Acceptable short-term outcomes after open heart surgery in kidney transplant recipients: a case control study

CURRENT STATUS: POSTED

Bartlomiej Jozef Witczak
Akershus Universitetssykehus HF
bwitczak@me.osCorresponding Author
ORCiD: https://orcid.org/0000-0001-8298-8136

Jan L. Svennevig
Oslo universitetssykehus Rikshospitalet

Anders Hartmann
Oslo universitetssykehus Rikshospitalet

Arnt E. Fiane
Oslo universitetssykehus Rikshospitalet

Anders Åsberg
Oslo universitetssykehus Rikshospitalet

DOI:
10.21203/rs.2.17407/v1

SUBJECT AREAS
Urology & Nephrology

KEYWORDS
Kidney transplantation, cardiac surgical procedures, coronary artery bypass, heart valve prosthesis implantation, postoperative complications, intraoperative complications, acute kidney injury, renal dialysis, mortality
Abstract
Background Cardiovascular disease is common in kidney transplant recipients. They are considered high risk surgery candidates due to comorbidity and immunosuppression. We assessed short-term results of open-heart surgery in kidney transplant recipients and matched controls between 1989 - 2016 at our center. Methods Ninety-five patients underwent open heart surgery (48 coronary artery bypass grafting, 27 valve replacements or repairs and 29 combined procedures) after kidney transplantation. Controls (n=95) were matched for age, sex, type and year of surgery. Mean follow-up was 5.6 (4.9) years. Independent two-sample t-test and chi-square test were used to compare continuous variables and frequencies, respectively. Logistic regression was used to identify preoperative risk factors for 30-day mortality. Results Included were 76 men and 19 women; mean age 60.3 (11.1) years, 7.1 (5.6) years after transplantation. Kidney transplants had lower renal function, more hypertension, but less pulmonary hypertension than matched controls. Intraoperative data was comparable between kidney transplants and controls. Kidney transplants experienced more frequent acute kidney injury (57% versus 23%, p<0.001), more bleeding (1288 (1081) mL versus 957 (548) mL, p=0.01) and more red cell transfusions (4.9 (5.6) versus 3.2 (5.4) units, p=0.04). Infections were borderline more frequent in kidney transplants (30% versus 20%, p=0.10). Thirty-day mortality was 6.3% in kidney transplants and 2.1% in controls (p=0.14). Independent risk factors for 30-day mortality were acute myocardial infarction last 90 days before surgery (OR 12.5, p=0.02) and current smoking (OR 17.3, p=0.02). Conclusions Kidney transplant recipients undergoing cardiac surgery have acceptable short-term results compared with matched controls; 30-day mortality rates were similar. Careful peri- and postoperative management is, however, warranted as kidney transplant recipients experience more bleeding and higher frequency of AKI.

Background
Cardiovascular disease is common in patients with advanced chronic kidney disease (CKD) and in kidney transplant recipients (KTR) (1, 2). It is, amongst others, characterized by accelerated atherosclerosis and calcification resulting in stiff and dysfunctional arteries and left-sided valvular disease (3, 4). The number of KTR undergoing open heart surgery is steadily rising, as KTR live longer
and have multiple risk factors for coronary heart and valve disease, including CKD, dialysis, post-transplant diabetes, arterial stiffness and immunosuppression (5). Even though surgical revascularization confers a high short-term risk, it is associated with favorable long-term outcome in the CKD population and probably also in KTR (6-11). Since the first report on coronary artery bypass grafting in KTR in 1974 (12), numerous studies have been published (13-24). These studies were, however, either small, uncontrolled or included unmatched controls. Recently, there have been several publications of higher quality (25-27) with somewhat diverging short- and long-term result. We present detailed short-term results of heart surgery in KTR and matched controls performed in Norway during a time period of almost three decades. The aim of our study was to assess the short-term risk of open-heart surgery in KTR and describe the influence of preoperative risk factors.

