Original Article
Clinics in Orthopedic Surgery 2024;16:382-389 • https://doi.org/10.4055/cios23351

Total Hip Arthroplasty Outcomes before or after Renal Transplant: A Retrospective Large Cohort Analysis

Zhichang Zhang, MD*,†, Elizabeth Driskill, MS†, Jialun Chi, BS†, Richard P. Gean, MD†, Quanjun Cui, MD†

*Department of Orthopaedic Surgery, The First Affiliated Hospital of Xinxiang Medical University, Weihui, Henan, China
†Department of Orthopaedic Surgery, University of Virginia School of Medicine, Charlottesville, VA, USA

Background: While it is known that patients with end-stage renal disease (ESRD) are at an increased risk of complications following total hip arthroplasty (THA), there is a gap in the literature in comparing patients with ESRD to patients who undergo renal transplant (RT) before or after THA. This study is to address this gap by analyzing outcomes of THA in ESRD patients, RT patients, and RT candidates.

Methods: Using the PearlDiver Mariner database, ESRD patients, RT patients, and RT candidates undergoing primary THA were identified and compared. Multivariable logistic regression analyses were done for medical complications up to 90 days and surgical complications up to 2 years. Ninety-day emergency department (ED) visits and inpatient readmission were also documented.

Results: A total of 7,868 patients were included: 5,092 had ESRD, 2,520 had RT before THA, and 256 were candidates for RT. Compared to patients with ESRD, RT patients demonstrated lower rates of medical complications such as pneumonia (3.61% vs. 5.99%, $p = 0.039$) and transfusion (4.60% vs. 7.66%, $p < 0.001$). Additionally, RT patients displayed decreased rates of surgical complications, including wound complications (2.70% vs. 4.22%, $p = 0.001$), periprosthetic joint infection (PJI) at 1 year (2.30% vs. 4.81%, $p < 0.001$) and 2 years (2.58% vs. 5.42%, $p < 0.001$), and aseptic loosening at 2 years (0.79% vs. 1.43%, $p = 0.006$). Similarly, when compared to RT candidates, RT patients demonstrated a lower incidence of postoperative complications, including 1-year PJI (2.30% vs. 5.08%, $p = 0.013$), 2-year PJI (2.58% vs. 5.08%, $p = 0.028$), 1-year aseptic loosening (0.56% vs. 2.73%, $p < 0.001$), and 2-year aseptic loosening (0.79% vs. 2.73%, $p = 0.005$). RT patients also had lower rates of ED visits and hospital readmissions.

Conclusions: Compared to ESRD patients and RT candidates, patients with RT have a significantly lower likelihood of medical complications, PJI, aseptic hardware loosening, ED visits, and hospital readmission. Patients with ESRD on the RT waiting list should delay THA until after RT surgery. For those not eligible for RT, it is vital to take extra precautions to reduce the risk of complications.

Keywords: *End-stage renal disease, Renal transplant, Total hip arthroplasty, Complications, Hip*

Chronic kidney disease (CKD) remains a significant global health challenge, affecting an estimated 9% of the global population.[1)] Notably, the incidence of CKD is on an upward trajectory in the United States.[2)] A substantial proportion of patients with CKD eventually advance to end-stage renal disease (ESRD). The primary management strategies for advanced CKD encompass long-term hemodialysis (HD) or renal transplant (RT), the latter being the predominant solid organ transplant procedure executed

Received November 9, 2023; Revised December 17, 2023;
Accepted December 17, 2023
Correspondence to: Quanjun Cui, MD
Department of Orthopaedic Surgery, University of Virginia School of Medicine, 2280 Ivy Rd, Charlottesville, VA 22903, USA
Tel: +1-434-982-4832, Fax: +1-434-245-2035
E-mail: qc4q@uvahealth.org

globally.[3)] Individuals with CKD, particularly those undergoing HD or post-RT, are predisposed to an elevated risk for total hip arthroplasty (THA) due to several unique risk factors. This susceptibility can be attributed to high rates of osteonecrosis, femoral neck fracture, and osteoarthritis resulting from renal osteodystrophy, amyloid deposition secondary to long-term HD, as well as the use of immunosuppressive medication after RT.[4,5)] It is noteworthy that the incidence of THA is markedly higher in HD-dependent patients and RT recipients compared to the general population.[6)]

