Short- and long-term outcomes in patients undergoing valve surgery with end-stage renal failure receiving chronic hemodialysis

Vinod H. Thourani, MD,^a Eric L. Sarin, MD,^a Patrick D. Kilgo, MS,^b Omar M. Lattouf, MD, PhD,^a John D. Puskas, MD,^a Edward P. Chen, MD,^a and Robert A. Guyton, MD^a

Objectives: The objective of this study was to evaluate the effect of chronic preoperative hemodialysis for end-stage renal failure in patients undergoing valve surgery.

Methods: A retrospective review of patients undergoing primary valve with or without coronary artery bypass surgery from 1996 to 2008 at a US academic center was performed. The patients were divided into two groups: group 1 underwent valve surgery without preoperative dialysis ($n = 5084$) and group 2 underwent valve surgery with preoperative dialysis ($n = 224$). The outcomes were evaluated using multivariate regression analysis, and long-term survival was assessed with Kaplan-Meier plots.

Results: The patients in group 2 were younger ($P < .001$), were more likely women ($P = .04$), and presented with New York Heart Association class III-IV ($P < .001$). The ejection fraction was similar between the two groups ($P = .36$). The adjusted perioperative morbidity was similar between the two groups for stroke ($P = .79$) and myocardial infarction ($P = .68$). Resource use (postoperative length of stay) was greater in group 2 ($P < .001$), as was in-hospital mortality (group 1, 263/5084 [5.2%] vs group 2, 41/224 [18.3%]; $P < .001$). The 1-, 5-, and 10-year survival was less in group 2 ($P < .001$); the median survival was 12 or more years in group 1 and 1.8 years in group 2. Preoperative end-stage renal disease, among others, show a trend as an independent predictor for short-term mortality and was a significant predictor for long-term mortality.

Conclusions: In this large cohort of patients, preoperative dialysis conferred a high risk of perioperative morbidity and mortality and poor long-term survival after valve surgery. Risk stratification and future research efforts should focus on more precise identification of the benefits of valve surgery in this high-risk patient population. (J Thorac Cardiovasc Surg 2012;144:117-23)

The prevalence of end-stage renal disease (ESRD) continues to increase in the United States. The 2009 annual data report from the United States Renal Data System revealed that as of 2007, 527,282 patients had ESRD in the United States.¹ The projections from this report estimate that the prevalence of ESRD in the United States will approach 775,000 by 2020. This steady increase in patients with ESRD parallels similar trends seen around the world.^{2,3} Furthermore, the United States Renal Data System data report revealed that the prevalence rates are increasing most rapidly among patients aged 65 years and older.

Cardiovascular disease and its complications are the most common cause of death among patients with ESRD, especially among the older age groups. The multiple shared risk factors that lead to the development of cardiovascular and renal disease cause the two disease processes to often exist and progress in concert with one another.^{4,5} Once patients have developed ESRD and dialysis dependence, they have often already developed significant symptoms related to coronary artery disease, heart failure, and valve-related cardiac abnormalities.⁶

Although multiple studies have examined the outcomes in patients with ESRD undergoing cardiac surgery, many of these studies examined the outcomes after all types of cardiac surgery and did not focus solely on the outcomes after valve-related procedures.^{3,7-16} Therefore, the purpose of the present study was to investigate the short- and long-term outcomes in patients requiring preoperative dialysis and undergoing cardiac valve surgery.

METHODS

The present retrospective, cohort study sought to determine the effect of a preoperative diagnosis of renal failure requiring dialysis on the clinical outcomes after cardiac valve surgery. The patients were classified into two groups—those requiring dialysis preoperatively and those who did not. The patients were identified by querying the institutional Society of Thoracic Surgeons (STS) Adult Cardiac Database for consecutive qualified

From the Clinical Research Unit,^a Division of Cardiothoracic Surgery, Joseph B. Whitehead Department of Surgery, Emory University School of Medicine, Atlanta, Ga; and Department of Biostatistics,^b Emory University Rollins School of Public Health, Atlanta, Ga.

The funding for this report was internal funds from the Division of Cardiothoracic Surgery Clinical Research Unit.

Disclosures: Authors have nothing to disclose with regard to commercial support. Received for publication Feb 4, 2011; revisions received July 4, 2011; accepted for publication July 26, 2011; available ahead of print Aug 26, 2011.

