Cardiac Surgery Outcomes in Patients Receiving Hemodialysis Versus Peritoneal Dialysis

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Rationale & Objective: We sought to compare outcomes of patients receiving dialysis after cardiothoracic surgery on the basis of dialysis modality (intermittent hemodialysis [HD] vs peritoneal dialysis [PD]).

Study Design: This was a retrospective analysis.

Setting & Participants: In total, 590 patients with kidney failure receiving intermittent HD or PD undergoing coronary artery bypass graft and/or valvular cardiac surgery at Cleveland Clinic were included.

Exposure: The patients received PD versus HD (intermittent or continuous).

Outcomes: Our primary outcomes were in-hospital and 30-day mortality. Secondary outcomes were length of stay, days in the intensive care unit, the number of intraoperative blood transfusions, postsurgical pericardial effusion, and sternal wound infection, and a composite of the following 4 in-hospital events: death, cardiac arrest, effusion, and sternal wound infection.

Analytical Approach: We used χ^2, Fisher exact, Wilcoxon rank sum, and *t* tests, Kaplan-Meier survival, and plots for analysis.

Results: Among the 590 patients undergoing cardiac surgery, 62 (11%) were receiving PD, and 528 (89%) were receiving intermittent HD. Notably, 30-day Kaplan-Meier survival was 95.7% (95% CI: 93.9-97.5) for HD and 98.2% (95% CI: 94.7-100) for PD ($P = 0.30$). In total, 75 patients receiving HD (14.2%) and 1 patient receiving PD (1.6%) had a composite of 4 in-hospital events (death, cardiac arrest, effusion, and sternal wound infection) ($P = 0.005$). Out of 62 patients receiving PD, 16 (26%) were converted to HD.

Limitations: Retrospective analyses are prone to residual confounding. We lacked details about nutritional data. Intensive care unit length of stay was used as a surrogate for volume status control. Patients have been followed in a single health care system. The HD cohort outnumbered the PD cohort significantly.

Conclusions: When compared with PD, HD does not appear to improve outcomes of patients with kidney failure undergoing cardiothoracic surgery. Patients receiving PD had a lower incidence of a composite outcome of 4 in-hospital events (death, cardiac arrest, pericardial effusion, and sternal wound infections).

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Kidney and cardiovascular disease are clinically intertwined. Indeed, chronic kidney disease is an independent risk factor for the development of coronary artery disease, and coronary artery disease remains the leading cause of morbidity and mortality in patients with chronic kidney disease, contributing to 40%-50% of deaths among this patient population.[1,2] Thus, they are more likely to undergo invasive cardiac revascularization procedures but unfortunately experience higher peri- and postoperative mortality (up to 3.9 times higher).[3-5]

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Studies have shown improved mortality when patients receiving dialysis undergo coronary artery bypass grafting (CABG) as opposed to percutaneous coronary artery intervention.[6,7] Consequently, CABG is increasingly performed in patients receiving dialysis.

Currently, hemodialysis (HD) remains the most frequently used modality for kidney replacement therapy and fluid management.[8] Peritoneal dialysis (PD), however, offers multiple potential advantages over HD. Indeed, PD does not require a dialysis nurse to be physically present during treatment and it can provide an adequate ultrafiltration volume with less hemodynamic impact.[9] Additionally, the incidence of catheter-related blood stream infections appears to be larger than the incidence of PD-related peritonitis in patients undergoing CABG (35% vs 12.5%, respectively).[10,11]

Nevertheless, many patients receiving PD are converted to HD after cardiac surgery. Concerns for inadequate volume control, more perioperative bleeding, and an increased risk of pericardial effusions and sternal wound infections are often raised with patients receiving PD. The current literature has not adequately addressed if these concerns are valid. In the studies reporting the outcomes of patients receiving dialysis after cardiothoracic surgeries,[12-14] the total number of patients receiving PD was small, and no direct comparison of PD versus HD was made. Our study examines the differences in outcomes of patients with kidney failure receiving PD versus HD following cardiac surgery.

