Long-Term Survival of Dialysis Patients with Bacterial Endocarditis
Undergoing Valvular Replacement Surgery in the United States

Running title: Leither et al.; Bacterial endocarditis in dialysis

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Abstract:

Background—Bacterial endocarditis in dialysis patients is associated with high mortality rates. The literature is limited regarding long-term outcomes of valvular replacement surgery and choice of prosthesis in dialysis patients with bacterial endocarditis.

Methods and Results—Dialysis patients hospitalized for bacterial endocarditis, 2004-2007, were studied retrospectively using data from the US Renal Data System. Long-term survival of patients undergoing valve replacement surgery with tissue or non-tissue valves was compared using the Kaplan-Meier method. A Cox proportional hazards model was used to identify independent predictors of mortality in patients undergoing valvular replacement surgery. During the study period, 11,156 dialysis patients were hospitalized for bacterial endocarditis and 1267 (11.4%) underwent valvular replacement surgery (tissue valve 44.3%, non-tissue valve 55.7%). In the valve replacement cohort, 60% were men, 50% white, 54% aged 45-64 years, and 36% diabetic. Estimated survival with tissue and non-tissue valves, respectively, at 0.5, 1, 2, and 3 years was 59% and 60%, 48% and 50%, 35% and 37%, and 25% and 30% (log rank \( P = 0.42 \)).

Staphylococcus was the predominant organism (66% of identified organisms). Independent predictors of mortality in patients undergoing valve replacement surgery included older age, diabetes as cause of end-stage renal disease, surgery during index hospitalization, staphylococcus as the causative organism, and dysrhythmias as a comorbid condition.

Conclusions—Valve replacement surgery is appropriate for well-selected dialysis patients with bacterial endocarditis, but is associated with high mortality rates. Survival does not differ with tissue or non-tissue prosthesis.

Key words: endocardium, kidney, valve
Introduction

Approximately 415,000 patients with end-stage renal disease (ESRD) were receiving maintenance dialysis in the United States in 2010, and this number continues to rise.1 The reported incidence of bacterial endocarditis in maintenance dialysis patients is 267 per 100,000 person-years. This rate is markedly higher than in the general population, and translates to an age-adjusted incidence ratio of 17.9 compared with the general population.2 The recent International Collaboration on Endocarditis-Prospective Cohort Study (ICE-PCS) reported that 21% of all bacterial endocarditis cases in North America occurred in people on hemodialysis, compared with less than 5% elsewhere.3 The higher incidence in dialysis patients is likely due to multiple factors, but largely related to frequent episodes of bacteremia related to dialysis access4 and a higher rate of valvular heart disease predisposing the valves to bacterial seeding.5 This represents a significant health care burden because short-term and long-term outcomes are poor for dialysis patients who develop bacterial endocarditis.2,6-13 Shroff et al6 previously reported in-hospital mortality of 23.5% and 1-year mortality of 61.6%, much higher than in the general population or in hospitalized dialysis patients without bacterial endocarditis.14 Despite the higher incidence of bacterial endocarditis and poor outcomes related to this diagnosis, no substantial change in mortality has occurred in the last two decades in these patients,6 likely due to no substantial change in the therapeutic armamentarium.

Valve replacement surgery is a key therapeutic option for left-sided endocarditis in the general population,15 but no guideline recommendations pertain specifically to valve replacement surgery in dialysis patients with bacterial endocarditis. The existing literature comprises retrospective studies with incongruent results.7,9,12 In a large observational study, Rankin et al16 reported an operative mortality of 24.4% in dialysis patients undergoing valve replacement
surgery, but data regarding long-term follow-up or pertaining to microbiology were not available. Because annual mortality is high overall in the dialysis population, an understanding of long-term survival after valvular surgery for endocarditis is of vital importance for clinicians. Similarly, selection of valve type for dialysis patients is a topic of debate. The largest analysis to date showed no difference in outcomes between dialysis patients receiving tissue and non-tissue valves, but this was not specific to bacterial endocarditis. To our knowledge, no studies have addressed valve selection in dialysis patients with bacterial endocarditis.