Address for reprints: Vinod H. Thourani, MD, Department of Surgery, Division of Cardiothoracic Surgery, Emory University School of Medicine, 550 Peachtree Street, Crawford Long Hospital, 6th Floor, Medical Office Tower, Atlanta, GA 30308 (E-mail: vthoura@emory.edu).

0022-5223/\$36.00

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doi:10.1016/j.jtcvs.2011.07.057

Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CI	= confidence interval
CPB	= cardiopulmonary bypass
ESRD	= end-stage renal disease
STS	= Society of Thoracic Surgeons

patients treated at Emory University Healthcare Hospitals from January 1, 1996 to December 31, 2008. Patients with concomitant coronary artery bypass grafting (CABG) were included and those with previous valve surgery, those with previous CABG, and those undergoing salvage treatment were excluded.

During this period, 5308 qualified patients underwent valve surgery. Of these, 224 patients (4.2%) were receiving preoperative dialysis. Of the 5084 patients not receiving dialysis, 305 patients (6.0%) were diagnosed with nondialysis-dependent chronic renal failure and were categorized in the “no preoperative dialysis” group. The extracted records included the demographic data, pre-existing conditions, and clinical outcomes. The study was formally approved by the Emory University institutional review board in compliance with Health Insurance Portability and Accountability Act regulations and the Declaration of Helsinki. The institutional review board waived individual patient consent for these patients.

Interventions, Surgeons, and Surgical Technique

Each patient underwent a single surgical session performed at the discretion of any of 20 faculty surgeons. Cardiac catheterization was performed in all patients older than 40 years or in younger patients with risk factors for coronary artery disease. The nephrology service was consulted before surgical intervention and treated the patients for renal replacement and electrolyte management in all patients requiring preoperative dialysis. Standard cardiopulmonary bypass (CPB) techniques for valve operations were used in all patients. The surgical approach, valve prosthesis or repair techniques, and conduct of CPB and myocardial protection were left to the discretion of the attending cardiac surgeon. Typically, conventional CPB was performed using roller head pumps, membrane oxygenators, cardiomy suction, arterial filters, cold antegrade and retrograde blood cardioplegia, and moderate systemic hypothermia (32° to 34°C). The operative field was routinely flooded with carbon dioxide, and de-airing maneuvers were performed in all cases before releasing the cross-clamp. In those requiring preoperative dialysis, postoperative extubation was generally performed after dialysis.

Long-Term Follow-up

The Social Security Death Index is a public, national database of death records extracted from the United States Social Security Administration's Death Master File Extract. Patients with a Social Security number who have died after 1963 and whose death has been reported to the Social Security Administration will be listed in the Social Security Death Index. For all patients who died before the cutoff date of June 30, 2008, a mortality date was provided, allowing creation of Kaplan-Meier long-term survival curves. The cause of death was not available for any of the patients; thus, the present study described all-cause long-term mortality.

Variables of Interest

Before analysis, 19 preoperative risk factors were harvested from the STS database (Table 1). Standard STS definitions for each risk factor and outcome were used. Race was dichotomized as either white or nonwhite. Chronic lung disease (chronic obstructive pulmonary disease) was ordinally measured in some latter years and dichotomously

TABLE 1. Preoperative demographics and clinical characteristics by dialysis status