Methods
Between January 1989 and July 2016 more than 12000 coronary artery bypass graft procedures (CABG) and/or heart valve replacements or repairs were performed at the Department of Thoracic Surgery at Oslo University Hospital, Rikshospitalet. The departmental database, Datacor, was cross-checked with the Norwegian Renal Registry to identify KTR that underwent CABG, valve replacement or a combined procedure after kidney transplantation. The Renal Registry is a nationwide quality registry with 100% coverage of all KTR in Norway. In total, we identified 95 KTR who underwent open heart surgery at Oslo University Hospital, Rikshospitalet. Three of the patients were simultaneous kidney-pancreas recipients. Controls were selected from the thoracic surgery database on a 1:1 basis, matched for age, sex, type of procedure, year of procedure (+/- 2 years). All 190 patient records were meticulously manually reviewed to double check the data from the registries, and supplement with relevant additional data such as accurate patient history, total peri- and postoperative blood product transfusions, all postoperative complications up to 30 days after surgery. For procedures performed between 1989-2003, paper records were reviewed, whereas electronic records were available after 2003.

Short-term mortality was defined as mortality within 30 days after heart surgery and is presented as Kaplan-Meier actuarial survival estimates. Log-rank test was used to compare survival rates. Analyses
Comparing continuous variables were based on independent two-sample t-test (except for age that was matched). Chi-square test was used to compare frequencies between two groups, whereas Fisher`s exact test was used if any observed count was less than 5. Binary logistic regression was used to calculate risk factors for 30-day mortality. The multivariable model was based on the backward stepwise (Wald) selection. All statistical analyses were performed using SPSS for Windows, version 23 and 24 (IBM Corp, Armonk, NY) software or R, version 3.3.2 (The R Foundation for Statistical Computing).

Results
Demographic data and baseline characteristics are presented in Table 1. Eighty percent were men and average age for all patients was 60.3 (11.1) years. The procedures were 51% CABG (n=48), 28% (n=27) isolated valve replacements or repairs and 21% (n=20) combined procedures, all performed on average 7.1 (5.6) years after transplantation. The most common valve procedure was aortic valve replacement (AVR). Twenty-four isolated AVRs and 18 combined CABG and AVR procedures were performed. Three KTR and seven controls had active endocarditis at time of surgery (p=0.33). Thirteen KTR had experienced graft loss and were established on chronic dialysis treatment at time of heart surgery. In those not on dialysis (n=82), the CKD-EPI estimated GFR at time of surgery was lower compared to controls; 45 vs 77 mL/min/1.73m² (p<0.001).

Table 1. Demographics and baseline characteristics of 95 kidney transplant recipients (including three simultaneous kidney pancreas recipients) who underwent heart surgery (48 CABG, 27 valve replacements or repairs and 20 combined procedures) and 95 controls.
Transplant recipients (n=95) | Controls (n=95) | P value
---|---|---
Men | 76/19 (80%) | 76/19 (80%) | NA
Age, years | 60.3 (11.1) | 60.4 (11.1) | NA
Hypertension | 87 | 64 | <0.001
Diabetes mellitus | 36 | 27 | 0.17
  Type 1 | 12 | 0 | <0.001
  Type 2 | 21 | 27 | 0.40
Post-transplant | 3 | 0 | N.A.
Pulmonary disease | 6 | 13 | 0.09
Cerebrovascular disease | 10 | 14 | 0.38
Family history of CVD\(^a\) | 20 | 32 | 0.05
Atrial fibrillation | 24 | 19 | 0.39
VF/VT | 6 | 8 | 0.58
Earlier CABG/Valve | 5 | 5 | 1.0
Angina | 66 | 64 | 0.76
Dyspnea | 66 | 68 | 0.75
NYHA class (average) | 2.85 | 2.84 | 0.93
AMI last 90 days | 12 | 17 | 0.31
Active endocarditis | 3 | 7 | 0.33
Pulmonary hypertension\(^b\) | 14 (n=93) | 43 | <0.001
Ejection fraction % (SD) | 53.1 (13.3) (n=93) | 53.8 (18.4) (n=95) | 0.78
Body surface (m\(^2\)) | 1.96 (0.24) (n=92) | 1.95 (0.29) (n=91) | 0.76
Serum creatinine mg/dL\(^c\) | 1.84 (0.81) (n=78) | 1.07 (0.46) (n=82) | <0.001
Estimated GFR\(^3\) | 45.4 (21.8) (n=78) | 76.8 (21.7) (n=82) | <0.001
Chronic dialysis\(^d\) | 13 | 0 | NA
Years since transplantation | 7.1 (5.6) | NA | NA
Range | 23 days - 22 years | 25 days - 26 years | 22 days - 23 years
Emergency oper.\(^e\) | 17 | 14 | 0.70

\(^a\) Acute myocardial infarction in first-degree male relative before age of 55 or in first-degree female relative before age of 65.  
\(^b\) Pulmonary arterial systolic pressure above 35 mmHg. Two missing values in KTR.  
\(^c\) Estimated glomerular filtration rate based on CKD-EPI creatinine formula. Patients on maintenance dialysis treatment were excluded from the calculation. Additionally, four missing values in KTR and 13
missing values in controls.

d  Established on maintenance hemodialysis or peritoneal dialysis at time of heart surgery.

e  Heart surgery within 24-hours from diagnosis.

