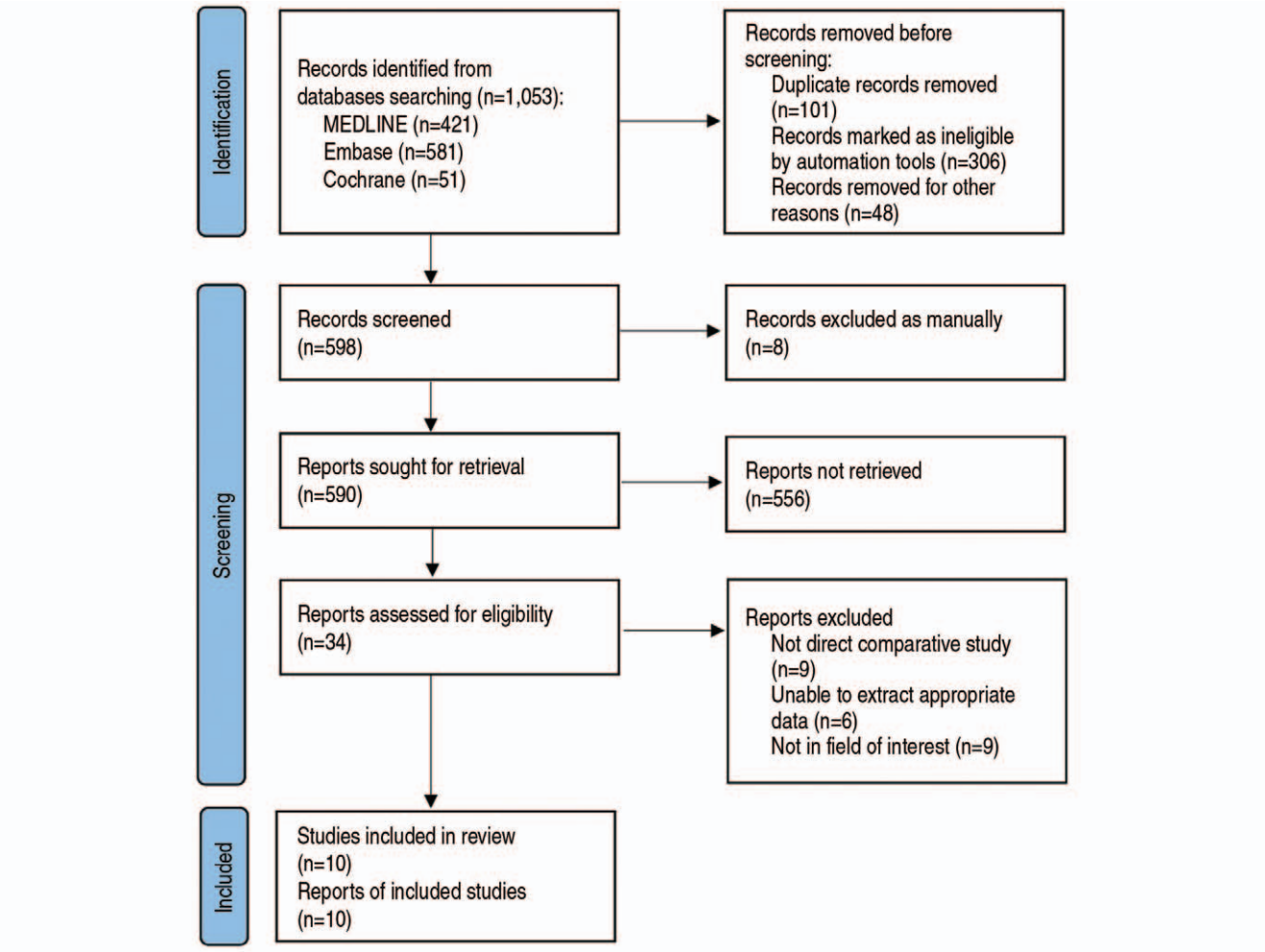

Fig. 1. New 2020 PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) flow diagram for identification and selection of studies included in the meta-analysis.