THA implants have demonstrated satisfactory survivorship in both HD and RT patients.[7,8)] HD has previously been established as a significant risk factor for poor outcomes and perioperative complications following THA due to concerns such as increased mortality and surgical site infections.[7,9)] In comparison to the general population, RT patients also appear to be at higher risk for sustaining postoperative complications.[8,10)] However, existing comparative studies analyzing postoperative clinical outcomes following THA between these two cohorts (HD and RT patients) are either antiquated, fraught with limitations, or yield inconsistent results.[11-14)] Additionally, patients who are candidates for RT are distinct from the broader ESRD patient population. According to the guideline on the evaluation and management, RT candidates are younger and have fewer risk factors and comorbidities,[15)] but no studies to date have drawn a comparison of THA outcomes between general ESRD patients and transplant candidates. If there is a delineation in outcomes between these 2 populations, this would allow providers to avoid delaying pain-relieving arthroplasty procedures. The purpose of this research was to examine the outcomes after THA in patients with ESRD, those who have received RT, and RT candidates.

METHODS

Ethical Statements

This retrospective research study utilized the PearlDiver Patient Records Database, a national private payer insurance database that contains indexed and de-identified data. The database consists of procedural volumes and patient demographics for patients with International Classification of Diseases, 9th Revision diagnoses (ICD-9), 10th Revision diagnoses (ICD-10), and procedures or Current Procedural Terminology (CPT) codes. The Institutional Review Board deemed this study exempt from ethical approval and the need for participants' consent to participate in the study and publish the results.

Data Source

This research utilized the PearlDiver database (www.pearldiverinc.com), a national patient record database that operates on a fee-based model. The database integrates patient demographics and medical records, including diagnoses under the International Classification of Diseases, 9th Revision (ICD-9-CM) and 10th Revision (ICD-10-CM), as well as procedures identified by Current Procedural Terminology (CPT) codes. These records are derived from a variety of insurance sources, such as commercial insurance, Medicare, Medicaid, and self-pay. The Mariner161 dataset, which contains approximately 161 million individual patient records from 2010 to 2022, was the specific dataset extracted for analysis. Access to the PearlDiver database was granted by PearlDiver Technologies for research purposes. All patient data were de-identified, leading to an exemption from the Institutional Review Board for this study.

Study Population

Adult patients who underwent primary THA from January 1, 2010, to April 30, 2020, with the aim of a minimum 2-year follow-up or reaching the endpoint of mortality within 2 years postoperatively were identified using CPT and ICD-9 and 10 codes. Three groups were created subsequently. Group A consisted of patients with ESRD (ICD-9 585.6 and ICD-10 N18.6) prior to THA and without a history of RT history. Group B included patients with an RT prior to THA who were identified using CPT and ICD-9 and 10 codes (CPT-50360, CPT-50365, ICD-9-D-V42.0, and ICD-10-D-Z94.0). Group C included RT candidates who were identified through RT records within 1 year after THA.

Patients in each group were queried for basic demographic information, including sex, age, and tobacco abuse. Comorbidities for each patient were assessed using ICD-9 and ICD-10 codes, including obesity, morbid obesity, chronic obstructive pulmonary disease, diabetes mellitus, coronary artery disease, congestive heart failure, hyperlipidemia, peripheral vascular disease, hypertension, and depression. A total of 5,092 ESRD patients, 2,520 RT patients prior to THA, and 256 RT candidates within 1 year after THA were included in the study. Additionally, indications for THA, including hip osteoarthritis, osteonecrosis of the femoral head, and femoral neck fracture, were queried (Table 1).

Outcomes of Interest

Rates of medical complications within 90 days postoperatively were collected. These included pneumonia, pul-