PLAIN-LANGUAGE SUMMARY

Patients receiving peritoneal dialysis (PD) are frequently switched to hemodialysis (HD) around the time of an open-heart surgery. More times than not, this is driven by the preference of nonkidney doctors, because HD is perceived to control toxins and fluids better. PD is, however, more advantageous and can achieve similar results while being gentler. In an effort to keep patients on their home PD, we analyzed how they fared when compared with their HD counterparts. Patients maintained on PD did just as well if not better around and after their open-heart surgery. Given the expected increase in patients treated with PD, efforts should be made to maintain them on their home modality even around major surgeries.

METHODS

Patient Population

We used the electronic health record–based Cardio-Thoracic Surgery registry at Cleveland Clinic to evaluate the outcomes of patients with kidney failure receiving HD and PD undergoing a major cardiac surgery. For this analysis, we included patients who had kidney failure and were receiving kidney replacement therapy (PD or HD) undergoing CABG and/or valvular surgery from October 2009 to October 2019. Exclusion criteria included acute kidney injury requiring kidney replacement therapy; transcatheter aortic valve replacement, a prior kidney transplant, or a kidney transplant during the current surgery; and PD to HD conversions happening before surgery. Only the first surgery per patient was included in this study. Informed consent was waived by the Cleveland Clinic Institutional Review Board (19-087) owing to the nature of the study.

Patient Characteristics

Demographic details (age, sex, and race) and comorbid conditions such as diabetes mellitus, hypertension, coronary artery disease, malignancy, congestive heart failure, dyslipidemia, stroke, obesity, and previous surgeries were collected in the Cardio-Thoracic Surgery registry. Cardio-Thoracic Surgery registry data are collected manually through an intake form and according to the Society of Thoracic Surgery adult cardiac surgery guidelines. For comorbid conditions, any diagnosis present before the admission date for surgical intervention was considered as the presence of that comorbid condition.

Dialysis Modality

We obtained data from the Cardio-Thoracic Surgery registry for patients who had a history of dialysis. We performed chart reviews to ensure patients had a history of kidney failure (defined as an estimated glomerular filtration rate < 15 mL/min/1.73 m^2 on kidney replacement therapy by HD or PD for at least 3 months before the date of surgery). We obtained data on dialysis procedure orders to evaluate the type of dialysis the patients were receiving during the admission associated with the current surgery. Charts were also reviewed to confirm the type of dialysis (PD vs HD) and whether patients receiving PD were converted to HD after the surgical intervention. HD modalities included intermittent hemodialysis and continuous venovenous hemodialysis.

Outcomes

Our primary outcomes were in-hospital death, and death at 30 days following a cardiac surgery, defined as the following: within 30 days after a surgery in or out of the hospital; and after 30 days during the same hospitalization after the surgery. Secondary outcomes included length of stay, time in the intensive care unit, the number of intraoperative packed red blood cell transfusions, sepsis, and postsurgical complications (pericardial effusion and whether intervention was required, gastrointestinal bleed, cardiac arrest, sternal wound infections, and whether intervention was required), and the composite of the following 4 in-hospital events: death, cardiac arrest, pericardial effusion, and sternal wound infection. We also evaluated sternal wound infections and pericardial effusions in-hospital and within 60 days.

Statistical Analysis

We compared the baseline demographics and comorbid conditions between patients receiving PD and those receiving HD using χ^2, Fisher exact, Wilcoxon rank sum, and t tests for categorical and continuous variables, respectively.

We compared binary outcomes during the hospital admission using χ^2 tests and Fisher exact tests, and continuous outcomes using Wilcoxon rank sum tests. We used logistic regression analysis to evaluate the association between dialysis modality and the composite outcome of 4 in-hospital events while adjusting for age and type of surgery. We were unable to fit large models adjusted for many covariates owing to our limited number of patients receiving PD and the number of events.