2. Study Characteristics

All 10 articles[5,13-21] reported on retrospective studies; propensity score-matched analyses were performed in seven[13-18,20] of these studies. A total of 3,631,861 patients who underwent hip arthroplasty, including 14,996 patients who had previously undergone SOT and 3,616,865 patients who had not undergone SOT, were analyzed in these studies. Six studies were conducted in the United States, and the other four studies were conducted in Asian countries. Mean ages of patients ranged between 44 and 69.4 years, and the minimum duration of follow-up was two years. SOT types varied among the included studies. Half of the studies[5,13,14,16,20] examined several SOT types (e.g., kidney, liver, lung, heart, pancreas), two studies[18,19] examined KT only, two studies[15,21] examined LT only, and one study[17] examined KT and LT only. All studies included participants who underwent primary total hip arthroplasty (THA), and one study[16] also included patients who underwent bipolar hemiarthroplasty. Descriptions of the outcomes of interest for each study, along with additional details, are shown in Table 1.

3. Risk of Bias Assessment

The mean MINORS score for assessment of methodological quality was 15.5/24 (range, 12-18) (Table 1). Regarding the eight main parameters for evaluation, the aim of this analysis was clearly addressed in all 10 studies[5,13-21] (item 1: a clearly stated aim). One study[17] received a point deduction because the authors did not describe the consecutiveness of patient inclusion (item 2: inclusion of consecutive patients). All 10 studies received a point deduction for their retrospective study design (item 3: prospective

Table 1. Study Design, Demographic Data, Study Details, and MINORS Scores of Included Studies

Study	Study design	Country	No. of sample size		Mean age (yr)	F/U duration (yr)	Type of SOT	Type of arthroplasty	Reason for arthroplasty	Outcome investigated	MINORS score
			SOT	Control							
Agarwal et al.[13] (2022)	PSM	U.S.	3,103	6,196	<40 to 80	>2	Overall	THA	OA	Medical Cx., sugical Cx.	18
Choi et al.[14] (2013)	PSM	Korea	163	326	46.2	N/A	Overall	THA	ONFH	AKI	14
Douglas et al.[15] (2021)	PSM	U.S.	513	10,246	60	>5	LT	THA	N/A	Medical Cx., sugical Cx., LOS, readmission, total costs care	16
Klement et al.[5] (2017)	RCS	U.S.	3,180	771,498	<65 to >85	>2	Overall	THA	N/A	Medical Cx., sugical Cx.	16
Ledford et al.[16] (2021)	PSM	U.S.	31	31	69.4	3	Overall	THA, HA	FNF	Medical Cx., sugical Cx., PeriOp. outcomes, revision, mortality	15
Li et al.[17] (2014)	PSM	China	300	600	55.1	N/A	LT, KT	THA	ONFH	AKI	12
Lim et al.[18] (2012)	PSM	Korea	45	96	44	7.2	KT	THA	ONFH	Medical Cx., sugical Cx., outcome score, radiologic outcome, revision	18
Malkani et al.[19] (2020)	RCS	U.S.	94	54,902	>65	>5	KT	THA	N/A	Medical Cx., sugical Cx., readmission, mortality	16
Navale et al.[20] (2017)	PSM	U.S.	7,558	2,772,943	>18	N/A	Overall	THA	N/A	Medical Cx., sugical Cx., mortality, LOS, total costs care	14
Oya et al.[21] (2021)	RCS	Japan	9	27	56.3	N/A	LT	THA	ONFH	Medical Cx., sugical Cx., PreOp. Lab data, Op. time, outcome score	16

MINORS: methodological index for non-randomized studies, SOT: solid organ transplantation, F/U: follow-up, PSM: propensity score matched analysis, THA: total hip arthroplasty, OA: osteoarthritis, Cx.: complication, N/A: not available, ONFH: osteonecrosis of the femoral head, AKI: acute kidney injury, LT: liver transplantation, LOS: length of stay, RCS: retrospective cohort study, HA: hemiarthroplasty, FNF: femur neck fracture, Op.: operation, KT: kidney transplantation.