Table 1. Patient Demographics

Variable	A (ESRD; n = 5,092)	B (Renal transplant; n = 2,520)	C (Candidates; n =2 56)	*p*-value (A vs. B)	*p*-value (A vs. C)	*p*-value (B vs. C)
Age (yr)	66.34 ± 11.35	59.65 ± 12.42	59.68 ± 12.52	< 0.001*	< 0.001*	0.969
Sex (female)	2,393 (47.00)	1,015 (40.28)	115 (44.92)	< 0.001*	0.516	0.149
Comorbidity						
Obesity (BMI 30–39.9 kg/m^2)	763 (14.98)	314 (12.46)	26 (10.16)	0.002*	0.033*	0.283
Morbid obesity (BMI ≥ 40 kg/m^2)	466 (9.15)	112 (4.44)	14 (5.47)	< 0.001*	0.044*	0.453
Chronic obstructive pulmonary disease	2,252 (44.23)	670 (26.59)	64 (25.00)	< 0.001*	< 0.001*	0.583
Diabetes mellitus	2,601 (51.08)	1006 (39.92)	73 (28.52)	< 0.001*	< 0.001*	< 0.001*
Coronary artery disease	2,614 (51.34)	867 (34.40)	79 (30.86)	< 0.001*	< 0.001*	0.254
Congestive heart failure	1,875 (36.82)	607 (24.09)	52 (20.31)	< 0.001*	< 0.001*	0.176
Hyperlipidemia	3,764 (73.92)	1,812 (71.90)	128 (50.00)	0.123	< 0.001*	< 0.001*
Peripheral vascular disease	1,542 (30.28)	415 (16.47)	33 (12.89)	< 0.001*	< 0.001*	0.138
Hypertension	4,564 (89.63)	2,210 (87.70)	181 (70.70)	0.012*	< 0.001*	< 0.001*
Depression	1,554 (30.52)	560 (22.22)	57 (22.27)	< 0.001*	0.004*	0.987
Substance abuse						
Tobacco	1,558 (30.60)	525 (20.83)	54 (21.09)	< 0.001*	0.001*	0.922
Indications for total hip arthroplasty						
Hip osteoarthritis	2,644 (51.92)	1,126 (44.68)	123 (48.05)	< 0.001*	0.225	0.302
Osteonecrosis of femoral head	928 (18.22)	913 (36.23)	67 (26.17)	< 0.001*	0.001*	0.001*
Femoral neck fracture	956 (18.77)	225 (8.93)	34 (13.28)	< 0.001*	0.027*	0.022*
Unknown	564 (11.08)	256 (10.16)	32 (12.50)	-	-	-

Values are presented as mean ± standard deviation or number (%).
ESRD: end-stage renal disease, BMI: body mass index.
*Statistical significance with $p < 0.05$.

monary embolism, cerebrovascular accident, deep vein thrombosis, transfusion, urinary tract infection (UTI), sepsis, acute heart failure, and myocardial infarction. Surgical complications included 90-day wound complications, periprosthetic joint infection (PJI), dislocation, aseptic loosening, periprosthetic fracture, and all-cause revision within 1 and 2 years. Ninety-day emergency department (ED)-visit and inpatient readmission were also queried.

Statistical Analysis

Statistical analyses were performed using the R statistical software (version 4.1.0; R Project for Statistical Computing) integrated within the PearlDiver software with an α level set to 0.05, with results reported as adjusted odds ratios (ORs) with 95% confidence intervals (CIs). The average age of the patient cohorts was assessed by *t*-test. The chi-square test was used to assess the statistical significance of differences among the groups in sex, comorbidities, tobacco abuse, and indications for primary THA. Rates of postoperative complications were compared using multivariate logistic regression, adjusting for age, sex, tobacco abuse, diabetes mellitus, chronic obstructive pulmonary disease, and coronary artery disease, which are all factors that would likely not be directly affected by RT.

RESULTS

Patient Characteristics

The analysis demonstrated that ESRD patients (group A) were significantly older with a mean age of 66.34 ± 11.35