This study aimed to determine the short-term and long-term survival of dialysis patients with bacterial endocarditis undergoing left-sided heart valve replacement surgery and to determine differences in survival between tissue and non-tissue prostheses. Using the US Renal Data System (USRDS) database, we examined characteristics and outcomes of dialysis patients hospitalized for bacterial endocarditis undergoing left-sided valve replacement surgery.

Methods

The institutional review board at Hennepin County Medical Center approved this study. All data were derived from the USRDS database. This study is a retrospective analysis of dialysis patients with an index hospitalization for bacterial endocarditis after initiation of renal replacement therapy during a 4-year period between January 2004 and December 2007. Patients hospitalized for bacterial endocarditis were identified by International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code 421.0. For patients with repeated hospitalizations for endocarditis, only the first was included in the analysis. All eligible patients were Medicare eligible and had been receiving dialysis for at least 60 days before hospitalization for bacterial endocarditis. We identified patients who underwent aortic and/or mitral valve
replacement surgery within 6 months after the bacterial endocarditis hospitalization (ICD-9-CM codes 35.21, 35.22, 35.23, 35.24). Prosthetic valve type (tissue versus non-tissue) was identified by ICD-9-CM codes (tissue valve codes 35.21 and 35.23, non-tissue valve codes 35.22 and 35.24). Patients with previous valvular surgery were excluded. For comparison, we also identified dialysis patients without endocarditis who underwent left-sided valve replacement surgery in the same time period. Concomitant coronary artery bypass surgery was identified by ICD-9-CM code 36.1X.

Patient demographic data included age, sex, race, etiology of ESRD, ESRD duration, and dialysis modality. The chi-square test was used to compare differences in baseline groups; \( P \) value < 0.05 was considered statistically significant. In-hospital survival was determined and long-term survival was estimated by the Kaplan-Meier method from date of surgery and compared for patients undergoing tissue or non-tissue valve surgery. Patients were followed up through death or December 31, 2007, and censored if they underwent renal transplant in the interim. Independent predictors of death were examined in a Cox proportional hazards model.\(^{18}\)

Although causative organisms for endocarditis cannot be definitively determined using observational data, we evaluated the database to identify patients with an ICD-9-CM code for bacteremia (790.7) or septicemia (038) and with associated supplementary ICD-9-CM codes for specific organisms (see Supplemental Material). We included these organisms in the Cox proportional hazards model in three categories (streptococcus including pneumococcus, staphylococcus, and other). Additionally, we studied long-term survival for dialysis patients with endocarditis who received non-surgical/medical management, and for dialysis patients without endocarditis who underwent valve replacement, in this time period. All statistical analyses were performed using SAS for Windows, version 9 (SAS Institute Inc, Cary, NC).
Results

During the 4-year study period, 11,156 dialysis patients were hospitalized for bacterial endocarditis. Of these, 1267 (11.4%) underwent valve replacement surgery; 588 (46.4%) underwent aortic valve replacement, 565 (44.6%) mitral valve replacement, and 114 (9.0%) both. Dialysis patients with bacterial endocarditis were more likely to undergo valve replacement with non-tissue (706 patients, 55.7%) than with tissue valves (561 patients, 44.3%). In all, 5140 dialysis patients underwent valve replacement surgery in the study period; 1267 of these surgeries (25%) were for endocarditis.