Thirty-day mortality was 6.3% in KTR and 2.1% in controls (p=0.14; Log rank test), see Figure 1.

Figure 1. Kaplan-Meier actuarial 30-day survival after heart surgery in 95 kidney transplant recipients versus controls. Overall comparison with long-rank (Mantel-Cox) test, chi-square 2.13, df=1, p=0.14.

There was no difference in mortality rates in the 13 KTR on chronic dialysis versus those with a functioning kidney graft; 7.7% (n=1) vs 6.1% (n=5) (p=1.00). Three of the six KTR who died within first 30-days underwent CABG, two had valve surgery and one had a combined procedure. The causes of death were identified in all but one KTR: cardiac arrest after bleeding, progressive heart failure after perioperative AMI, cerebral infarction, Enterococcus endocarditis and bacterial pneumonia. In the control patients two died within the first 30-days; one had CABG surgery and died of postoperative myocardial infarction and progressive heart failure and the other underwent a combined procedure and died of Pseudomonas septicemia.

The frequency of acute kidney injury (AKI) was significantly higher in KTR, 57% vs. 23% (p<0.001), driven mainly by a higher incidence of AKI stage 1, i.e. an absolute increase in serum creatinine of 0.3 mg/dL or 25%. See Table 2. The incidence of AKI requiring dialysis was similar between groups (7 vs. 5 patients, p=0.76). In two KTR the kidney function did not recover and maintenance dialysis was established. In a univariate logistic regression, likelihood ratio (LR) for AKI in KTR vs. controls was 4.46 (2.33-8.62, p<0.001). After adjustment for preoperative estimated GFR, there was still an increased risk of AKI in KTR, LR 2.4 (1.11-5.17, p=0.025).

Average serum creatinine at admission in the KTR group was 1.84 (0.81) mg/dL (n=78, 5 missing values and 13 patients on maintenance dialysis) and for controls 1.07 (0.46) mg/dL (n=82, excluding 13 controls that matched the 13 patients with non-functioning graft). See Table 1. The average peak in-hospital creatinine for KTR was 2.44 (1.22) mg/dL and for all controls 1.29 (0.80) mg/dL (p<0.001) while the mean discharge creatinine was 2.15 (1.17) mg/dL and 1.15 (0.78) mg/dL, respectively. The
difference between creatinine at discharge versus admission of 0.3 mg/dL was significant for KTR (p<0.001) only.

KTR experienced also more postoperative bleeding, 1288 (1081) mL vs 957 (548) mL (p=0.01) and received a higher number of postoperative red cell transfusions than matched controls, 4.9 (5.6) vs 3.2 (5.4) (p=0.04). There was no difference in the use of acetylic salicylic acid, warfarin or low-molecular weight heparin among KTR vs. controls (72% vs 65%, p=0.35, 21% vs 18%, p=0.58 and 12% vs 12%, p=1.00, respectively). Although borderline significant, postoperative infections were more common in KTR, 29 (30.5%) vs. 19 (20.0%) patients (p=0.10), mainly driven by the increased frequency of wound infections (10 (10.5%) vs. 3 (3.2%), p=0.09). Postoperative data are presented in Table 2.