collection of data) and lack of prospective calculation of the sample size (item 8: prospective calculation of the study size). The criteria used to evaluate the main outcomes of interest for this analysis were addressed in all studies (item 4: endpoints appropriate to the aim of the study). All studies received a point deduction because the authors did not perform unbiased assessments of their study endpoints (item 5: unbiased assessment of the study endpoint). Three articles[14,17,20] each received a point deduction because the authors did not describe the length of follow-up, and one study[16] received a point deduction because it included patients who did not undergo adequate follow-up (item 6: follow-up period appropriate to the aim of the study). Eight studies[5,14-17,19-21] each received a point deduction because a description of their follow-up rate was not included (item 7: loss to follow-up less than 5%). No deductions were made from the additional criteria domains (an adequate control group, contemporary groups, baseline equivalence of groups, and adequate statistical analyses).

4. Meta-analysis

1) Medical complications of hip arthroplasty according to SOT (overall) status

Data regarding post-arthroplasty medical complication were extracted from seven articles[5,13-15,17,20,21] for comparisons between the overall SOT group and the control group. Among the seven articles, cardiac complications were reported in four articles[5,13,15,20] including 1,985/14,354 patients (13.8%) in the SOT group and 217,644/3,560,883 patients (6.1%) in the control group. The incidence of pneumonia was reported in four articles[5,13,15,20], including 362/14,354 patients (2.5%) in the SOT group and 32,081/3,560,883 patients (0.9%) in the control group. PTE data were reported in five articles[5,13,15,20,21], including 107/14,363 patients (0.7%) in the SOT group and 12,208/3,560,910 patients (0.3%) in the control group. DVT was reported in three articles[5,15,21], including 41/1,083 patients (3.8%) in the SOT group and 19,585/781,771 patients (2.5%) in the control group. According to the findings of four studies[5,13,14,17], AKI was observed in 945/6,746 patients (14.0%) in the SOT group and 26,447/778,620 (3.4%) in the control group.

Regarding medical complications, cardiac complications were examined in four studies[5,13,15,20]; significantly higher incidences were observed in the SOT group compared with the control group (OR, 1.54; 95% CI, 1.02-2.31; P=0.04; I^2=97%). Myocardial infarction (MI), arrhythmia, and heart failure as cardiac complications were compared in two studies[5,13]. The other two studies compared only MI as a cardiac complication[15,20]. Significantly higher incidences of pneumonia (OR, 1.57; 95% CI, 1.24-2.01; P<0.01; I^2=71%) and AKI (OR, 7.68; 95% CI, 3.48-16.95; P<0.01; I^2=98%) following hip arthroplasty were observed in the SOT group compared with the control group. No significant differences in the rates of PTE and DVT were observed between the SOT group and the control group. The relevant forest plot and additional details are shown in Fig. 2.

2) Surgical complications of hip arthroplasty following overall SOT

Data regarding surgical complications were extracted from eight studies[5,13,15,16,18-21]. Regarding the details, the four studies[5,13,15,20] reported data on transfusion after hip arthroplasty; 3,253/14,354 patients (22.7%) in the SOT group and 701,199/3,560,883 patients (19.7%) in the control group underwent transfusion after hip arthroplasty. The incidence of PJI was reported in six studies[5,13,15,19-21]; 233/14,457 cases (1.6%) in the SOT group and 26,392/3,615,812 cases (0.7%) in the control group. In addition, the six studies[5,13,16,18-20] reported on hip D/L after arthroplasty; 245/14,011 cases (1.7%) in the SOT group and 27,853/3,605,666 cases (0.8%) in the control group. From three studies[13,16,18], aseptic loosening was reported in 26/3,179 patients (0.8%) in the SOT group and 68/6,323 patients (1.1%) in the control group, and, from six studies[5,13,15,16,18,19], the incidences of revision surgeries for any reasons were 265/6,966 (3.8%) in the SOT group and 38,299/842,969 (4.5%) in the control group. The results from the pooled analyses showed that the transfusion rate was higher in the SOT group compared with the control group (OR, 1.43; 95% CI, 1.30-1.58; P<0.01; I^2=69%), and, among surgical complications, this is the only variable that showed significant differences between the SOT group and the control group. No differences in the incidence of PJI, D/L, aseptic loosening, and revision surgeries were observed between groups. A forest plot and additional details are shown in Fig. 3.