Table 1 lists demographic characteristics of patients with endocarditis in the study period. Baseline characteristics of patients undergoing valve surgery or receiving medical therapy for endocarditis differed significantly. Patients undergoing surgery for endocarditis were more likely to be male (60.2% versus 49.9%, \( P < 0.0001 \)) and black (46.6% versus 42.0%, \( P = 0.009 \)); a higher proportion were aged 45-64 years (53.8% versus 43.3%) and a lower proportion had diabetic ESRD (35.8% versus 47.5%). The tissue and non-tissue valve cohorts did not differ significantly by sex or race. However, younger patients were more likely to receive non-tissue valves (26.4% of patients aged \( \leq 44 \) years received non-tissue valves, as did 57.0% of those aged 45-64 years, 13.1% of those aged 65-74 years, and 3.5% of those aged \( \geq 75 \) years; corresponding percentages for tissue valves were 20.0%, 49.7%, 20.7%, and 9.6%; \( P < 0.001 \)). The comorbidity profiles of patients receiving tissue or non-tissue valves did not differ significantly, except that congestive heart failure was significantly higher among patients receiving tissue valves (84.3% versus 78.0%; \( P = 0.007 \)). Coronary artery bypass surgery was simultaneously performed in 21% of patients who underwent surgery for endocarditis.

A majority of valve replacement surgeries occurred during the hospitalization for
bacterial endocarditis (56.8% in the surgical cohort). The surgical cohort was 60.2% male and 50.4% white. Regarding dialysis modality, hemodialysis patients were more likely to undergo non-tissue than tissue valve replacement (98.0% versus 97.3%) and peritoneal dialysis patients were more likely to undergo tissue than non-tissue valve replacement (2.7% versus 2.0%); this difference was not statistically significant ($P = 0.71$). Similarly, in subgroups based on ESRD etiology, dialysis duration, and comorbid conditions, there were no statistically significant differences between the tissue and non-tissue cohorts.

In-hospital mortality for the entire cohort of patients undergoing valve replacement surgery for bacterial endocarditis was 13.7%. Figure 1 shows Kaplan-Meier curves for estimated survival by valve type. Survival did not differ for patients with tissue or non-tissue valves. Survival with a tissue valve at 0.5, 1, 2, and 3 years was 59%, 48%, 35%, and 25%, respectively. Corresponding survival with a non-tissue valve was 60%, 50%, 37%, and 30%. Survival was lower in the cohort of dialysis patients with bacterial endocarditis who received medical (non-surgical) management: 49%, 39%, 28%, and 21% at the same time intervals (log rank $P < 0.0001$). Compared with survival for endocarditis patients undergoing valvular surgery, survival was higher for patients with non-endocarditis indications for valve replacement surgery (survival at 0.5, 1, 2, and 3 years was 65%, 57%, 43%, and 34%; log rank $P < 0.0001$). Estimated 30-day mortality was 17% for all non-endocarditis patients undergoing valvular surgery and 19% for all endocarditis patients receiving valve surgery.

Table 2 shows independent predictors of mortality from a Cox proportional hazards model for patients undergoing valve replacement. The strongest predictors of mortality following valve surgery for endocarditis were age (ages 65-74 years, hazard ratio [HR] 1.33, 95% confidence interval [CI] 1.02-1.72; age $\geq$ 75 years, HR 1.60, 95% CI 1.07-2.38) and diabetes as
cause of ESRD (HR 1.36, 95% CI 1.02-1.82). Aortic valve replacement was associated with reduced mortality compared with mitral valve replacement (HR 0.74, 95% CI 0.60-0.91), and replacement of both valves was associated with higher mortality (HR 1.64, 95% CI 1.18-2.27). Adjusted mortality for valve replacement surgery occurring during the hospital admission was higher than for surgery occurring after discharge (HR 1.44, 95% CI 1.18-1.75). Importantly, mortality did not differ based on valve type (tissue versus non-tissue, \( P = 0.65 \)), sex, or race. The presence of a dysrhythmia was also a predictor of higher mortality (HR 1.40, 95% CI 1.15-1.71).