Table 2. Patient Postoperative Outcomes

Variable	A (ESRD; n = 5,092)	B (Renal transplant; n = 2,520)	C (Candidates; n = 256)	Adjusted OR (95% CI) (*p*-value B vs. A)	Adjusted OR (95% CI) (*p*-value C vs. A)	Adjusted OR (95% CI) (*p*-value B vs. C)
Pneumonia (90 days)	305 (5.99)	91 (3.61)	15 (5.86)	0.76 (0.59–0.98) (0.039)*	1.28 (0.71–2.14) (0.374)	0.59 (0.33–1.05) (0.076)
Pulmonary embolism (90 days)	25 (0.49)	18 (0.71)	1 (0.39)	1.53 (0.78–2.95) (0.198)	0.86 (0.04–4.29) (0.892)	1.77 (0.35–32.1) (0.580)
Cerebrovascular accident (90 days)	110 (2.16)	28 (1.11)	2 (0.78)	0.69 (0.44–1.06) (0.103)	0.51 (0.08–1.66) (0.361)	1.34 (0.39–8.36) (0.689)
Deep vein thrombosis (90 days)	156 (3.06)	77 (3.06)	6 (2.34)	1.26 (0.94–1.69) (0.114)	0.94 (0.36–2.01) (0.902)	1.33 (0.62–3.47) (0.500)
Transfusion (90 days)	390 (7.66)	116 (4.60)	11 (4.30)	0.61 (0.49–0.77) (< 0.001)*	0.57 (0.31–1.07) (0.084)	1.06 (0.59–2.12) (0.847)
Urinary tract infection (90 days)	392 (7.70)	199 (7.90)	25 (9.77)	1.36 (1.12–1.65) (0.001)*	1.68 (1.06–2.55) (0.019)*	0.81 (0.53–1.29) (0.362)
Sepsis (90 days)	244 (4.79)	88 (3.49)	9 (3.52)	0.82 (0.62–1.07) (0.140)	0.86 (0.40–1.62) (0.685)	0.94 (0.49–2.05) (0.881)
Myocardial infarction (90 days)	92 (1.81)	26 (1.03)	5 (1.95)	0.88 (0.54–1.38) (0.594)	1.85 (0.63–4.29) (0.192)	0.47 (0.19–1.42) (0.134)
Wound complication (90 days)	215 (4.22)	68 (2.70)	9 (3.52)	0.61 (0.45–0.81) (0.001)*	0.79 (0.37–1.50) (0.520)	0.76 (0.39–1.67) (0.469)
Periprosthetic joint infection (1 year)	245 (4.81)	58 (2.30)	13 (5.08)	0.45 (0.33–0.61) (< 0.001)*	0.99 (0.53–1.71) (0.992)	0.45(0.24–0.84) (0.013)*
Periprosthetic joint infection (2 years)	276 (5.42)	65 (2.58)	13 (5.08)	0.43 (0.32–0.57) (< 0.001)*	0.87 (0.46–1.49) (0.638)	0.50 (0.28–0.81) (0.028) *
Dislocation (1 year)	189 (3.71)	84 (3.33)	13 (5.08)	0.95 (0.72–1.25) (0.745)	1.43 (0.75–2.48) (0.230)	0.66 (0.37–1.27) (0.187)
Dislocation (2 year)	210 (4.12)	87 (3.45)	14 (5.47)	0.88 (0.67–1.15) (0.368)	1.37 (0.74–2.33) (0.272)	0.64 (0.37–1.20) (0.138)
Aseptic loosening (1 year)	43 (0.84)	14 (0.56)	7 (2.73)	0.58 (0.31–1.10) (0.098)	2.97 (1.18–6.47) (0.010)*	0.19 (0.08–0.53) (< 0.001)*
Aseptic loosening (2 years)	73 (1.43)	20 (0.79)	7 (2.73)	0.48 (0.28–0.79) (0.006)*	1.68 (0.69–3.53) (0.200)	0.28 (0.12–0.74) (0.005)*
Periprosthetic fracture (1 year)	80 (1.57)	27 (1.07)	4 (1.56)	0.80 (0.49–1.25) (0.346)	1.18 (0.35–2.94) (0.741)	0.67 (0.25–2.29) (0.465)
Periprosthetic fracture (2 years)	95 (1.87)	36 (1.43)	6 (2.34)	0.86 (0.57–1.30) (0.489)	1.47 (0.63–3.45) (0.369)	0.58 (0.24–1.42) (0.233)
Revision (1 year)	151 (2.97)	61 (2.42)	10 (3.91)	0.75 (0.54–1.03) (0.079)	1.18 (0.57–2.18) (0.617)	0.63 (0.33–1.33) (0.194)
Revision (2 years)	184 (3.61)	69 (2.74)	10 (3.91)	0.67 (0.49–0.90) (0.009)*	0.92 (0.44–1.70) (0.818)	0.72 (0.38–1.52) (0.360)
ED visit (90 days)	1,150 (22.58)	396 (15.71)	58 (22.66)	0.69 (0.60–0.79) (< 0.001)*	1.09 (0.79–1.48) (0.559)	0.63 (0.46–0.87) (0.004)*
Readmit (90 days)	1,036 (20.35)	301 (15.20)	48 (18.75)	0.57 (0.49–0.66) (< 0.001)*	0.99 (0.70–1.36) (0.966)	0.57 (0.41–0.81) (0.001)*

Values are presented as number (%) unless otherwise indicated. OR (95% CI) and *p*-value were adjusted for age, sex, obesity, chronic obstructive pulmonary disease, diabetes mellitus, coronary artery disease, and tobacco abuse.
ESRD: end-stage renal disease, OR: odds ratio, CI: confidence interval, ED: emergency department.
*Statistical significance with $p < 0.05$.