Characteristic	No preoperative dialysis (n = 5084)	Preoperative dialysis (n = 224)	P value
Age (y)			<.001
Mean ± SD	61.2 ± 14.8	54.1 ± 14.0	
Median	63	55	
Female gender (n)	2172 (42.7)	111 (49.6)	0.043
Status (n)			<.001
Elective	4017 (79.0)	143 (63.8)	
Urgent	849 (16.7)	64 (28.6)	
Emergent	216 (4.3)	17 (7.6)	
White race (n)	3523 (80.1)	58 (31.5)	<.001
Hypertension (n)	3264 (64.2)	213 (95.1)	<.001
Ejection fraction (n)			.36
Mean ± SD	52.8 ± 13.1	53.7 ± 13.3	
Median	55	55	
NYHA class III or IV (n)	683 (19.4)	56 (31.5)	<.001
Previous stroke	370 (7.3)	48 (21.4)	<.001
Chronic lung disease			.40
None	2623 (81.5)	137 (83.5)	
Mild	379 (11.8)	13 (7.9)	
Moderate	85 (2.6)	6 (3.7)	
Severe	130 (4.0)	8 (4.9)	
Diabetes	933 (18.45)	87 (38.8)	<.001
Chronic lung disease	594 (11.7)	27 (12.1)	.87
Previous myocardial infarction	798 (15.7)	46 (20.5)	.053
Cerebrovascular disease	647 (12.7)	53 (23.7)	<.001
Peripheral vascular disease	301 (5.9)	42 (18.8)	<.001
Preoperative serum creatinine			<.001
Mean ± SD	1.14 ± 0.61	7.34 ± 3.17	
Median	1.00	7.05	
Chronic renal insufficiency	305 (6.0)	224 (100.0)	<.001
Infectious endocarditis	327 (6.4)	78 (34.8)	<.001
Current smoker	1756 (34.5)	83 (37.1)	.44
Preoperative IABP	42 (0.8)	2 (0.9)	.91
Immunosuppressive therapy	250 (4.9)	33 (14.7)	<.001
STS predicted risk of mortality (%)			<.001
Mean ± SD	4.1 ± 4.2	14.8 ± 9.2	
Median	2.8	13.0	

Data in parentheses are percentages. SD, Standard deviation; NYHA, New York Heart Association; IABP, Intra-aortic balloon counterpulsation; STS, Society of Thoracic Surgeons.

measured in earlier years; in the present study, it was dichotomized. The new York Hospital Association heart failure classification was dichotomized as class III-IV or I-II. The primary outcomes examined in the present study were in-hospital mortality and long-term survival; other endpoints of interest included permanent stroke (cerebrovascular accident), myocardial infarction, the composite endpoint for any of these major adverse cardiac and cerebrovascular events, and operative re-intervention.

Data Management and Statistical Analysis

All data for the consecutive patients were entered into a computerized surgical database, using the fields and definitions of the STS National Adult Cardiac Database. Checks for data quality were used at both the

institutional level and before final entry into the STS National Adult Cardiac Database.

To statistically evaluate the effects of preoperative dialysis on in-hospital mortality, a multivariate logistic regression model was constructed. The model contained preoperative covariates to adjust for potential selection bias; age, gender, body mass index, renal failure, heart failure, ejection fraction, presence of concomitant CABG, infectious endocarditis, previous stroke, diabetes mellitus, and chronic lung disease. Adjusted odds ratios associated with preoperative dialysis and other covariates, along with the 95% confidence intervals (CIs), were computed.

Long-term survival comparisons were made using adjusted Cox proportional hazards regression (PHREG) models and Kaplan-Meier product-limit estimates (unadjusted). Kaplan-Meier curves were generated that provide survival estimates at postoperative points. Differences between dialysis status were determined using log-rank tests. These estimates included operative deaths.

Adjusted long-term survival comparisons were made using PHREG to model the instantaneous hazard of death as a function of dialysis, adjusted for age, gender, body mass index, renal failure, heart failure, ejection fraction, presence of concomitant CABG, infectious endocarditis, previous stroke, diabetes mellitus, and chronic lung disease. The proportional hazards assumption was verified using a correlation analysis of the Schoenfeld residuals and ranked follow-up time. Adjusted hazard ratios were generated for each model term, along with the 95% CIs.

The data were managed and analyzed using SAS, version 9.1 (SAS Institute, Cary, NC). Unadjusted comparisons were performed using chi-square tests and two-sample *t* tests for categorical and numerical predictors, respectively. All statistical tests were two-sided using an $\alpha = 0.05$ level of significance.

RESULTS

Preoperative and Operative Characteristics

A total of 5308 patients underwent valve surgery at a single academic institution and constituted the study group. The patients were divided into two groups: group 1 received no preoperative dialysis (n = 5084) and group 2 received preoperative dialysis (n = 224). The preoperative characteristics are listed in Table 1. Despite being younger and with equally preserved ejection fractions, patients requiring preoperative dialysis were uniformly sicker preoperatively compared with the nondialysis patients. This was evident in the STS Predicted Risk of In-hospital Mortality of 4.1% versus 14.8% (*P* < .001).

Table 2 describes the operative procedures according to the need for preoperative chronic dialysis. In both groups, the most common surgery was concomitant valve and CABG; and aortic valve replacement was the most common in those not requiring CABG. Bioprosthetic valve implantation was more commonly used in the dialysis patients. The aortic cross-clamp and CPB times were both significantly longer for the dialysis patients.