Finally, we searched the USRDS database for organisms with a putative role in endocarditis. ICD-9-CM codes for bacteremia and septicemia and their causative organisms were identified (see Supplemental Material for organism codes). Of the 1267 dialysis patients undergoing valvular surgery for bacterial endocarditis, 697 (55%) had an associated code for bacteremia or septicemia with a specified organism. Of these, streptococcal organisms were identified in 105 (15%), staphylococcal in 457 (66%), and other organisms in 135 (19%) patients. The other organisms category consisted mostly of unspecified bacteria (80%). These three categories were included in the Cox proportional hazards model (Table 2); staphylococcus (HR 1.34, 95% CI 1.00-1.79) and other organisms (HR 1.64, 95% CI 1.18-2.29) were associated with a higher mortality than streptococcus.

**Discussion**

This large observational study identified 11,156 dialysis patients hospitalized for bacterial endocarditis and analyzed the subset of 1267 patients (11.4%) who underwent left-sided valve replacement surgery. Dialysis patients with endocarditis in general, and those undergoing valve replacement surgeries in particular, constitute a high-risk group characterized by a large burden
of comorbidity and high long-term mortality. Based on our results, valve replacement surgery appears to be a reasonable and appropriate option for selected dialysis patients hospitalized with endocarditis. Importantly, among dialysis patients with bacterial endocarditis undergoing valve replacement surgery, long-term survival did not differ significantly between tissue and non-tissue valves.

Previous studies have addressed the high short-term and long-term mortality rates in this population. Abbott and Agodoa\textsuperscript{2} published a large retrospective review of 2075 dialysis patients with bacterial endocarditis from the USRDS database, 1992-1997, and reported 2-year survival of only 48\%. Shroff et al\textsuperscript{6} analyzed a similar cohort of patients from the USRDS database, 1997-2000, and reported survival rates at 1, 2, and 3 years of only 38\%, 25\%, and 18\%, respectively. Similarly, survival rates at 1, 2, and 3 years in our study population (2004-2007) were approximately 40\%, 30\%, and 20\%, respectively. Thus, the survival of dialysis patients with endocarditis has not materially improved in the past two decades. Interestingly, we found a steep increase in mortality rates between 1 and 6 months post-discharge, despite relatively lower in-hospital and 1-month mortality rates (13.7\% and 19.0\%, respectively). These findings may reflect the natural history of endocarditis and the underlying comorbidity in this population; they are less likely to represent surgical complications.

The indications for valve replacement for bacterial endocarditis in the general population based on consensus guidelines include valvular disease causing heart failure, recurrent emboli, persistent infection despite appropriate antibiotic therapy, large mobile vegetations, and myocardial abscess formation.\textsuperscript{15} However, no guidelines pertain specifically to dialysis patients, and whether these indications are appropriate for and applicable to dialysis patients is debatable. Dialysis patients represent a much higher-risk population due to high mortality rates in the
context of bacterial endocarditis, relatively low life expectancy, high peri-operative surgical risk, and frequent systemic comorbid conditions.

To date, two small retrospective studies and one large retrospective analysis report outcomes of dialysis patients with bacterial endocarditis undergoing valvular surgery, with conflicting results. Spies et al\(^7\) retrospectively evaluated 40 dialysis patients with bacterial endocarditis at three hospitals in Hawaii over 11 years. They reported that 15 patients (38%) underwent valvular surgery with a peri-operative mortality of 73%. A more recent study by Kamalaklannan et al\(^9\) retrospectively analyzed 69 dialysis patients with bacterial endocarditis between January 1990 and December 2004 at one hospital in Detroit, Michigan. They found that in-hospital survival was much higher for patients who underwent valvular surgery (12/15 patients; 80%) than for those who were medically managed (23/54, 43%). Interestingly, 24 of 69 patients had an indication for valvular surgery based on guidelines for the general population, but only 15 patients underwent surgery, indicating that selection bias likely strongly influenced the outcomes reported in these small studies. Unfortunately, there are no mortality data in either of these studies beyond the initial hospitalization.