We used Kaplan-Meier survival to evaluate the time to 30-day or in-hospital mortality based on PD or HD for all patients. We obtained postdischarge mortality information for Ohio residents through the Ohio mortality files. Non-Ohio residents were censored either at discharge or at the follow-up visit per 30 days (when a follow-up visit occurred within 60 days after surgery).

We used Kaplan-Meier plots to evaluate the time to postsurgery effusion within 60 days of discharge and used cumulative incidence functions with death as a competing risk. Patients were censored at their last follow-up within 60 days of discharge, and when no follow-up visits were available, at discharge. We evaluated external infection within 60 days in a similar manner. We performed all

Table 1. Baseline Characteristics

Factor	No. Missing	Overall (N = 590)	HD (N = 528)	PD (N = 62)	*P* Value
Age	0	61.3 ± 13.0	61.1 ± 13.1	62.9 ± 12.0	0.31[a]
Sex	0				0.40[b]
Female		219 (37.1)	199 (37.7)	20 (32.3)	
Male		371 (62.9)	329 (62.3)	42 (67.7)	
Race	0				0.52[c]
White		385 (65.3)	339 (64.2)	46 (74.2)	
African American		171 (29.0)	157 (29.7)	14 (22.6)	
Other		27 (4.6)	25 (4.7)	2 (3.2)	
Unknown		7 (1.2)	7 (1.3)	0 (0.0)	
Ethnicity	0				0.97[c]
Hispanic		16 (2.9)	14 (2.8)	2 (3.3)	
Non-Hispanic		526 (95.1)	471 (95.5)	55 (91.7)	
Unavailable		48 (8.1)	43 (8.1)	5 (8.1)	
Weight	0	81.1 (69.7, 94.0)	80.9 (68.9, 94.0)	83.8 (71.7, 93.0)	0.37[d]
BMI	0	27.6 (23.7, 32.3)	27.4 (23.5, 32.5)	28.7 (25.8, 31.0)	0.29[d]
Albumin	111	3.5 (3.1, 4.0)	3.6 (3.1, 4.0)	3.2 (2.8, 3.6)	<0.001[d]
Hemoglobin A1c	280	6.1 (5.4, 6.9)	6.0 (5.4, 6.8)	6.5 (5.6, 7.5)	0.01[d]
History of hypertension	0	519 (88.0)	463 (87.7)	56 (90.3)	0.55[b]
History of diabetes	1	351 (59.6)	310 (58.8)	41 (66.1)	0.27[b]
History of heart failure	1	412 (69.9)	381 (72.3)	31 (50.0)	<0.001[b]
LVEF	28	55 (45, 60)	55 (45, 60)	56 (50, 62)	0.07[d]
History of dyslipidemia	0	472 (80.0)	415 (78.6)	57 (91.9)	0.01[b]
History of chronic lung disease	1	241 (40.9)	218 (41.4)	23 (37.1)	0.52[b]
History of arrhythmia surgery	26	8 (1.4)	6 (1.2)	2 (3.4)	0.20[c]
History of smoking	16	360 (62.7)	318 (62.0)	42 (68.9)	0.29[b]
History of CABG	4	69 (11.8)	67 (12.8)	2 (3.2)	0.03[b]
History of ICD implant	4	20 (3.4)	17 (3.2)	3 (4.8)	0.46[c]
History of pacemaker implant	4	34 (5.8)	30 (5.7)	4 (6.5)	0.77[c]
History of PCI	4	167 (28.5)	147 (28.1)	20 (32.3)	0.49[b]
History of myocardial infarction	1	234 (39.7)	205 (38.9)	29 (46.8)	0.23[b]
History of stroke	5	131 (22.4)	120 (22.9)	11 (18.0)	0.39[b]
History of TIA	4	78 (13.3)	73 (13.9)	5 (8.1)	0.20[b]