In-Hospital Morbidity and Mortality

The unadjusted in-hospital outcomes are listed in Table 3. In those patients undergoing dialysis preoperatively, in-hospital morbidity was overwhelming increased compared with those without preoperative dialysis. Furthermore, resource use as indicated by the time on a ventilator and the

TABLE 2. Operative characteristics by dialysis status

Operative data	No preoperative dialysis (n = 5084)	Preoperative dialysis (n = 224)	P value
Isolated aortic valve replacement	1446 (28.4)	64 (28.6)	.97
Isolated mitral valve repair or replacement	1149 (22.6)	38 (17.0)	.048
Any valve plus concomitant CABG	1672 (32.9)	65 (29.0)	.23
Other isolated valve or combo valves	817 (16.1)	57 (25.5)	<.001
Bioprosthetic valve	2500 (49.2)	128 (57.1)	.02
Body mass index (kg/m ²)			.057
Mean ± SD	27.8 ± 5.9	26.9 ± 6.7	
Median	26.9	25.8	
Aortic cross-clamp time (min)			<.001
Mean ± SD	93.5 ± 38.0	104.6 ± 40.4	
Median	86.0	98.0	
Cardiopulmonary bypass time (min)			<.001
Mean ± SD	131.3 ± 49.3	144.2 ± 50.7	
Median	121	137	
Intraoperative IABP implanted	258 (5.1)	13 (4.8)	.63

Data presented as numbers (%), unless otherwise noted. CABG, Coronary artery bypass grafting; SD, Standard deviation; IABP, Intra-aortic balloon counterpulsation.

intensive care unit and overall postoperative length of stay was significantly greater for those with preoperative dialysis. The in-hospital mortality rate for the entire cohort was 5.7% (n = 304). Mortality was significantly greater for those with preoperative dialysis (18.3% vs 5.2%; *P* < .0001). The observed STS Predicted Risk of In-hospital Mortality expected ratio was 1.27 for those without preoperative dialysis compared with 1.24 for those with preoperative dialysis. Among the major cardiac adverse events, only in-hospital death was statistically greater for the dialysis patients (Table 4). However, on multivariate logistic regression analysis (Table 5), chronic preoperative dialysis showed a trend toward, but was not an independent predictor for, in-hospital mortality (odds ratio, 1.51; 95% CI, 0.96 to 2.39; *P* = .08). Other covariates included advanced age, female gender, nondialysis renal failure, coronary artery disease requiring CABG, and endocarditis.

Long-Term Mortality

The median follow-up for all patients was 4.4 years. The survival estimates for each group are listed in Table 6 and revealed that those patients undergoing preoperative dialysis had significantly reduced all-cause mid- and long-term survival. Graphically, this is represented in the Kaplan-Meier curves (Figures 1 to 5). In an all patient subgroup analysis, the patients with preoperative dialysis

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TABLE 3. Unadjusted short-term postoperative outcomes by dialysis status

Outcome	No preoperative dialysis (n = 5084)	Preoperative dialysis (n = 224)	P value
Myocardial infarction	24 (0.5)	3 (1.3)	.074
Stroke	151 (3.0)	14 (6.3)	.006
Mediastinitis	39 (0.8)	8 (3.6)	<.001
Renal failure	363 (7.1)	—	—
Dialysis	140 (2.8)	—	—
Septicemia	147 (2.9)	26 (11.6)	<.001
Heart block requiring pacemaker	164 (3.2)	10 (4.7)	.31
MSOF	86 (1.7)	16 (7.1)	<.001
Re-exploration for hemorrhage	300 (5.9)	19 (8.5)	.11
Postoperative pneumonia	324 (6.4)	34 (15.2)	<.001
Postoperative ventilator (h)			<.001
Mean $\pm$ SD	43 $\pm$ 127	122 $\pm$ 218	
Median	9.1	33.2	
Prolonged ventilation	744 (14.6)	106 (47.3)	<.001
Postoperative IABP insertion	38 (0.8)	1 (0.5)	.61
Gastrointestinal complication	219 (4.3)	32 (14.3)	<.001
Total initial ICU LOS (h)			<.001
Mean $\pm$ SD	103 $\pm$ 173	247 $\pm$ 304	
Median	46	121	
Postoperative LOS (d)			<.001
Mean $\pm$ SD	9.1 $\pm$ 9.0	17.4 $\pm$ 16.6	
Median	6.0	11.0	
In-hospital mortality	263 (5.2)	41 (18.3)	<.001
STS PROM (%)			<.001
Mean $\pm$ SD	4.1 $\pm$ 4.2	14.8 $\pm$ 9.2	
Median	2.8	13.0	
O/E mortality	1.27	1.24	—