A larger retrospective study by Rankin et al\(^16\) used the Society of Thoracic Surgeons national database to analyze 1862 valvular surgery operations in dialysis patients with endocarditis, 1994-2003, and reported an operative mortality of 24.4%. One unique aspect of this study was the proposal of a risk model that was accurately predictive of in-hospital mortality (salvage surgery/shock, double valve surgery, older age, mitral valve involvement, high body surface area, arrhythmia, active endocarditis, and female sex). Our study, involving large numbers of patients from a nationally representative cohort, is similar to and differs from the Rankin et al\(^16\) study in important ways. We found an in-hospital mortality rate for patients
undergoing left-sided surgery lower than the rate reported by Rankin et al.\textsuperscript{16} whose population was comparatively higher risk (including patients with previous valve surgery, re-do operations, and all valve surgeries including right-sided replacements). Also, our cohort is more contemporaneous, suggesting a possible interval improvement in perioperative survival. Our study confirms the independent predictors of mortality identified by Rankin et al\textsuperscript{16} (increasing age, double valve surgery, mitral valve involvement, arrhythmia), and provides data regarding long-term survival, differences in survival between tissue and non-tissue prosthesis, and causative organisms.

A primary objective of this study was to compare survival after use of tissue and non-tissue valves in a cohort of dialysis patients with bacterial endocarditis. Historically, there have been concerns about using tissue valves in dialysis patients after two case series (\(n = 4\) patients) published in the 1970s documented accelerated calcification of tissue valves.\textsuperscript{19,20} However, a large retrospective study in 2002 by Herzog et al\textsuperscript{17} and several smaller retrospective studies\textsuperscript{21-24} showed no significant difference in outcomes after use of tissue and non-tissue valves in dialysis patients. Although durability of tissue valves should be considered in valve selection, the average life expectancy for dialysis patients is shorter than the longevity of a tissue valve, despite potentially accelerated rates of valve degeneration. Thourani et al\textsuperscript{25} recently showed 10-year survival of only 18.1\% in dialysis patients with a prosthetic valve, with no difference between tissue and non-tissue valves at 10 years. Prior studies have raised concerns regarding use of non-tissue valves in dialysis patients due to a higher incidence of bleeding and cerebrovascular events compared with tissue valves\textsuperscript{21,23} and the additional burden of long-term anticoagulation, which is problematic in the ESRD population due to higher predisposition to bleeding complications.\textsuperscript{26} A recent meta-analysis combined nine studies comparing mechanical and bioprosthetic valves in
the ESRD population and found no survival difference but fewer valve-related complications with bioprostheses.27

Despite the evidence-based literature, our study found that dialysis patients with bacterial endocarditis who were referred for valve replacement surgery were more likely to receive a non-tissue prosthesis. Similar to findings in the overall dialysis population, we found no difference in short-term or long-term mortality after use of tissue and non-tissue valves in dialysis patients with bacterial endocarditis. Due to lack of any significant survival advantage attributable to mechanical prosthesis, our findings and those of previous studies support use of tissue prosthesis in most dialysis patients with bacterial endocarditis, especially patients judged to be at high risk of complications related to anticoagulation. Non-tissue valves, however, may be desirable in young, otherwise healthy patients whose anticipated life expectancy is longer than the life of a bioprosthetic valve, and potentially in younger patients who are candidates for future kidney transplant.