3) Readmission rate and 90-day mortality rate following primary hip arthroplasty according to SOT (overall) status

Three studies reported on readmission rates after primary hip arthroplasty; 77/638 patients (12.1%) in the SOT group and 16,980/65,179 patients (26.1%) in the control group were readmitted. A significantly higher readmission rate was observed in the SOT group compared with the control group (OR, 1.65; 95% CI, 1.03-2.65; P=0.04; I^2=49%).

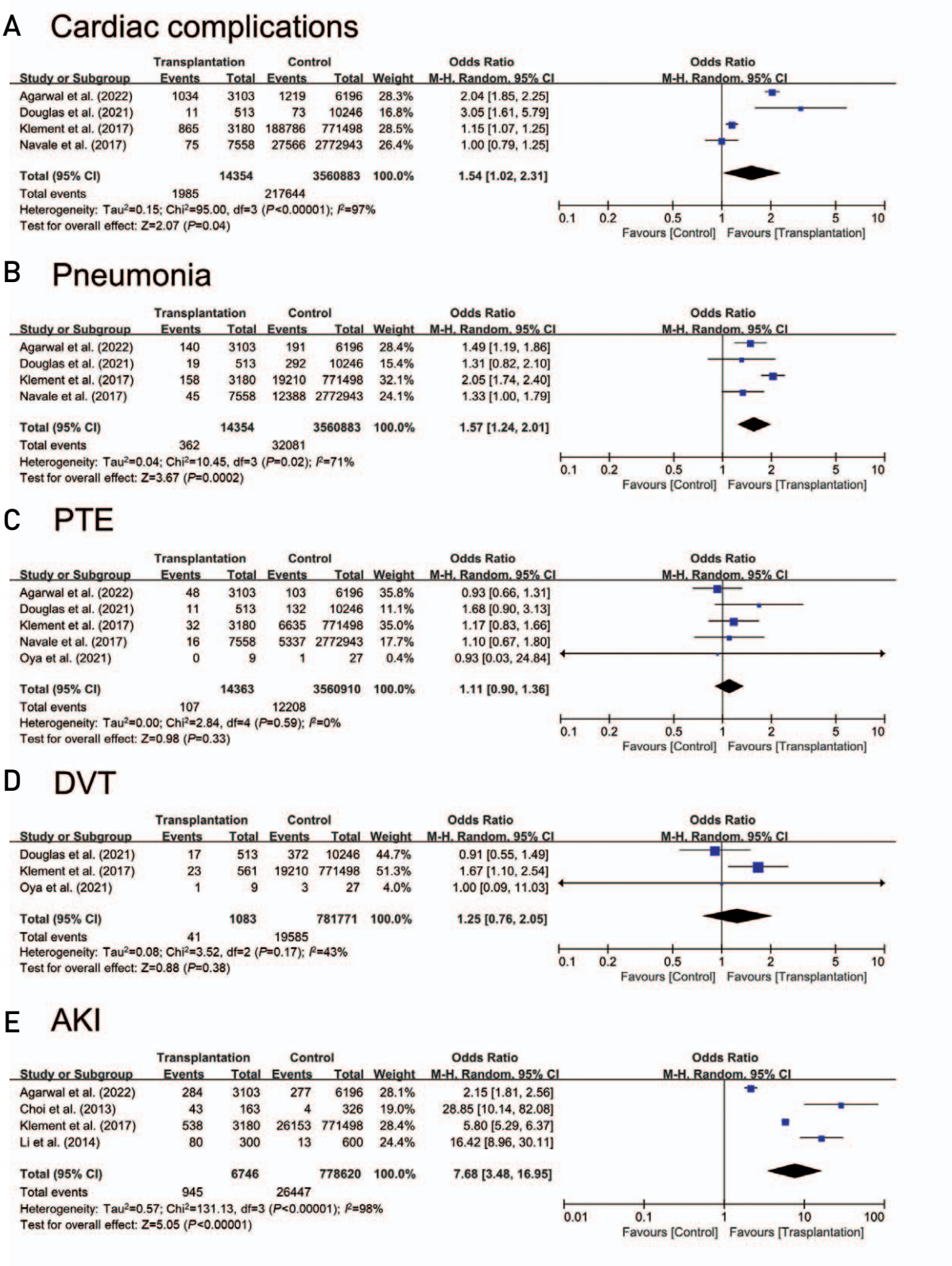

Fig. 2. Forest plot showing the medical complications of hip arthroplasty following solid organ transplantation; the incidence of (**A**) cardiac complications, (**B**) pneumonia, (**C**) pulmonary thromboembolism (PTE), (**D**) deep vein thrombosis (DVT), and (**E**) acute kidney injury (AKI).
CI: confidence interval.