Note: Statistics are presented as mean ± standard deviation, median (P25, P75), or N (column %).
Abbreviations: BMI, body mass index; CABG, coronary artery bypass graft; HD, hemodialysis; ICD, implantable cardioverter defibrillator; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; PD, peritoneal dialysis; TIA, transient ischemic attack.
[a]*P* value calculated using the *t* test.
[b]*P* value calculated using the χ^2 test.
[c]*P* value calculated using the Fisher exact test.
[d]*P* value calculated using the Wilcoxon rank sum test.

analyses as intent-to-treat with the dialysis group assigned at the time of surgery. We described the number, timing, and reasons for PD conversions after surgery.

RESULTS

Patient Characteristics

In total, 590 patients were included in the analysis (Fig S1). Three patients were converted from PD to HD before surgery and were excluded from the study. They were converted 3, 1, and 17 days before surgery, respectively. Out of the total study population, 62 (11%) were receiving PD and 528 (89%) were receiving HD. Patient characteristics are further described in Table 1; missing data are described in Tables S1-S3. Patients receiving PD had a lower prevalence of heart failure (50% among those receiving PD vs 72.3% among those receiving HD), a history of CABG (3% vs 13%), and a lower median cardiopulmonary bypass time (median, 106 vs 122 minutes). Patients receiving PD had a higher percentage of dyslipidemia (92% vs 79%).

Patients receiving PD also had a higher proportion of CABG (38.7% vs 25.4%) and combined CABG and valve surgery (29% vs 25.9%). Patients receiving PD were admitted for a shorter period before surgery compared with patients receiving HD (median, 2 days vs 5 days). Perioperative characteristics stratified based on PD or HD are presented in Table 2. Patients receiving PD and HD had 51.6% and 37.5% elective surgeries, respectively.

Sixteen (26%) patients receiving PD converted to HD. Five converted postoperatively on the day of the surgery and 11 afterward. The reasons for conversion cited were

Table 2. Perioperative Characteristics Based on HD Versus PD

Factor	No. Missing	Overall (N = 590)	HD (N = 528)	PD (N = 62)	*P* Value
Preoperative anticoagulant medication	0				0.98[a]
None		307 (52.0)	274 (51.9)	33 (53.2)	
Heparin (low molecular weight)		2 (0.34)	2 (0.38)	0 (0.00)	
Heparin (unfractionated)		240 (40.7)	214 (40.5)	26 (41.9)	
Other		3 (0.51)	3 (0.57)	0 (0.0)	
Thrombin inhibitors		1 (0.17)	1 (0.19)	0 (0.0)	
Unknown type		37 (6.3)	34 (6.4)	3 (4.8)	
Preoperative aspirin	1	326 (55.3)	289 (54.8)	37 (59.7)	0.47[b]
Preoperative ADP inhibitors	1	14 (2.4)	13 (2.5)	1 (1.6)	0.99[a]
Days from admit to surgery	0	5 (0, 10)	5 (0, 10)	2 (0, 7)	0.006[c]
Surgery	0				0.03[b]
CABG		158 (26.8)	134 (25.4)	24 (38.7)	
CABG and valve		155 (26.3)	137 (25.9)	18 (29.0)	
Valve		277 (46.9)	257 (48.7)	20 (32.3)	
Surgery status	0				0.06[b]
Elective		230 (39.0)	198 (37.5)	32 (51.6)	
Emergent		14 (2.4)	14 (2.7)	0 (0.0)	
Urgent		346 (58.6)	316 (59.8)	30 (48.4)	
Intraoperative blood products given	2	461 (78.4)	413 (78.5)	48 (77.4)	0.84[b]
Total CPB time (min)	60	120 (88, 160)	122 (91, 161)	106 (78, 146)	0.02[c]
Circulatory arrest	0	17 (2.9)	17 (3.2)	0 (0.0)	0.24[a]