years, compared to RT patients and RT candidates (groups B and C) with mean ages of 59.65 ± 12.42 years and 59.68 ± 12.52 years, respectively. Group A exhibited a higher proportion of female patients (47.00%) compared to group B (40.28%) and group C (44.92%). Moreover, ESRD patients in group A were found to have higher incidences of medical comorbidities such as obesity (14.98% vs. 12.46% and 10.16%), morbid obesity (9.15% vs. 4.44% and 5.47%), chronic obstructive pulmonary disease (44.23% vs. 26.59% and 25.00%), diabetes mellitus (51.08% vs. 39.92% and 28.52%), coronary artery disease (51.34% vs. 34.40% and 30.86%), congestive heart failure (36.82% vs. 24.09% and 20.31%), peripheral vascular disease (30.28% vs. 16.47% and 12.89%), depression (30.52% vs. 22.22% and 22.27%), and tobacco abuse (30.60% vs. 20.83% and 21.09%). Osteoarthritis emerged as the primary diagnosis across all groups, although it was markedly higher in group A (51.92%) compared to group B (44.68%) and group C (48.05%). Femoral neck fracture was the second most common indication in group A (18.77%), contrasting with groups B and C, where osteonecrosis of the femoral head was the second most common indication (36.23% and 26.17%, respectively) (Table 1).

Postoperative Outcomes

The multivariate regression analysis unveiled that relative to group A, RT patients in group B had lower rates of pneumonia (3.61% vs. 5.99%; adjusted OR, 0.76; 95% CI, 0.59–0.98; $p = 0.039$) and transfusion (4.60% vs. 7.66%; adjusted OR, 0.61; 95% CI, 0.49–0.77; $p < 0.001$), but a higher rate of UTIs (7.90% vs. 7.70%; adjusted OR, 1.36; 95% CI, 1.12–1.65; $p = 0.001$) within 90 days postoperatively. A significantly higher rate of UTIs was also observed in RT candidates in group C compared to group A (9.77% vs. 7.70%; adjusted OR, 1.68; 95% CI, 1.06–2.55; $p = 0.019$). No other significant differences in medical complications were found among the 3 groups (Table 2).

Regarding surgical complications, RT patients in Group B exhibited superior outcomes relative to ESRD patients in group A. This included lower incidences of wound complications (2.7% vs. 4.22%; adjusted OR, 0.61; 95% CI, 0.45–0.81; $p = 0.001$), 1-year PJI (2.30% vs. 4.81%; adjusted OR, 0.45; 95% CI, 0.33–0.61; $p < 0.001$), 2-year PJI (2.58% vs. 5.42%; adjusted OR, 0.43; 95% CI, 0.32–0.57; $p < 0.001$), 2-year aseptic loosening (0.79% vs. 1.43%; adjusted OR, 0.48; 95% CI, 0.28–0.79; $p = 0.006$), and 2-year revision (2.74% vs. 3.61%; adjusted OR, 0.67; 95% CI, 0.49–0.90; $p = 0.009$). Similarly, when compared to group C, group B demonstrated a lower incidence of postoperative complications, including 1-year PJI (2.30% vs. 5.08%; adjusted OR, 0.45; 95% CI, 0.24–0.84; $p = 0.013$), 2-year PJI (2.58% vs. 5.08%; adjusted OR, 0.45; 95% CI, 0.28–0.81; $p = 0.028$), 1-year aseptic loosening (0.56% vs. 2.73%; adjusted OR, 0.19; 95% CI, 0.08–0.53; $p < 0.001$), and 2-year aseptic loosening (0.79% vs. 2.73%; adjusted OR, 0.28; 95% CI, 0.12–0.74; $p = 0.005$). No significant differences were observed in surgical complications between groups C and A, except for 1-year aseptic loosening (2.73% vs. 0.84%; adjusted OR, 2.97; 95% CI, 1.18–6.47; $p = 0.010$) (Table 2).

Furthermore, RT patients in Group B exhibited significantly lower rates of 90-day ED visits (15.71% vs. 22.58% and 22.66%) and hospital readmissions (15.20% vs. 20.35% and 18.75%) when compared to groups A and C (Table 2).

DISCUSSION

With the increasing prevalence of ESRD, RT has become the most commonly performed solid-organ transplants worldwide.[3] THA is often required in this patient population, and both ESRD and RT are recognized as risk factors for postoperative outcomes when compared to the general population undergoing THA.[6-8] The present retrospective study illustrated that RT patients have lower rates of postoperative complications when compared to both ESRD patients and RT candidates. To our knowledge, the present study is the only large cohort analysis probing the impact of RT on postoperative outcomes following THA by comparing patients with a history of RT prior to THA to both ESRD patients and RT candidates.

The results of this study showed that the rates of pneumonia and blood transfusion within 90 days postoperatively were significantly lower in RT patients undergoing THA compared to ESRD patients (adjusted OR, 0.61 and 0.23, respectively). These findings are largely in agreement with the prior literature.[13] Higher blood transfusion rates in ESRD patients can be explained by the fact that ESRD is characterized by anemia with decreased red blood cell production and frequent coagulopathy,[16] both of which are factors that can lead to increased intraoperative bleeding. Patients with RT should theoretically no longer have these hematologic complications once their defective kidney is transplanted.