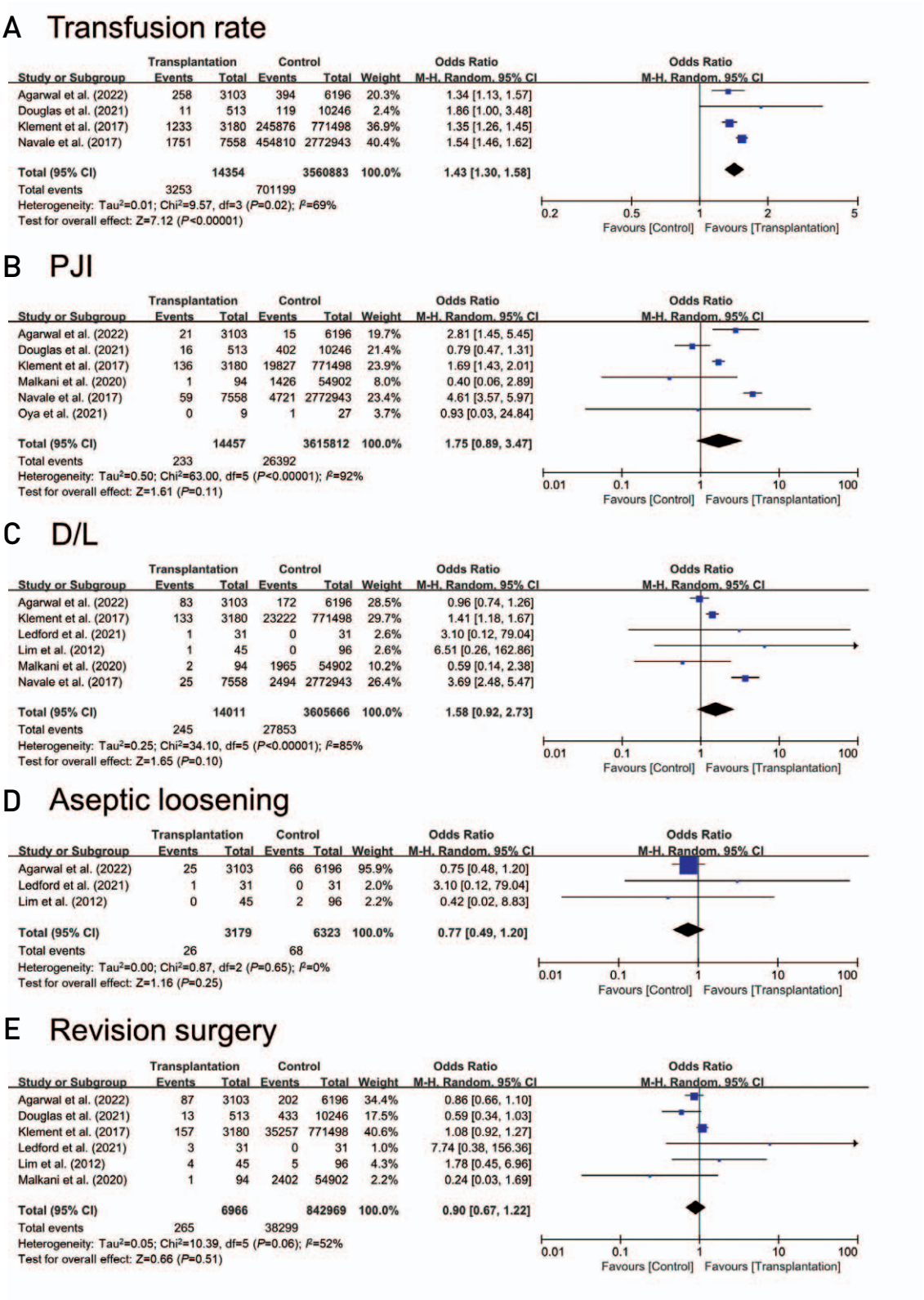

Fig. 3. Forest plot showing the surgical complications of hip arthroplasty following solid organ transplantation; (**A**) the transfusion rate after hip arthroplasty, (**B**) the rate of prosthetic joint infection (PJI), (**C**) postoperative dislocation (D/L) rate, (**D**) the incidence of aseptic loosening, and (**E**) the rate of revision surgery for any reasons.
CI: confidence interval.

Regarding 90-day mortality rates, three studies reported on 16/3,228 patients (0.5%) in the SOT group and 469/61,129 patients (0.8%) in the control group. A significantly higher 90-day mortality rate was observed in the SOT group compared with the control group (OR, 2.02; 95% CI, 1.03-3.98; P=0.04; I^2=0%). The relevant forest plot and additional details are shown in Fig. 4.

4) Subgroup analyses: primary hip arthroplasty outcomes among KT and LT recipients

For KT recipients, data regarding DVT, D/L, and the rate of revision surgery were extracted from three studies[5,18,19], which included 2,460 patients in the KT group and 826,496 patients in the control group. A significantly higher incidence of DVT was observed in the KT subgroup compared with the control group (OR, 1.62; 95% CI, 1.33-1.96; P<0.01; I^2=0%); however, there was no such difference in terms of the rates of D/L and revision surgery. For the LT subgroup, meta-analyses of the rates of PTE, DVT, and PJI were performed, using data from three studies[5,15,21] which included 1,083 patients in the LT subgroup and 781,771 patients in the control group. The incidence of PTE, DVT, or PJI in the LT subgroup did not differ significantly from that of the control group (Table 2).

DISCUSSION

The findings of this meta-analysis demonstrated that, compared with control subjects, the incidence of medical complications (cardiac complication, pneumonia, and AKI), and the rates of transfusion, readmission, and mortality are higher for SOT recipients following primary hip arthroplasty.