Data presented as numbers (%), unless otherwise noted. *MSOF*, Multisystem organ failure; *IABP*, Intra-aortic balloon counterpulsation; *ICU*, Intensive care unit; *LOS*, Length of stay; *STS*, Society of Thoracic Surgeons; *PROM*, Predicted risk of mortality; *O/E*, observed to expected.

had reduced survival. In the unadjusted survival analysis for long-term mortality (Table 7), the instantaneous hazard for death was 4.67 times greater if the patient required preoperative dialysis. After an age adjustment was performed, it was shown that younger patients requiring preoperative dialysis had worse survival (hazard ratio, 6.54; 95% CI, 5.41 to 7.89). When a full adjustment was performed using 11 covariates, preoperative chronic dialysis was still

TABLE 5. Significant preoperative predictors of in-hospital survival from multivariate survival analysis

Preoperative variable	Odds ratio (95% CI)	P value
Age	1.03 (1.02–1.04)	<.001
Chronic lung disease	0.99 (0.73–1.34)	.94
CVA	1.31 (0.95–1.81)	.10
EF	1.00 (0.988–1.004)	.32
Infectious endocarditis	1.62 (1.11–2.35)	.012
Female gender	1.59 (1.30–1.95)	<.001
Heart failure	0.91 (0.74–1.13)	.40
Renal failure	2.62 (1.90–3.62)	<.001
Renal failure requiring dialysis	1.51 (0.96–2.39)	.08
CAD requiring CABG	1.47 (1.18–1.82)	<.001
Body mass index	1.01 (0.993–1.024)	.29
Diabetes	1.04 (0.82–1.33)	.74

CI, Confidence interval; CVA, Cerebrovascular accident; EF, Ejection fraction; CAD, Coronary artery disease; CABG, Coronary artery bypass grafting.

associated with reduced long-term survival (hazard ratio, 2.34; 95% CI, 1.83 to 2.99). Other independent covariates for long-term survival (Table 8) included age, female gender, nondialysis renal failure, heart failure, lower ejection fraction, coronary artery disease requiring CABG, endocarditis, preoperative stroke, diabetes, and chronic lung disease.

DISCUSSION

It has been estimated that approximately 50% of deaths in patients with ESRD occurs from cardiovascular disease.⁴ Although it has been appreciated that the 2-year survival rate in the dialysis population after a diagnosis of peripheral vascular disease is approximately 40%, after cerebrovascular accident is 30%, after congestive heart failure is 42%, and after coronary revascularization is 45%, the outcomes after cardiac valve surgery have not been so clearly defined.⁴ Most published series regarding cardiac surgical procedures for patients with dialysis-dependent ESRD have included a heterogeneous population of patients undergoing isolated CABG, isolated valve surgery, or valve surgery with concomitant CABG.^{7,8,10,12-14,16,17} The present series differs in that we did not include any patients undergoing isolated CABG; because all patients underwent at least one valve surgery. In the present series, concomitant CABG was noted in 33% of the patients without preoperative dialysis compared with 29% with dialysis. In concordance with

TABLE 4. Adjusted odds ratios for in-hospital outcomes

Complications	No preoperative dialysis (n = 5084)	Preoperative dialysis (n = 224)	Unadjusted P value	Adjusted odds ratios (95% CI)	Adjusted P value
In-hospital mortality	263 (5.2)	41 (18.3)	<.001	1.80 (1.09–2.97)	.021
Stroke	151 (3.0)	14 (6.3)	.006	1.11 (0.53–2.31)	.79
Myocardial infarction	24 (0.47)	3 (1.34)	.074	1.47 (0.23–9.35)	.68
MACCE	394 (7.8)	48 (21.4)	<.001	1.52 (0.96–2.40)	.07

Data presented as numbers (%), unless otherwise noted. CI, Confidence interval; MACCE, Major adverse cardiac and cerebrovascular events.