Note: Statistics are presented as mean ± standard deviation, median (P25, P75), or N (column %).
Abbreviations: ADP, adenosine diphosphate; CABG, coronary artery bypass graft; CPB, cardiopulmonary bypass; HD, hemodialysis; PD, peritoneal dialysis.
[a]*P* value calculated using the Fisher exact test.
[b]*P* value calculated using the χ^2 test.
[c]*P* value calculated using the Wilcoxon rank sum test.

catheter malfunction (N = 3), cardiac tamponade (N = 1), surgeon's preference (N = 4), hemodynamic instability (N = 7), and gadolinium exposure (N = 1). Conversion reasons are described in Table 3.

Outcomes

Univariable analysis of primary outcomes showed no evidence that PD has different postsurgical outcomes compared with HD. Table 4 describes the in-hospital postoperative outcomes based on dialysis type. The table shows column percentages and medians (P25, P75). In-hospital death was 5% for HD versus 2% for PD (P = 0.51). The estimated Kaplan-Meier survival at 30 days after surgery was 95.7% (95% confidence interval [CI]: 93.9-97.5) for HD and 98.2% (95% CI: 94.7-100) for PD (P = 0.30) (Fig 1). Among the Ohio residents, the estimated survival at 1 year was 77.3 (95% CI: 73.1-81.8) for HD and 76.0% (95% CI: 64.0-90.2) for PD (P = 0.12).

Patients receiving PD and HD did not require different amounts of intraoperative blood transfusions (median of 2 units for PD and HD; P = 0.84). The median postoperative length of stay was 10 days for the PD group and 11 days for the HD group (P = 0.21). Patients receiving PD spent a median of 93.3 hours in the intensive care unit, whereas those receiving HD spent 96.1 hours (P = 0.52). Postoperative sepsis rates were 4.9% for patients receiving PD and 2.7% for those receiving HD (P = 0.32). Patients receiving HD experienced a higher proportion of the composite of the 4 in-hospital events (death, cardiac arrest, pericardial effusion, and sternal wound infection) (Table 5).

When evaluated across different strata, we found that patients receiving HD experienced more events than patients receiving PD only among those undergoing combined CABG and valvular surgery or among patients with heart failure. When adjusting for age and type of surgery in a logistic regression model, we found that patients receiving HD had significantly higher odds of experiencing the composite of 4 in-hospital events versus patients receiving PD, but the CIs were very wide

Table 3. Reasons for PD to HD Conversion After Cardiac Surgery

Reason Cited	No.	Percentage
Absolute indications (N = 5)		
Catheter malfunction	3	18.75%
Gadolinium exposure	1	6.25%
Pericardio-peritoneal shunt	1	6.25%
Relative indications (N = 11)		
Clinician driven	4	25%
Hemodynamic instability or vasopressor requirement	7	43.75%

Abbreviations: HD, hemodialysis; PD, peritoneal dialysis.

Table 4. Outcomes Based on HD Versus PD

Factor	No. Missing	Overall (N = 590)	HD (N = 528)	PD (N = 62)	*P* Value
Units of RBC required intraoperatively	2	2 (0, 3)	2 (0, 3)	2 (1, 3)	0.84[a]
Length of stay post surgery	0	11 (8, 18)	11 (8, 19)	10 (7, 17)	0.21[a]
ICU total hours	2	96 (52, 189)	96.1 (52, 194)	93 (58, 165)	0.52[a]
Sepsis	2	17 (2.9)	14 (2.7)	3 (4.9)	0.41[b]
Blood products given	0	456 (77.3)	411 (77.8)	45 (72.6)	0.35[c]
Gastrointestinal bleed	0	48 (8.1)	42 (8.0)	6 (9.7)	0.64[c]
Cardiac arrest	0	29 (4.9)	29 (5.5)	0 (0)	0.06[b]
Death in hospital	0	26 (4.4)	25 (4.7)	1 (1.6)	0.51[b]
Effusion in hospital	1[d]	31 (5.3)	31 (5.9)	0 (0)	0.06[b]
Sternal wound infection in hospital	0	5 (0.85)	5 (0.95)	0 (0)	0.99[b]