Patients with ESRD on HD are at an elevated risk of infection compared to the general population due to their frequent healthcare contact while attending dialysis, typically 3 times per week, which increases their risk of both community-acquired and nosocomial infections.[17] Previous studies have reported that approximately 20% of all infections in patients with ESRD can be attributed to pulmonary causes, including pneumonia.[17)] Compared to patients with RT, patients with ESRD on HD have much more frequent healthcare contact and thus higher likelihood of coming into contact with infected respiratory secretions. This likely outweighs the elevated risk of pneumonia that patients with RT may have as a result of taking immunosuppressive medications and could partially explain the finding of higher rates of pneumonia in ESRD patients in this study.[18)]

The present study also found a higher rate of UTI in RT patients (adjusted OR, 1.36), which indicates that RT increases the risk of UTI. This finding is consistent with the report by Tandogdu et al.,[19)] which recognized UTI as the most common infection in RT patients. This could be due to the fact that most RT patients are taking immunosuppressive medications to decrease the risk of transplant rejection, but these immunosuppressive medications come with an increased risk of infection. Due to the limited cases of RT candidates, no significant differences in medical complications were observed between RT patients and candidates.

Patients with ESRD are known to be at an increased risk for wound complications.[20)] In a comprehensive study conducted by Ponnusamy et al.,[21)] dialysis patients were found to have a higher likelihood of experiencing wound hematoma, seroma, and infection. However, in a meta-analysis by Luo et al.,[22)] no significant difference in wound complications following total joint arthroplasty was observed between ESRD and RT patients. Our study, on the other hand, reveals a significant difference, with RT patients experiencing significantly fewer wound complications compared to ESRD patients and RT candidates. This improvement may be attributed to recent advancements in postoperative management for transplant patients. Additionally, patients with ESRD are known to have impaired wound healing due to uremic toxins that can affect local mechanisms of wound healing.[23)] These patients also commonly have other comorbidities that can affect wound healing, such as poorly controlled diabetes and peripheral vascular disease, both of which were seen at higher rates in patients with ESRD in this study.[23)]

Notably, our study also demonstrates lower rates of PJI at 1-year and 2-year intervals in RT patients compared to ESRD patients and RT candidates, with adjusted ORs of approximately 0.45. Infection is commonly seen following RT, but the highest risk of infection occurs within the first year after transplant.[24)] It is likely that most RT patients were not medically cleared for surgery within the first year after transplant due to this risk, and their risk of infection at the time of surgery was likely much lower, although we do not have access to the specific dates that each patient had RT and THA and cannot confirm that the majority of patients in the RT group were greater than 1-year post-transplant. The elevated risk of PJI in patients with ESRD has already been reported in prior studies and is likely related to ESRD patients' elevated risk of overall infection that has been described above.[25,26)]

The results of this study showed elevated rates of aseptic loosening at 1-year and 2-year intervals in RT candidates compared to RT patients. Altered calcium metabolism due to renal dysfunction can lead to increased bone resorption and decreased bone formation at the bone-cement interface, which can contribute to loosening.[27)] RT patients should theoretically have better renal function compared to RT candidates and thus should not experience loosening as a result of this phenomenon, which could at least partially explain the difference seen in this study. Considering the reduced rates of PJI and aseptic loosening, it is not surprising that RT patients exhibited a lower revision rate compared to ESRD patients. The prior literature with fewer samples or short-term follow-up periods reported similar results in terms of revision rate.[11,12,14)] Our analysis strengthened this characteristic of RT patients. RT patients also had lower rates of ED visit and hospital readmission within 90 days. Common reasons for ED visit and hospital readmission after THA in the general population include PJI, wound complications, and pulmonary infections, complications that are all seen at elevated rates in patients with ESRD in this study.[28)] Since ESRD patients and RT candidates have a higher rate of these complications, it follows that they also have a higher rate of having to present to the ED or be readmitted to the hospital for these issues.

This study benefits from the inherent advantages that come with the use of large national databases, namely the ability to examine rare conditions on a large scale. The inclusion of 5,092 patients with ESRD, 2,520 RT patients, and 256 RT candidates ensured that this study was adequately powered and did not suffer from the limitations of a small sample size and regional biases that can arise in single-center observational studies that are underpowered. This is particularly notable as it is the first study to illustrate the outcomes of RT candidates undergoing THA. Furthermore, the PearlDiver database uniquely offers the capacity to track patient data longitudinally after operation. In comparison to other databases, which can only track complications that occur in-hospital or within 30 days after surgery, outcomes can be recorded in the PearlDiver database at any time during enrollment, providing a reliable source of short- and intermediate-term data.[29]

The study included patients who underwent THA from January 1, 2010, to April 30, 2020, with the intention of achieving a regular postoperative follow-up period of at least 2 years. To ensure a comprehensive understanding of complications, the analysis also included patients who passed away within 2 years postoperatively. Nonetheless, there are limitations in tracking complications for patients with lost records, often due to insurance changes or other factors.