Table 2. Postoperative data in 95 kidney transplant recipients who underwent open heart surgery and 95 matched controls.
| Postoperative data                      | Transplant recipients (n=95) | Controls (n=95) | P value |
|----------------------------------------|-----------------------------|----------------|---------|
| 30-day mortality                       | 6 (6.3%)                    | 2 (2.1%)       | 0.14    |
| Any AKI (AKIN⁹ criteria)               | 47/82 (57%)                 | 21/91 (23%)    | <0.001  |
| Stage 1                                | 37                          | 15             | <0.001  |
| Stage 2                                | 2                           | 0              | 0.50    |
| Stage 3                                | 8 (7 dialysis)              | 6 (5 dialysis) | 0.58    |
| Readmission within 30 days             | 13 (13.7%)                  | 9 (9.5%)       | 0.36    |
| Hemorrhage (ml)                        | 1288 (1081)                 | 957 (548)      | 0.01    |
| Red cells (units)                      | 4.9 (5.6)                   | 3.2 (5.4)      | 0.04    |
| Plasma (units)                         | 3.9 (5.0)                   | 3.6 (8.3)      | 0.77    |
| Platelets (units)                      | 0.9 (1.8)                   | 0.6 (2.0)      | 0.29    |
| Whole blood                            | 0.1 (0.6)                   | 0.1 (0.4)      | 0.41    |
| Any blood product                      | 9.7 (10.8)                  | 7.4 (15.4)     | 0.23    |
| Reoperation for hemorrhage             | 8 (8.4%)                    | 10 (10.5%)     | 0.62    |
| Sepsis                                 | 8                           | 5              | 0.54    |
| Pneumonia                              | 15                          | 16             | 0.84    |
| Wound infection                        | 10                          | 3              | 0.09    |
| Mediastinitis                          | 2                           | 1              | 1.00    |
| Any postoperative infection            | 29 (30.5%)                  | 19 (20%)       | 0.10    |
| Postoperative arrhythmia¹             | 42                          | 38             | 0.56    |
| Ventilation support (hours)            | 13.0 (29.1)                 | 15.5 (41.0)    | 0.62    |
| ICU days                               | 2.0 (2.8)                   | 1.8 (2.4)      | 0.51    |
| Length of stay (days)                  | 7.2 (7.5)                   | 6.0 (3.0)      | 0.15    |

³Acute Kidney Injury Network  ¹New onset postoperative atrial fibrillation, atrial flutter, ventricular tachycardia, ventricular fibrillation

There was no statistical difference in intraoperative data and perioperative complications. However, perioperative stroke occurred in 6 KTR (6.3%) and in only 1 control patient (1.1%), p=0.12, see Table 3.

Table 3. Intraoperative data and perioperative complications in 95 kidney transplant recipients who underwent open heart surgery (48 CABG, 27 valve replacements or repairs and 20 combined procedures) and 95 controls.
### Comparison of Preoperative Risk Factors

| Risk Factor                                | Transplant Recipients (n=95) | Controls (n=95) | p |
|--------------------------------------------|------------------------------|----------------|---|
| Perfusion time (min)                       | 91 (35)                      | 99 (50)        | 0.22 |
| Ischemia time (min)                        | 59 (29)                      | 62.6 (39)      | 0.48 |
| Perioperative myocardial infarction        | 6                            | 3              | 0.50 |
| Perioperative cerebrovascular accident     | 6                            | 1              | 0.12 |
| Number of distal coronary anastomoses<sup>a</sup> | 2.8 (1.15)                  | 2.9 (1.03)     | 0.70 |
| Use of internal thoracic artery<sup>a</sup> | 91% (n=62)                   | 85% (n=58)     | 0.29 |

<sup>a</sup>CABG only, n=68

Uni- and multivariable logistic regression analyses of preoperative risk factors for 30-day mortality in KTR are presented in Tables 4 and 5, respectively.

Table 4. Univariable logistic regression. Preoperative risk factors for 30-day mortality after heart surgery in 95 kidney transplant patients.
| Risk factor                                | Odds ratio (95% CI) | P value |
|-------------------------------------------|---------------------|---------|
| Age per year                              | 1.05 (0.96-1.14)    | 0.29    |
| Age (<70 vs =>70 years)\(^a\)             | 3.45 (0.65-18.44)   | 0.15    |
| Chronic lung disease                       | 0.00 (0.00-0.00)    | 1.00    |
| Pulmonary hypertension\(^b\)               | 1.17 (0.13-10.83)   | 0.89    |
| Diabetes mellitus                          | 1.70 (0.32-8.90)    | 0.53    |
| Dialysis                                  | 1.28 (0.14-11.95)   | 0.83    |
| Estimated GFR\(^c\)                        | 1.02 (0.98-1.06)    | 0.29    |
| Statin use                                 | 2.68 (0.30-23.90)   | 0.38    |
| Ejection fraction £ 35%                   | 0.00 (0.00-0.00)    | 1.00    |
| NYHA Class III/IV vs I/II                  | 2.18 (0.24-19.54)   | 0.49    |
| Previous AMI                               | 2.45 (0.43-14.07)   | 0.32    |
| AMI within 90 days before surgery          | 8.89 (1.56-50.76)   | 0.01    |
| Previous cerebrovascular event             | 1.78 (0.19-16.95)   | 0.62    |
| Smoking current                            | 12.12 (1.35-108.81) | 0.03    |
| Period of surgery\(^d\)                   | 0.26 (0.03-2.29)    | 0.22    |
| Previous heart surgery                     | 0.00 (0.00-0.00)    | 1.00    |
| Emergency surgery                          | 2.47 (0.41-14.71)   | 0.32    |
| Valve surgery                              | 1.02 (0.20-5.34)    | 0.98    |
| Kidney-pancreas transplant                 | 0.00 (0.00-0.00)    | 1.00    |