Note: Statistics are presented as median (P25, P75) or N (%).
Abbreviations: HD, hemodialysis; ICU, intensive care unit; PD, peritoneal dialysis; RBC, red blood cell.
[a]*P* value calculated using the Kruskal-Wallis test.
[b]*P* value calculated using the Fisher exact test.
[c]*P* value calculated using the χ^2 test.
[d]One patient had effusion on the day before the surgery and is excluded.

owing to the limited sample size (odds ratio, 9.5; 95% CI: 1.3-70.1). The 60-day external infection–free survival was 98% (95% CI: 96.2-99.2) for HD and 100% for PD (P = 0.32) (Fig 2). The 60-day effusion–free survival was 93.6% (95% CI: 91.4-95.8) for HD and 100% for PD (P = 0.05) (Fig 3).

DISCUSSION

Our study did not show a difference in the short-term mortality of PD and intermittent patients receiving HD after cardiac surgery. There was also no difference in the individual outcomes of volume control, bleeding risk, pericardial effusions, or sternal wound infection rates. Patients receiving PD, however, did have a lower incidence of a composite of 4 in-hospital events including death, cardiac arrest, pericardial effusion, and sternal wound infection. Key learning points are presented in Box 1.

The impact of dialysis modalities on outcomes after cardiac surgery is not well established; the studies reporting outcomes in patients receiving PD are few and include small numbers of patients. Head-to-head comparisons between patients receiving HD and patients receiving PD are rare and present contradicting findings. Zhong et al[11] performed a comparison and reported an increased risk of in-hospital mortality for patients receiving PD after cardiothoracic surgery (adjusted odds ratio, 22.58; P = 0.02). The authors did not, however, provide baseline demographic characteristics for the cohorts.

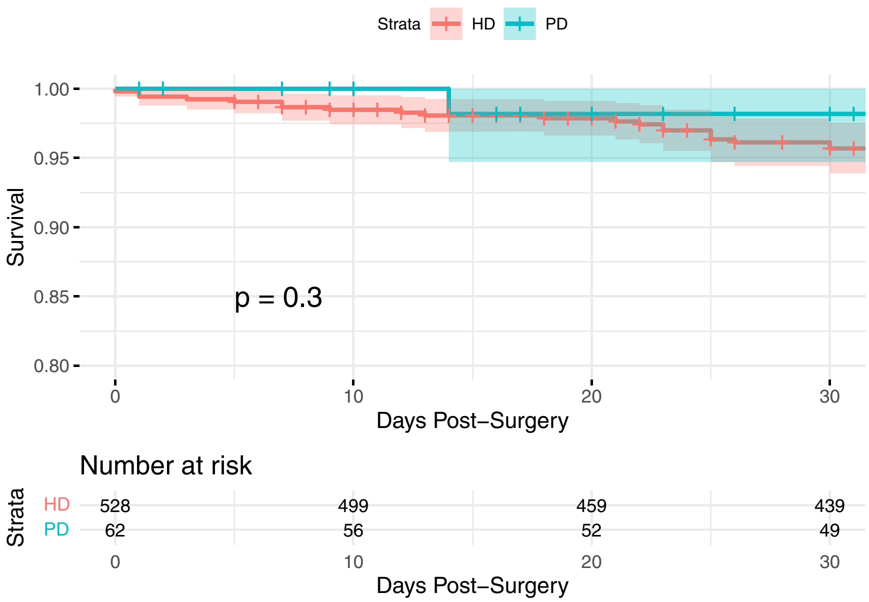

Figure 1. Thirty-day or in-hospital survival. HD, hemodialysis; PD, peritoneal dialysis.