TABLE 6. Survival estimates by dialysis status

Variable	No preoperative dialysis (n = 5084)	Preoperative dialysis (n = 224)
Median survival (y)	12+	1.78
1-Year survival (SE), number left at risk	89.5% (0.4%), n = 3985*	59.2% (3.4%), n = 105
3-Year survival (SE), number left at risk	84.4% (0.5%), n = 2887*	42.3% (3.7%), n = 48
5-Year survival (SE), number left at risk	78.4% (0.7%), n = 1949*	28.9% (4.1%), n = 18
10-Year survival (SE), number left at risk	63.9% (1.1%), n = 530*	19.6% (4.9%), n = 1

SE, Standard error. **P* < .001.

published series, we also revealed significant preoperative comorbid characteristics in those patients with dialysis-dependent renal failure. It is without doubt that the increased incidence of these variables lead to increased in-hospital morbidity and mortality.^{7,8,10,12-14,16,17}

In a retrospective review of 245 dialysis-dependent patients undergoing cardiac surgery at a single institution during an 8-year period, Rahmanian and colleagues¹⁶ have shown that patients with ESRD had an in-hospital mortality rate that was 3.7 times greater than that of non-dialysis patients (12.7% vs 3.9%). An examination by surgery type found that the mortality rate for isolated/multiple valve procedures was 17.1% compared with 12.8% and 10.3% for valve/CABG and isolated CABG, respectively. Unlike the report by Rahmanian and colleagues,¹⁶ the present series only included patients undergoing at least one valvular operation. We demonstrated a similarly dramatic increase in the morbidity and mortality for valve procedures, with an in-hospital mortality rate for the dialysis group of 18.3% compared with a rate of 5.2% for the nondialysis group. Similarly, a multicenter retrospective review from Germany identified 522 patients with ESRD undergoing a variety of cardiac surgical procedures; including 192 (36.8%) with valve plus concomitant CABG.¹² The patients in the ESRD group had a 30-day mortality rate of 11.5% and an overall survival rate at 5 years of 41.5%, with the patients with isolated CABG

demonstrating improved survival compared with those receiving valve plus concomitant CABG. Despite the improvements in the perioperative treatment of patients undergoing valve surgery, those patients requiring dialysis for ESRD continue to have a three- to fourfold increase in in-hospital mortality.

It has been noted that the average survival rate of patients from the time of dialysis was started was 52% at 3 years and 33% at 5 years.¹⁸ This aspect is critically important as we evaluate the mid- and long-term mortality in patients with dialysis-dependent chronic renal failure undergoing cardiac surgery.^{12,14,16,17} Although it is difficult to ascertain the survivability of a patients with ESRD who does not undergo the required cardiac surgical procedure, in the present series, we noted a 5-year overall survival rate of 29%. Rahmanian and colleagues¹⁶ noted an estimated 5-year survival rate of 39% in a series of 245 heterogenous patients undergoing cardiac surgery. In a series of 192 patients, Bechtel and colleagues¹² noted an overall survival rate at 5 years of 41.5%, with patients undergoing isolated CABG demonstrating improved survival compared with those undergoing valve plus concomitant CABG. In that study, they showed that the determinants of long-term mortality included emergency surgery, diabetes mellitus, age at surgery, and number of allogenic transfusions. Subsequent renal transplantation, the presence of sinus rhythm, and the use of the internal thoracic artery were associated with

FIGURE 1. Kaplan-Meier survival estimates for all patients by preoperative dialysis status (*P* < .001 comparing groups).

FIGURE 2. Kaplan-Meier survival estimates for isolated aortic valve replacement by preoperative dialysis status (*P* < .001 comparing groups).

FIGURE 3. Kaplan-Meier survival estimates for isolated mitral valve procedures by preoperative dialysis status ($P < .001$ comparing groups).

longer survival.¹² In a much smaller series, Kogan and colleagues¹⁴ showed an actuarial survival rate at 1 and 5 years of 59% and 21% for isolated aortic valve replacement and 44% and 33% for those undergoing other valve plus CABG procedures, respectively.