\(^a\)n=23 versus n=72, respectively  \(^b\)Systolic pulmonary artery pressure > 35 mmHg  \(^c\)Estimated glomerular filtration rate based on CKD-EPI creatinine formula  \(^d\)1989-2002 versus 2003-2016

Table 5. Multivariable logistic regression\(^a\). Preoperative risk factors for 30-day mortality in 95 kidney transplant recipients.

| Risk factor                              | Odds ratio (95% CI) | P value |
|------------------------------------------|---------------------|---------|
| Current smoker                           | 17.32 (1.62-185.63) | 0.02    |
| AMI within 90 days before surgery        | 12.49 (1.60-97.40)  | 0.02    |

\(^a\)Backward Wald selection procedure was used to identify the final multivariable model.

Discussion
Our study demonstrates acceptable short-term results of coronary artery bypass and valve surgery in KTR compared with matched controls. The 30-day mortality was 6.3% in KTR versus 2.1% in controls (p=0.15). There was no difference in perioperative data between KTR and controls, but KTR experienced more postoperative bleeding and a higher frequency of AKI stage 1. Postoperative infections tended to be more frequent in the KTR group (p=0.10). These are acceptable outcomes, bearing in mind that only 50% of patients underwent isolated CABG procedures and 21% underwent combined CABG and valve procedures. Additionally, 15% underwent emergency surgery, i.e. within 24-hour of diagnosis. We also demonstrate that independent risk factors for short-term mortality were current smoking and AMI within 90-days before surgery.

The 6.3% 30-day mortality compares well with previous studies. In the largest registry study published to date, Vargo et al report 7% in-house mortality for 2,712 KTR versus 4% for non-transplanted controls, extracted from the US Nationwide Inpatient Sample in the period 2004-2008 (28). This study is not only interesting due to the significant sample size, but also due to a similar distribution of cardiac procedures performed compared with our study. Others report a varying range of short-term mortality rates (11, 13-20, 22-25, 27, 29, 30), ranging from 1.4% (17) to 14% (30) depending on type of procedures and patient population.

Perioperative stroke was more frequent among KTR than controls, 6.3% vs 1.1% (n=6 vs n=1, p=0.12) although not statistically significant. Kohmoto et al (25) showed a significantly higher frequency of perioperative stroke among transplant recipients (kidney, kidney-pancreas and liver transplant recipients) than in matched controls, 4.3% vs 0.6% (p=0.005). Interestingly, both the actual number and percentage of KTR with perioperative stroke was very similar in our cohort (6 out of 95) compared to KTR in the Kohmoto study (5 out of 97) (25). Worth noting, all five strokes in the Kohmoto study were in KTR only. No strokes were observed in the 18 liver transplant or 15 kidney-pancreas transplant recipients also included in their study. The possible reasons for stroke not being significantly more frequent in our KTR versus controls is the lower number of controls (1:1 vs 1:3 matching) and possibly the high preoperative prevalence of stroke in our control patients (15% of our controls had a history of cerebrovascular event), i.e. signifying a high risk for repeat stroke. Other
studies have not shown any difference in perioperative stroke frequency in KTR vs matched control patients.