The effect of surgery timing on subsequent mortality should also be factored into the clinical decision making analysis in this high-risk population. Using a Cox proportional hazards model, we identified surgery performed during the index hospitalization as an independent risk factor for mortality. This finding corroborates previous reports by Rankin et al16 and Gaca et al,14 who reported higher mortality rates in the setting of emergent/salvage operations. However, these findings should be interpreted with caution. The higher risk related to surgeries performed during the hospital stay in observational studies likely reflects sicker patients in need of emergent operations (i.e., patients too sick to be discharged from the hospital), and should not dissuade clinicians from referring appropriate patients for early surgery. In fact, a recent randomized trial in the general population demonstrated a significant benefit for the combined primary outcome
of in-hospital death and embolic events at 6 weeks with early valve surgery in patients with large
vegetations, but the benefit was driven by reductions in embolic events, not in mortality.28
Similarly, the observation pertaining to improved survival rates in surgically managed versus
medically managed dialysis patients with endocarditis in this observational study likely reflects a
strong selection or survival bias, as some dialysis patients with bacterial endocarditis were
presumably not offered surgery because they were deemed too ill to survive surgery or died
before surgery was feasible. Thus, although no firm conclusions regarding surgical versus
medical management or timing of surgical intervention can be drawn from this observational
study, these data suggest that offering valve replacement surgery to well-selected dialysis
patients with endocarditis who may benefit from surgical intervention would be appropriate.

The data pertaining to organisms associated with endocarditis are noteworthy. Among the
cohort of patients with bacterial endocarditis undergoing valve surgery, staphylococcus was the
most commonly identified organism (66%), and the mortality hazard was higher for patients with
bacteremia/septicemia with staphylococcus than for patients with streptococcal (including
pneumococcal) infection. In the general population, streptococcus is the most common causative
organism with endocarditis, but likelihood of staphylococcal infections is higher among dialysis
patients than in the general population, as corroborated by our findings.29 In the general
population, mortality with endocarditis is estimated to be 4% to 16% with streptococci, 15% to
25% with enterococci, 25% to 47% with staphylococcus aureus, and more than 50% for
pseudomonas and enterobacteriaceae.30 The higher mortality hazard associated with
staphylococcal bacteremia/septicemia in our study is also consistent with the general population.

Finally, these study results may provide additional guidance to clinicians regarding
clinical variables that could be factored in to determine which patients are most likely to benefit
from surgical intervention. On the basis of these observational data, outcomes are poorer for dialysis patients with endocarditis who are aged older than 65 years (especially those aged older than 75 years), and those with staphylococcal endocarditis, diabetes as a cause of ESRD, or dysrhythmias. However, definitive recommendations based on observational data are problematic due to the possibility of significant selection bias.

Our study has several important limitations inherent to the use of observational, administrative data with the potential for selection bias and unmeasured confounders. Because USRDS data are administrative and we lacked clinical data, we could not study important clinical variables such as echocardiographic findings (valvular vegetations, myocardial abscess, valvular regurgitation, left ventricular ejection fraction, etc.), coronary angiographic data, specific information regarding prosthetic valve endocarditis, or indications for surgery and complications related to endocarditis. Similarly, since there is no separate diagnostic code for “possible endocarditis,” patients in this clinical category may be underrepresented in our study. Although we report associated diagnostic codes for organisms during the index hospitalization for endocarditis, it is not possible to determine whether these organisms were definitively causative of endocarditis using these observational data. A prospectively designed, randomized study would be optimal to evaluate medical versus surgical management in dialysis patients with bacterial endocarditis, including survival and timing of surgery.

In summary, our data challenge a commonly held belief that dialysis patients with endocarditis are too sick to be offered valve replacement surgery. Despite high overall mortality rates in this population, our findings suggest that valve replacement surgery may be appropriate and beneficial for judiciously selected dialysis patients with bacterial endocarditis. Extending the findings of our prior study, we found no difference in survival related to selection of tissue
versus non-tissue prosthesis in dialysis patients undergoing valve replacement surgery in the setting of bacterial endocarditis. These data should serve to reassure clinicians who wish to apply the general guidelines pertaining to valve replacement surgery to dialysis patients with bacterial endocarditis.

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Conflict of Interest Disclosures: Dr. Herzog owns equity interest in Johnson & Johnson and has received research support from Ortho-McNeil-Janssen, Johnson & Johnson. Dr. Gilbertson has provided consultation to Amgen, DaVita Clinical Research, and Affymax. The other authors report no conflicts of interest.