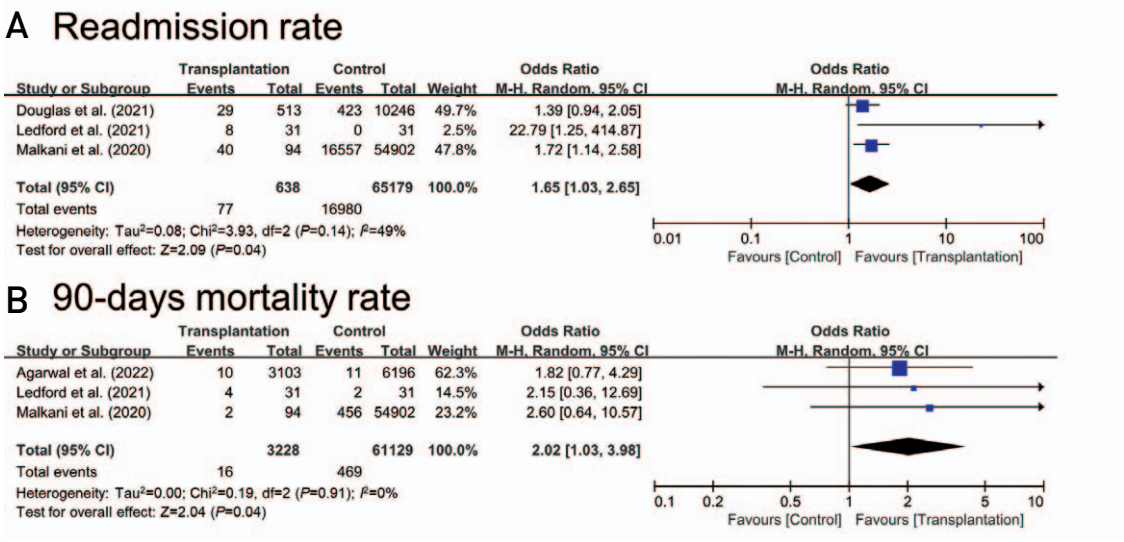

Fig. 4. Forest plot showing (A) the readmission rate, and (B) 90-day mortality rate for hip arthroplasty following solid organ transplantation.
CI: confidence interval.

Table 2. Odds Ratios of Outcomes following Each Sub-Analysis Comparing Organ Transplantation to Control Group

Subgroup and outcomes	No. of studies	OR (95% CI)	I^2 (%)	P-value
Kidney transplantation				
DVT	3	1.62 (1.33-1.96)	0	<0.001
D/L	3	1.33 (0.75-2.34)	17	0.330
Revision rate	3	1.09 (0.55-2.16)	33	0.810
Liver transplantation				
PTE	3	1.42 (0.86-2.34)	0	0.170
DVT	3	1.25 (0.76-2.05)	43	0.380
PJI	3	1.14 (0.62-2.12)	58	0.670

DVT: deep vein thrombosis, D/L: dislocation, OR: odds ratio, CI: confidence interval, PTE: pulmonary thromboembolism, PJI: prosthetic joint infection.

Specifically, cardiac complications, pneumonia, and AKI were significantly more common in the SOT group; however, no difference in the incidences of post-arthroplasty PTE and DVT was observed between the two groups. According to the findings of a previous meta-analysis of postoperative complications after total hip and knee arthroplasty in LT patients, conducted by Han and Deren[7], higher rates of MI, respiratory failure, and AKI were observed in 3,024 LT patients compared with control subjects. In the analysis of the THA subgroup, excluding total knee arthroplasty (TKA), a significantly higher rate of MI, arrythmia, respiratory failure, AKI, pneumonia, and sepsis was also reported. In addition, differences in rates of PTE or DVT after THA were not reported, even though significantly higher incidence of PTE and DVT was observed in the overall THA and TKA group, as well as in the TKA-only group. Despite application of different statistical methods, our results were comparable to those reported by Han and Deren[7]; therefore, compared with our results, this was an interesting finding. However, caution is required in the interpretation of these results. Because patients with SOT are more likely to have underlying disease, they are likely to suffer from these medical complications even if they did not undergo arthroplasty. Thus, caution should be used in order not to misinterpret arthroplasty as a risk factor for these medical complications; medical complications should be closely monitored, particularly cardiac complications, pneumonia, and AKI after THA in patients with a history of SOT.

The findings of the current analysis showed a significantly higher transfusion rate following hip arthroplasty in the SOT group compared with the control group (P<0.01). There were no intergroup differences in the rates of PJI, D/L, aseptic loosening, or revision surgery. A single-arm meta-analysis conducted by Han and Deren[7] to examine the surgical outcomes reported an over-3-fold higher rate of blood transfusion after THA among LT recipients compared with control subjects. They also reported that there were no intergroup differences in rates of revision surgery and post-THA D/L. These findings are also comparable with those reported in our study. Considering that most SOT patients, especially those who have undergone KT or LT, are at risk of coagulopathy (due to anti-coagulation medication or liver impairment causing impaired hemostasis[22]), these results are credible.