For ESRD patients, given their risk of infection and cardiovascular comorbidities, the mortality rate is a vital consideration. Higher rates of mortality among the ESRD patients have been reported in previous literatures.[25,30] Regrettably, the current database lacks mortality records, making it impossible to compare the actual mortality rates between the cohorts. Additionally, the validity of these results depends on the accuracy of the coding used within the database. Any coding errors during the data collection or query can produce research bias. Though a comprehensive multivariate regression analysis corrects any possible code-related confounding, it is incapable of controlling for variables not in the coding database (such as types and frequency of dialysis, operative time, surgical technique, and types of prosthesis), which might introduce potential biases. Additionally, observing this cohort beyond the 2-year postoperative mark might reveal more complications. Furthermore, the proportions of indications varied among the cohorts, which may affect outcomes of THA and, therefore, bias the impact associated with RT. Despite these limitations, this study was novel in its ability to highlight RT as a potential beneficial factor to improve outcomes following THA in this complex patient population.

The findings from this study reveal that patients who undergo RT before THA face reduced risks of postoperative complications, encompassing both surgical and medical issues. Specifically, compared to ESRD patients and RT candidates, patients with RT have a significantly lower likelihood of experiencing PJI, requiring ED visit, and facing hospital readmission. Our study adds to the current literature and suggests that with regard to specific indications, ESRD patients on the RT waiting list should defer THA until after they have undergone RT surgery. For ESRD patients who are not candidates for RT, it is crucial to exercise extreme care and implement additional strategies to minimize the elevated risk of complications that may be encountered. Providers should counsel their patients on the significantly elevated risks associated with arthroplasty and ESRD.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ORCID

Zhichang Zhang https://orcid.org/0009-0007-9225-2828
Elizabeth Driskill https://orcid.org/0000-0001-8819-6455
Jialun Chi https://orcid.org/0000-0003-2825-7361
Richard P. Gean https://orcid.org/0000-0003-2005-2839
Quanjun Cui https://orcid.org/0000-0003-4285-4488

REFERENCES

1. GBD Chronic Kidney Disease Collaboration. Global, regional, and national burden of chronic kidney disease, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2020;395(10225):709-33.

2. Centers for Disease Control and Prevention. Chronic kidney disease surveillance system—United States. Centers for Disease Control and Prevention; 2019.

3. Hariharan S, Israni AK, Danovitch G. Long-term survival after kidney transplantation. N Engl J Med. 2021;385(8):729-43.

4. Paydas S, Balal M, Demir E, Sertdemir Y, Erken U. Avascular osteonecrosis and accompanying anemia, leucocytosis, and decreased bone mineral density in renal transplant recipients. Transplant Proc. 2011;43(3):863-6.

5. Takao M, Abe H, Sakai T, Hamada H, Takahara S, Sugano N. Transitional changes in the incidence of hip osteonecrosis among renal transplant recipients. J Orthop Sci. 2020;25(3):466-71.

6. Abbott KC, Bucci JR, Agodoa LY. Total hip arthroplasty in chronic dialysis patients in the United States. J Nephrol. 2003;16(1):34-9.

7. Hoggard TM, Chen DQ, Quinlan ND, Bell JE, Werner BC, Cui Q. Outcomes following total hip arthroplasty for osteonecrosis of the femoral head in patients on hemodialysis. J Bone Joint Surg Am. 2022;104(Suppl 2):90-4.

8. Quinlan ND, Chen DQ, Werner BC, Cui Q. Outcomes following total hip arthroplasty for femoral head osteonecrosis in patients with history of solid organ transplant. J Bone Joint Surg Am. 2022;104(Suppl 2):76-83.

9. Patterson JT, Tillinghast K, Ward D. Dialysis dependence

predicts complications, intensive care unit care, length of stay, and skilled nursing needs in elective primary total knee and hip arthroplasty. J Arthroplasty. 2018;33(7):2263-7.