References:


27. Chan V, Chen L, Mesana L, Mesana TG, Ruel M. Heart valve prosthesis selection in patients


**Table 1.** Baseline characteristics of the study population: comparisons of medically and surgically treated patients with bacterial endocarditis and of surgically treated patients with tissue vs. non-tissue valve prosthesis in the United States

<table>
<thead>
<tr>
<th></th>
<th>Bacterial Endocarditis Patients</th>
<th>Surgically Treated Bacterial Endocarditis Patients</th>
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<tr>
<td></td>
<td>Medically Treated</td>
<td>Surgically Treated</td>
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<tr>
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<td>1267</td>
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<tr>
<td>Sex</td>
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<td></td>
</tr>
<tr>
<td>Men</td>
<td>49.9</td>
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<tr>
<td>Women</td>
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<tr>
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<td>≥ 5</td>
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Valve type | NA  | 0.4173  
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<td>Aortic and mitral</td>
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<td>NA</td>
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Valve placement timing | NA  | 0.1431  
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<td>After discharge</td>
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Dialysis modality | 0.087 | 0.7104  
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<td>Hemodialysis</td>
<td>98.4</td>
<td>97.7</td>
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<tr>
<td>Peritoneal dialysis</td>
<td>1.6</td>
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Comorbid conditions | 0.711 | 0.6078  
|-------------------|-----|--------|
| ASHD  
Yes | 46.9 | 46.4 | 68.6 | 67.2 |
No | 53.1 | 53.6 | 31.4 | 32.8 |
| CHF  
Yes | 64.6 | 67.2 | 84.3 | 78.0 |
No | 35.4 | 32.8 | 15.7 | 22.0 |
| CVA  
Yes | 31.8 | 31.5 | 36.8 | 36.6 |
No | 68.2 | 68.5 | 63.2 | 63.4 |
| PVD  
Yes | 48.0 | 47.4 | 51.2 | 49.6 |
No | 52.0 | 52.6 | 48.8 | 50.4 |
| Other cardiac  
Yes | 100.0 | 100.0 | 100.0 | 100.0 |
No | 0.0 | 0.0 | 0.0 | 0.0 |
| COPD  
Yes | 29.0 | 30.0 | 26.8 | 27.6 |
No | 71.0 | 70.0 | 73.2 | 72.4 |
| GI bleeding  
Yes | 17.1 | 16.7 | 16.1 | 15.9 |
No | 82.9 | 83.3 | 83.9 | 84.1 |
| Liver disease  
Yes | 11.6 | 12.8 | 13.0 | 12.4 |
No | 88.4 | 87.2 | 87.0 | 87.6 |
| Dysrhythmia  
Yes | 49.9 | 52.4 | 65.1 | 60.2 |
No | 50.1 | 47.6 | 34.9 | 39.8 |
| Cancer  
Yes | 8.1 | 7.8 | 7.1 | 6.0 |
No | 91.9 | 92.2 | 92.9 | 94.0 |

**Note:** Unless otherwise indicated, values are percentages.
ASHD, atherosclerotic heart disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CVA/TIA, cerebrovascular accident/transient ischemic attack; ESRD, end-stage renal disease; GI, gastrointestinal; NA, not applicable; PVD, peripheral vascular disease.
Table 2. Cox proportional hazards model for independent predictors of mortality among dialysis patients undergoing valvular surgery for endocarditis in the United States