Perioperative stroke is a primary concern in these patients. Dialysis-dependent patients are known to have a more severe atherosclerotic disease burden than patients without ESRD. In the general ESRD population, a new stroke is an extraordinarily ominous occurrence. Patients with ESRD aged 75 to 84 years have a 1-year mortality rate of 20%. A new stroke in that same age group is associated with increase in the annual mortality rate to 60%.¹ In the present series, the unadjusted stroke rates were 6% in dialysis patients compared with 3% in nondialysis patients ($P = .006$). Once adjusted, we found no significant difference in the postoperative stroke risk between the two groups ($P = .79$; Table 4). Similarly, Rahmanian and colleagues¹⁶ did not show an association between ESRD and

FIGURE 4. Kaplan-Meier survival estimates for multivalve procedures by preoperative dialysis status ($P < .001$ comparing groups).

FIGURE 5. Kaplan-Meier survival estimates for any valve with concomitant coronary artery bypass grafting (CABG) by pre-operative dialysis status ($P < .001$ comparing groups).

postoperative stroke (3.3% in patients with ESRD vs 2.5% without ESRD). However, the patient populations were quite varied between the two studies, because 40% of their series included patients with isolated CABG, who have a lower risk of postoperative stroke risk compared with patients undergoing valve and concomitant CABG in the present series. Although we were unable to predict the stroke risk according to the aortic disease burden in the present data set, this, along with the inherent increased globalized small- and large-vascular atherosclerosis might be a plausible explanation for the increased stroke rate in this high-risk patient population.

Study Limitations

The present study was limited by its observational nature and the inherent limitations of a retrospective database study. Although we controlled for confounding variables using logistic regression analysis, it is likely that all factors influencing selection bias were not accounted for in the present analysis. Furthermore, the heterogeneity of the study population could make it difficult to draw broad conclusions from these data. Although survival with dialysis has improved during the past 20 years, it seems that most of the gains have occurred within the first few years of treatment. In the present study, we are unable to quantify how long before admission, the patient's dialysis had been initiated. It is intuitive to believe that those patients who were receiving dialysis for years versus months would have had

TABLE 7. Adjusted survival estimates for long-term survival

Estimate	HR (95% CI)	P value
Crude estimate (no adjustment)	4.67 (3.88–5.62)	<.001
Age-adjusted estimate	6.54 (5.41–7.89)	<.001
Full adjustment	2.34 (1.83–2.99)	<.001

HR, Hazard ratio; CI, Confidence interval.

TABLE 8. Significant preoperative predictors of long-term survival from multivariate survival analysis

Preoperative variable	HR (95% CI)	P value
Age	1.04 (1.032–1.043)	<.001
Chronic lung disease	1.28 (1.07–1.53)	.006
CVA	1.54 (1.30–1.82)	<.001
EF	0.99 (0.988–0.997)	<.001
Infectious endocarditis	1.43 (1.16–1.78)	<.001
Female gender	1.28 (1.14–1.43)	<.001
Heart failure	1.25 (1.11–1.41)	<.001
Renal failure	2.33 (1.96–2.78)	<.001
Renal failure requiring dialysis	2.34 (1.83–2.99)	<.001
CAD requiring CABG	1.34 (1.19–1.51)	<.001
Body mass index	1.00 (0.99–1.01)	.94
Diabetes	1.23 (1.08–1.41)	.002

HR, Hazard ratio; CI, Confidence interval; CVA, Cerebrovascular accident; EF, Ejection fraction; CAD, Coronary artery disease; CABG, Coronary artery bypass grafting.

worse outcomes, and this is a current research investigation of our group. Finally, important operative variables were not available, such as the echocardiographic parameters. Although biologic versus mechanical valves were not evaluated in our study, Thourani and colleagues¹⁹ have noted similar mid- and long-term survival between valve types.

CONCLUSIONS

The present study represents one of the largest series to date to evaluate the outcomes of patients with ESRD after cardiac valve surgery. Although limited by its retrospective design, it illustrates the short-term morbidity and long-term mortality for this difficult patient cohort. Careful preoperative risk assessment and resource use should precede valve surgery in patients undergoing preoperative chronic dialysis for ESRD. Additional research investigation in the reduction of the high morbidity and mortality in patients with ESRD is warranted.

The authors from Emory University express their gratitude to staff members Kim Baio for project oversight, to Jean Walker and Susan Joyce for data abstraction, and to Deborah Canup for database management.

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