10. Lim BH, Lim SJ, Moon YW, Park YS. Cementless total hip arthroplasty in renal transplant patients. Hip Int. 2012;22(5): 516-20.
11. Inoue D, Yazdi H, Goswami K, Tan TL, Parvizi J. Comparison of postoperative complications and survivorship of total hip and knee arthroplasty in dialysis and renal transplantation patients. J Arthroplasty. 2020;35(4):971-5.
12. Ahlquist S, Kim ST, Hsiue PP, et al. Comparison of total hip arthroplasty outcomes between haemodyalisis and renal transplant patients. Hip Int. 2023;33(4):640-8.
13. Chou TA, Ma HH, Tsai SW, Chen CF, Wu PK, Chen WM. Dialysis patients have comparable results to patients who have received kidney transplant after total joint arthroplasty: a systematic review and meta-analysis. EFORT Open Rev. 2021;6(8):618-28.
14. Douglas SJ, Pervaiz SS, Sax OC, Mohamed NS, Delanois RE, Johnson AJ. Comparing primary total hip arthroplasty in renal transplant recipients to patients on dialysis for end-stage renal disease: a nationally matched analysis. J Bone Joint Surg Am. 2021 Jul 27 [Epub]. https://doi.org/10.2106/JBJS.20.01983
15. Chadban SJ, Ahn C, Axelrod DA, et al. KDIGO Clinical Practice Guideline on the evaluation and management of candidates for kidney transplantation. Transplantation. 2020;104(4S1 Suppl 1):S11-103.
16. Pavlou EG, Georgatzakou HT, Fortis SP, et al. Coagulation abnormalities in renal pathology of chronic kidney disease: the interplay between blood cells and soluble factors. Biomolecules. 2021;11(9):1309.
17. Sibbel S, Sato R, Hunt A, Turenne W, Brunelli SM. The clinical and economic burden of pneumonia in patients enrolled in Medicare receiving dialysis: a retrospective, observational cohort study. BMC Nephrol. 2016;17(1):199.
18. Tu G, Ju M, Zheng Y, et al. Early- and late-onset severe pneumonia after renal transplantation. Int J Clin Exp Med. 2015;8(1):1324-32.
19. Tandogdu Z, Cai T, Koves B, Wagenlehner F, Bjerklund-Johansen TE. Urinary tract infections in immunocompromised patients with diabetes, chronic kidney disease, and kidney transplant. Eur Urol Focus. 2016;2(4):394-9.
20. Maroz N. Impact of renal failure on wounds healing. J Am Coll Clin Wound Spec. 2018;8(1-3):12-3.
21. Ponnusamy KE, Jain A, Thakkar SC, Sterling RS, Skolasky RL, Khanuja HS. Inpatient mortality and morbidity for dialysis-dependent patients undergoing primary total hip or knee arthroplasty. J Bone Joint Surg Am. 2015;97(16):1326-32.
22. Luo Y, Gong J, Yang S. Knee and hip arthroplasty joint surgical site wound infection in end-stage renal disease subjects who underwent dialysis or a kidney transplant: a meta-analysis. Int Wound J. 2023;20(7):2811-9.
23. Maroz N, Simman R. Wound healing in patients with impaired kidney function. J Am Coll Clin Wound Spec. 2014;5(1):2-7.
24. Kazımoglu H, Harman R, Mercimek MN, Dokur M, Uysal E. Evaluation of early and late-term infections after renal transplantation: clinical experiences of Sanko University Medical Faculty Transplantation Center. Turk J Urol. 2018;45(1):63-9.
25. Lieu D, Harris IA, Naylor JM, Mittal R. Review article: total hip replacement in haemodialysis or renal transplant patients. J Orthop Surg (Hong Kong). 2014;22(3):393-8.
26. Popat R, Ali AM, Holloway IP, Sarraf KM, Hanna SA. Outcomes of total hip arthroplasty in haemodialysis and renal transplant patients: systematic review. Hip Int. 2021;31(2): 207-14.
27. Nowicki P, Chaudhary H. Total hip replacement in renal transplant patients. J Bone Joint Surg Br. 2007;89(12):1561-6.
28. Ali AM, Loeffler MD, Aylin P, Bottle A. Factors associated with 30-day readmission after primary total hip arthroplasty: analysis of 514 455 procedures in the UK National Health Service. JAMA Surg. 2017;152(12):e173949.
29. Bolognesi MP, Habermann EB. Commercial claims data sources: PearlDiver and individual payer databases. J Bone Joint Surg Am. 2022;104(Suppl 3):15-7.
30. Malkani JA, Heimroth JC, Ong KL, et al. Complications and readmission incidence following total hip arthroplasty in patients who have end-stage renal failure. J Arthroplasty. 2020;35(3):794-800.