Table 5. Composite of 4 In-Hospital Outcomes Based on HD Versus PD for Various Strata

	N	Overall	N	HD	N	PD	*P* Value
Composite of in-hospital death, cardiac arrest, effusion, and sternal wound infection							
Strata							
All patients	590	76 (12.9)	528	75 (14.2)	62	1 (1.6)	0.005[a]
CABG surgery	158	10 (6.3)	134	10 (7.5)	24	0 (0)	0.36[b]
Valve surgery	277	36 (13.0)	257	35 (13.6)	20	1 (5.0)	0.49[b]
CABG and valve surgery	155	30 (19.4)	137	30 (21.9)	18	0 (0)	0.03[b]
Elective surgery	230	18 (7.8)	198	18 (9.1)	32	0 (0)	0.09[b]
Emergent or urgent surgery	360	58 (16.1)	330	57 (17.3)	30	1 (3.3)	0.07[b]
No history of heart failure and LVEF ≥ 30	175	19 (10.9)	145	18 (12.4)	30	1 (3.3)	0.20[b]
History of heart failure or LVEF < 30	414	57 (13.8)	382	57 (14.9)	32	0 (0)	0.01[b]

Note: Statistics are presented as N (column %).
Abbreviations: CABG, coronary artery bypass graft; HD, hemodialysis; LVEF, left ventricular ejection fraction; PD, peritoneal dialysis.
[a]*P* value calculated using the χ^2 test.
[b]*P* value calculated using the Fisher exact test.

Furthermore, 6 out of the 7 patients receiving PD who had in-hospital deaths were switched to HD, making the cause of death difficult to ascertain. Li et al[15] examined 134 dialysis patients undergoing CABG in Taiwan in a retrospective study conducted from October 2005 to January 2015 and concluded that patients receiving PD (N = 12) had a higher in-hospital mortality rate (58.3% vs 14.8%; $P < 0.001$) when compared with hemodialysis patients. This increased mortality was attributed to septic shock in patients receiving PD.

On the other hand, Kumar et al[16] compared 36 patients receiving PD and matched them with patients receiving HD on a 2:1 ratio on the basis of age, diabetes, and the Charleston comorbidity score. They found that patients receiving PD did not experience increased early complications after cardiac surgery. Bäck et al[17] compared the 30-day mortality of 136 dialysis patients, 30 of whom were patients receiving PD, undergoing any cardiac surgery (valve replacement and revascularization) in a retrospective analysis (1998-2015) and found that patients receiving PD had a lower 30-day mortality rate as opposed to patients receiving HD (3% vs 14%; $P = 0.06$). This was, however, statistically insignificant, further confounding the evidence.

To our knowledge, this is the largest study examining the difference in outcomes of patients with kidney failure receiving PD as opposed to HD after cardiac surgery. In this large cohort of dialysis patients, we found no significant differences in the measured outcomes between patients receiving HD and those receiving PD following CABG and/or valvular surgery. There was no significant difference in the 30-day or in-hospital mortality observed when