As many as 57% of the our KTR experienced AKI, as compared to 23% of the controls. These high numbers were driven by the high incidence of AKI stage 1 in both patient groups, and especially in the former. This can be explained by the readily attainable 0.3 mg/dL increase in creatinine in KTR whose average preoperative creatinine was 1.8 mg/dL. Only 7% percent of KTR required acute dialysis and only 2% became dependent on chronic dialysis postoperatively. The perioperative ischemia time and perfusion time did not differ between KTR requiring acute dialysis postoperatively versus those who did not (data not shown). Farag et al reported AKI resulting in postoperative dialysis in as many as 16% of KTR, with an average preoperative creatinine of 2.2 mg/dL. The frequency was 5.7% for the matched controls in that study (preoperative creatinine 1.2 mg/dL). Vargo et al (28) reported 37.5% AKI in KTR versus 11.5% in controls. Another study with a control group published by John et al (17), showed 33% incidence of kidney dysfunction (acute dialysis in 11% and s-creatinine increase > 2 mg/dL in 22%) in KTR versus 6% in controls. Other studies report varying frequency of acute dialysis after cardiac surgery in KTR, 6-21% (13, 15, 18, 19). Interestingly, Rocha et al (13) reported 21% dialysis postoperatively, but only 3% permanent dialysis, a finding similar to ours.

More postoperative bleeding was reported in KTR. Some of this difference could be attributable to the uremic dialysis patients in the KTR group (n=13), but results were almost identical after excluding these patients from the analyses. However, KTR with functioning kidney grafts were in CKD 3, whereas controls had an estimated GFR within normal range. The use of acetylic salicylic acid, warfarin and low-molecular heparin was similar in the two patient cohorts. These results are consistent with both Farag et al and Vargo et al (27, 28). The Farag study reported more postoperative bleeding, higher frequency of re-exploration and higher need of intraoperative transfusions of all types of blood products, whereas Vargo reported an odds ratio for RBC transfusion of 1.63 in KTR versus controls.

Postoperative infections were frequent in both KTR and control patients, 30.5% and 20%, respectively (p=0.10). Pneumonia comprised the majority of infections in both patient groups, whereas wound
infection was the second most frequent infection type in KTR. Farag et al (27) reported also relatively high frequency of infections, 20% in KTR vs 13% in controls, not statistically significant. Pneumonia and septicemia were the most frequent type of infections. Two other controlled studies, Vargo et al and John et al (17, 28), report much lower frequencies of postoperative infections, approximately 7%, with no difference between groups. Others report rates of 9-21% (14, 15, 18). A possible explanation for the high frequency of reported infections in the present study was the meticulous manual review of all patient records, thus fewer infections were missed.

The only significant preoperative risk factors for 30-day mortality in our KTR were AMI within 90 days before surgery and active smoking. Although these risk factors are plausible, the interpretation requires caution as the mortality in our cohort was low. Rocha et al (13) reported age over 65, left ventricular ejection fraction below 35% and combined procedure (CABG and valve surgery) as preoperative risk factors for short-term mortality. Both Vargo et al and John et al (17, 28) report both pre- and perioperative risk factors, including age and AKI (28) and perfusion time, CHF symptoms, urgent surgery and left ventricular ejection fraction below 40% (17). However, the latter study included both transplant recipients (n=74) and all non-transplanted controls (n=895) in the risk analysis. The recent study of Farag et al (27) demonstrated perioperative risk factors to be other thoracic surgery (ASD and VSD closures, pulmonary embolectomy), intraoperative blood transfusions, new-onset dialysis and septicemia. We also evaluated potential perioperative risk factors in our KTR cohort. Like Farag et al we confirm that AKI requiring dialysis postoperatively is an independent risk factor for mortality (data not shown).

Conclusions
KTR undergoing cardiac surgery have acceptable short-term results compared with matched controls. Thirty-day mortality rates were 6.3% and 2.1%, respectively. Careful peri- and postoperative management is warranted as KTR do experience more bleeding and higher frequency of AKI.

List Of Abbreviations

**ACEI:** Angiotensin II converting enzyme inhibitor

**AKI:** Acute kidney injury
AKIN: Acute Kidney Injury Network
AMI: Acute myocardial infarction
ARB: Angiotensin II receptor blocker
ASD: Atrial septal defect
AVR: Aortic valve replacement
CABG: Coronary artery bypass grafting
CHF: Congestive heart failure
CI: Confidence interval
CKD: Chronic kidney disease
CKD-EPI: Chronic kidney disease epidemiology collaboration
CVD: Cardiovascular disease
DM: Diabetes mellitus
ESRD: End-stage renal disease
GFR: Glomerular filtration rate
ICU: Intensive care unit
KTR: Kidney transplant recipient(s)
LR: Likelihood ratio
NYHA: New York Heart Association classification
OR: Odds ratio
SD: Standard deviation
VF: Ventricular fibrillation
VT: Ventricular tachycardia
VSD: Ventricular septal defect

Declarations

Ethics approval and consent to participate

Consent for this study was obtained from the Data Protection Official at Oslo University Hospital, Rikshospitalet. All data from the departmental database Datacor and from the Norwegian Renal
Registry is approved for research and publications.