Both the readmission rate and 90-day mortality rate were also significantly more common in the SOT group. Even though we were not able to perform detailed meta-analyses with regard to the mortality rates, due to the lack of relevant studies, several studies reported similar results: previous SOT showed an association with higher readmission and mortality rates, over both short and intermediate intervals[6,23,24]. Conduct of additional well-structured prospective studies will be required in order to clarify these issues.

For the subgroup analyses, the meta-analysis could be performed for KT and LT patients. Even though it was not included in the meta-analysis (because it did not meet our criteria), our search yielded one recent well-structured study[2] comparing the clinical outcomes after TJA among patients with or without LT. After performance of a 1:10 propensity-score matching analysis of 43 TJA patients after LT, compared with 430 control subjects, the authors concluded that morbidity and mortality appear to be comparable between the groups. They reported no differences in 30-day and 90-day postoperative complication, readmission, reoperation, and mortality rates between the two groups. This finding is also comparable to that of our current meta-analysis. In the KT subgroup, the DVT rate was the only variables showing a difference in the control group after hip arthroplasty. A previous study reported that chronic kidney disease was an important risk factor for DVT following TJA[25]; therefore, this is an interesting finding. The authors emphasized the importance of postoperative prophylaxis against DVT after THA, especially for chronic kidney disease patients. DVT prophylaxis following hip arthroplasty should also be carefully considered, especially for KT patients.

The current study had several limitations. First, despite the large number of included studies and patients, all articles reported level III evidence. The strength of the conclusions is limited by the level of studies included in this review. However, a meta-analysis is an appropriate method for generating a high level of data regarding rare conditions, suggesting that our synthetic results are meaningful. Second, a high level of heterogeneity was observed in some of the pooled results. The small amount of data regarding each outcome could have resulted in bias. In addition, some studies included relatively large numbers of patients compared to other studies[5,20]. Sample size is not the only factor determining the weight of a study, careful interpretation of the results is also required. Thus, conduct of future prospective comparative studies will be helpful in providing a clearer analysis of these issues. Third, we attempted to perform a subgroup analysis in order to generate evidence for different indications for hip arthroplasty, e.g., age-related OA, hip fracture, and ONFH; however, such analyses could not be

performed due to the lack of studies examining this specific question. However, to the best of our knowledge, this study is the first double-arm meta-analysis that extensively examined the association between SOT and hip arthroplasty outcomes, including sub-analyses for different types of SOT.

Furthermore, despite these caveats, this study provided answers to clinically relevant questions based on the results of a statistical evaluation: previous SOT is associated with a higher risk of medical/surgical complications, as well as rates of readmission and mortality, after hip arthroplasty.

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CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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Hip Pelvis 34(3): 127-139, 2022

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Appendix 1. The Literature Search Algorithm and the Results from Relevant Clinical Studies

PubMed (January 5, 2022)

	Search queries	No. of articles
#1	"hip" [Title/Abstract]	156,173
#2	"replacement" [Title/Abstract] OR "arthroplast*" [Title/Abstract]	337,564
#3	"arthroplasty, hip replacement" [MeSH Terms]	31,779
#4	Search (#1 AND #2)	47,850
#5	Search (#3 OR #4)	54,498
#6	"transplant*" [Title/Abstract]	516,024
#7	Search (#5 AND #6)	421

Embase (January 5, 2022)

	Search queries	No. of articles
#1	hip:ti,ab,kw	211,510
#2	replacement:ti,ab,kw	382,769
#3	arthroplast*:ti,ab,kw	93,471
#4	Search (#2 OR #3)	457,819
#5	Search (#1 AND #4)	61,206
#6	transplant*:ti,ab,kw	803,630
#7	Search (#5 AND #6)	581

Cochrane Library (January 5, 2022)

	Search queries	No. of articles
#1	hip:ti,ab,kw	164
#2	replacement:ti,ab,kw	641
#3	arthroplast*:ti,ab,kw	50
#4	Search (#2 OR #3)	644
#5	Search (#1 AND #4)	72
#6	transplant*:ti,ab,kw	412
#7	Search (#5 AND #6)	51