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Hazard Ratio (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valve type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-tissue</td>
<td>1.05 (0.87-1.26)</td>
<td>0.6471</td>
</tr>
<tr>
<td>Tissue (ref)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Age, yrs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-44</td>
<td>1.00 (0.78-1.27)</td>
<td>0.974</td>
</tr>
<tr>
<td>45-64 (ref)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>65-74</td>
<td>1.33 (1.02-1.72)</td>
<td>0.034</td>
</tr>
<tr>
<td>≥ 75</td>
<td>1.60 (1.07-2.38)</td>
<td>0.0218</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>0.99 (0.81-1.22)</td>
<td>0.9572</td>
</tr>
<tr>
<td>Men (ref)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (ref)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>1.10 (0.90-1.35)</td>
<td>0.349</td>
</tr>
<tr>
<td>Other</td>
<td>0.78 (0.43-1.40)</td>
<td>0.3978</td>
</tr>
<tr>
<td>Cause of ESRD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.36 (1.02-1.82)</td>
<td>0.038</td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.94 (0.73-1.22)</td>
<td>0.6482</td>
</tr>
<tr>
<td>Other (ref)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Valve placement timing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>During hospitalization</td>
<td>1.44 (1.18-1.75)</td>
<td>0.0003</td>
</tr>
<tr>
<td>After discharge (ref)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Dialysis modality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemodialysis (ref)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Peritoneal dialysis</td>
<td>0.74 (0.32-1.68)</td>
<td>0.468</td>
</tr>
<tr>
<td>Valve type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitral (ref)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Aortic</td>
<td>0.74 (0.60-0.91)</td>
<td>0.004</td>
</tr>
<tr>
<td>Both</td>
<td>1.64 (1.18-2.27)</td>
<td>0.0029</td>
</tr>
<tr>
<td>Organism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Streptococcus</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Staphylococcus</td>
<td>1.34 (1.00-1.79)</td>
<td>0.0472</td>
</tr>
<tr>
<td>Other</td>
<td>1.64 (1.18-2.29)</td>
<td>0.0033</td>
</tr>
<tr>
<td>Comorbid conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASHD</td>
<td>1.07 (0.87-1.33)</td>
<td>0.5244</td>
</tr>
<tr>
<td>CHF</td>
<td>1.01 (0.80-1.29)</td>
<td>0.9214</td>
</tr>
<tr>
<td>CVA</td>
<td>1.02 (0.84-1.23)</td>
<td>0.8822</td>
</tr>
<tr>
<td>PVD</td>
<td>1.16 (0.95-1.40)</td>
<td>0.1453</td>
</tr>
<tr>
<td>COPD</td>
<td>1.13 (0.91-1.42)</td>
<td>0.2709</td>
</tr>
<tr>
<td>GI bleeding</td>
<td>1.09 (0.84-1.43)</td>
<td>0.5168</td>
</tr>
<tr>
<td>Liver disease</td>
<td>1.23 (0.93-1.63)</td>
<td>0.1558</td>
</tr>
<tr>
<td>Dysrhythmia</td>
<td>1.40 (1.15-1.71)</td>
<td>0.001</td>
</tr>
<tr>
<td>Cancer</td>
<td>0.93 (0.63-1.36)</td>
<td>0.6923</td>
</tr>
</tbody>
</table>

ASHD, atherosclerotic heart disease; CHF, congestive heart failure; CI, confidence interval; COPD, chronic obstructive pulmonary disease; CVA/TIA, cerebrovascular accident/transient ischemic attack; GI, gastrointestinal; HR, hazard ratio; PVD, peripheral vascular disease.
Figure Legend:

**Figure 1.** Kaplan-Meier survival curves for demonstrating long-term survival among dialysis patients with endocarditis undergoing valve surgery with tissue or non-tissue prosthesis.
Long-Term Survival of Dialysis Patients with Bacterial Endocarditis Undergoing Valvular Replacement Surgery in the United States
Maxwell D. Leither, Gautam R. Shroff, Shu Ding, David T. Gilbertson and Charles A. Herzog

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International Classification of Diseases, Ninth Revision, Clinical Modification Codes for Bacterial Organisms Causing Bacteremia and Septicemia

041.00
041.01
041.02
041.03
041.04
041.05
041.09
041.10
041.11
041.12
041.19
041.2
041.3
041.5
041.6
041.7
041.81
041.82
041.83
041.84
041.85
041.86
041.89
041.9