**Consent for publications**

Not applicable

**Availability of data and materials**

The dataset used and analyzed during the current study, un-personified, is available from the corresponding author on reasonable request.

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

Akershus University Hospital provided funding for the publication of this study.

**Authors’ contributions**

BJW: collected data, conducted data analyses, interpreted data and was a major contributor in writing the manuscript. JLS: collected data, conceptualized the ideas, research goals and aims and edited the paper. AH: interpreted data, was instrumental in research design and editing of the paper. AEF: collected data, research design. AÅ: conducted data analyses, conceptualized ideas, interpreted data and was indispensable in editing the paper. All authors read and approved the final manuscript.

**Acknowledgements**

The authors want like to express sincere gratitude to all physicians and registry coordinators for collecting all the data in the Department of Thoracic Surgery database, Datacor, and in the Norwegian Renal Registry.

**References**

1. Foley RN, Murray AM, Li S, Herzog CA, McBean AM, Eggers PW, et al. Chronic kidney disease and the risk for cardiovascular disease, renal replacement, and death in the United States Medicare population, 1998 to 1999. J Am Soc Nephrol. 2005;16(2):489-95.

2. Weiner DE, Carpenter MA, Levey AS, Ivanova A, Cole EH, Hunsicker L, et al. Kidney
function and risk of cardiovascular disease and mortality in kidney transplant recipients: the FAVORIT trial. Am J Transplant. 2012;12(9):2437-45.

3. London GM, Pannier B, Marchais SJ, Guerin AP. Calcification of the aortic valve in the dialyzed patient. J Am Soc Nephrol. 2000;11(4):778-83.

4. Yerkey MW, Kernis SJ, Franklin BA, Sandberg KR, McCullough PA. Renal dysfunction and acceleration of coronary disease. Heart. 2004;90(8):961-6.

5. Dahle DO, Eide IA, Asberg A, Leivestad T, Holdaas H, Jenssen TG, et al. Aortic Stiffness in a Mortality Risk Calculator for Kidney Transplant Recipients. Transplantation. 2015;99(8):1730-7.

6. Wang Y, Zhu S, Gao P, Zhang Q. Comparison of coronary artery bypass grafting and drug-eluting stents in patients with chronic kidney disease and multivessel disease: A meta-analysis. Eur J Intern Med. 2017.

7. Charytan DM, Li S, Liu J, Herzog CA. Risks of death and end-stage renal disease after surgical compared with percutaneous coronary revascularization in elderly patients with chronic kidney disease. Circulation. 2012;126(11 Suppl 1):S164-9.

8. Sharma R, Hawley C, Griffin R, Mundy J, Peters P, Shah P. Cardiac surgical outcomes in abdominal solid organ (renal and hepatic) transplant recipients: a case-matched study. Interact Cardiovasc Thorac Surg. 2013;16(2):103-11.

9. Charytan DM, Desai M, Mathur M, Stern NM, Brooks MM, Krzych LJ, et al. Reduced risk of myocardial infarct and revascularization following coronary artery bypass grafting compared with percutaneous coronary intervention in patients with chronic kidney disease. Kidney Int. 2016;90(2):411-21.

10. Chang TI, Leong TK, Kazi DS, Lee HS, Hlatky MA, Go AS. Comparative effectiveness of coronary artery bypass grafting and percutaneous coronary intervention for multivessel coronary disease in a community-based population with chronic kidney
disease. Am Heart J. 2013;165(5):800-8, e1-2.

11. Herzog CA, Ma JZ, Collins AJ. Long-term outcome of renal transplant recipients in the United States after coronary revascularization procedures. Circulation. 2004;109(23):2866-71.

12. Menzoian JO, Davis RC, Idelson BA, Mannick JA, Berger RL. Coronary artery by-pass surgery and renal transplantation: a case report. Ann Surg. 1974;179(1):63-4.

13. Rocha RV, Zaldonis D, Badhwar V, Wei LM, Bhama JK, Shapiro R, et al. Long-term patient and allograft outcomes of renal transplant recipients undergoing cardiac surgery. J Thorac Cardiovasc Surg. 2014;147(1):270-5.

14. Shayan H, Rocha R, Wei L, Gleason T, Zaldonis D, Pellegrini R, et al. Midterm outcomes of off-pump and on-pump coronary artery revascularization in renal transplant recipients. J Card Surg. 2011;26(6):591-5.

15. Zhang L, Garcia JM, Hill PC, Haile E, Light JA, Corso PJ. Cardiac surgery in renal transplant recipients: experience from Washington Hospital Center. Ann Thorac Surg. 2006;81(4):1379-84.

16. Rahmanian PB, Adams DH, Castillo JG, Silvay G, Filsoufi F. Excellent results of cardiac surgery in patients with previous kidney transplantation. J Cardiothorac Vasc Anesth. 2009;23(1):8-13.

17. John R, Lietz K, Huddleston S, Matas A, Liao K, Shumway S, et al. Perioperative outcomes of cardiac surgery in kidney and kidney-pancreas transplant recipients. J Thorac Cardiovasc Surg. 2007;133(5):1212-9.

18. Deb SJ, Mullany CJ, Kamath PS, Dearani JA, Daly RC, Orszulak TA, et al. Cardiac Surgery in Kidney and Liver Transplant Recipients. Mayo Clin Proc. 2006;81(7):917-22.

19. Ono M, Wolf RK, Angouras DC, Brown DA, Goldstein AH, Michler RE. Short and long
term results in cardiac surgery in tx 2002. Eur J Cardiothorac Surg. 2002;21:1061-72.

20. Reddy VS, Chen AC, Johnson HK, Pierson RN, 3rd, Christian KJ, Drinkwater DC, Jr., et al. Cardiac surgery after renal transplantation. Am Surg. 2002;68(2):154-8.

21. Ferguson ER, Hudson SL, Diethelm AG, Pacifico AD, Dean LS, Holman WL. Outcome after myocardial revascularization and renal transplantation: a 25-year single-institution experience. Ann Surg. 1999;230(2):232-41.

22. Mitruka SN, Griffith BP, Kormos RL, Hattler BG, Pigula FA, Shapiro R, et al. Cardiac Operations in Solid-Organ Transplant Recipients. The Annals of Thoracic Surgery. 1997;64(5):1270-8.

23. Dresler C, Uthoff K, Wahlers T, Kliem V, Schafers J, Oldhafer K, et al. Open heart operations after renal transplantation. Ann Thorac Surg. 1997;63(1):143-6.

24. Bolman RM, 3rd, Anderson RW, Molina JE, Schwartz JS, Levine B, Simmons RL, et al. Cardiac operations in patients with functioning renal allografts. J Thorac Cardiovasc Surg. 1984;88(4):537-43.

25. Kohmoto T, Osaki S, Kaufman DB, Leversion G, DeOliveira N, Akhter SA, et al. Cardiac Surgery Outcomes in Abdominal Solid Organ Transplant Recipients. Ann Thorac Surg. 2018;105(3):757-62.

26. Vargo KK, Ringdahl JE. An evaluation of resistance to change with unconditioned and conditioned reinforcers. J Appl Behav Anal. 2015;48(3):643-62.

27. Farag M, Nikolic M, Arif R, Schmack B, Sabashnikov A, Zeriouh M, et al. Cardiac Surgery in Patients With Previous Hepatic or Renal Transplantation: A Pair-Matched Study. Ann Thorac Surg. 2017;103(5):1467-74.

28. Vargo PR, Shilczt NK, Johnston DR, Smedira NG, Moazami N, Blackstone EH, et al. Outcomes of Cardiac Surgery in Patients With Previous Solid Organ Transplantation (Kidney, Liver, and Pancreas). Am J Cardiol. 2015;116(12):1932-8.
29. Charytan DM, Li S, Liu J, Qiu Y, Herzog CA. Risks of death and graft failure after surgical versus percutaneous coronary revascularization in renal transplant patients. J Am Heart Assoc. 2013;2(1):e003558.

30. Sharma A, Gilbertson DT, Herzog CA. Survival of kidney transplantation patients in the United States after cardiac valve replacement. Circulation. 2010;121(25):2733-9.

Figures

![Kaplan-Meier actuarial 30-day survival after heart surgery in 95 kidney transplant recipients versus controls. Overall comparison with long-rank (Mantel-Cox) test, chi-square 2.13, df=1, p=0.14.](image-url)