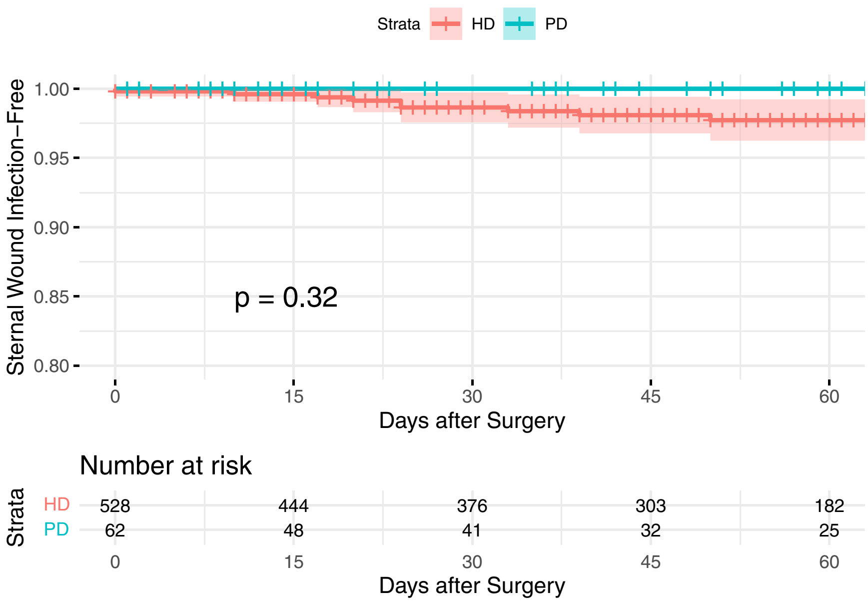

Figure 2. Sternal wound infection–free survival after surgery. HD, hemodialysis; PD, peritoneal dialysis.

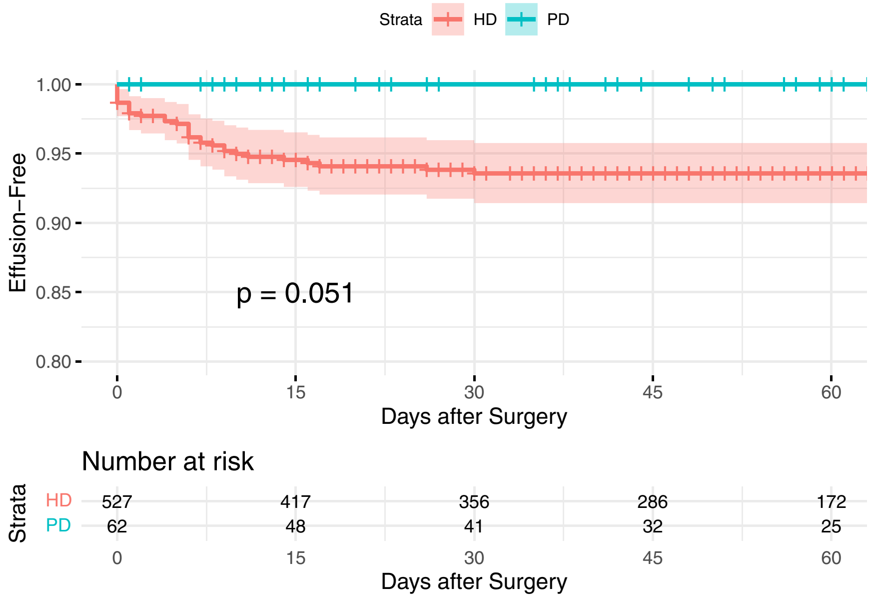

Figure 3. Pericardial effusion–free survival after surgery. HD, hemodialysis; PD, peritoneal dialysis.

comparing patients receiving PD and HD (0%, 4.8%; P = 0.25). Furthermore, patients receiving PD had a lower incidence of a composite outcome of 4 inpatient events consisting of death, cardiac arrest, pericardial effusion, and sternal wound infection (1.6% vs 14.2%; P = 0.005).

Fluid overload is a major risk factor for mortality, and even minimal hypervolemia is associated with worse outcomes in critically ill adults.[18] In our study, PD appeared to be as effective as HD in controlling volume status postoperatively. This was reflected by a similar observed postsurgical length of stay in the intensive care unit for both groups. Greater volume removal can be achieved in patients receiving PD by increasing dwell cycling or using increasingly hypertonic dwell solutions. Furthermore, data from pediatric cardiac surgery support the use of PD as a safe and effective method of fluid removal postsurgical intervention.[19]

Pericardial effusions and tamponade are also common and dreaded complications of cardiac surgeries.[20,21] The fear of a peritonea-pericardial communication leading to dialysate-induced tamponade has only been documented in case reports.[22] We did not find an increased incidence or the risk of pericardial effusions (acute or chronic) requiring intervention in patients receiving PD (Fig 3).

Bleeding tendencies have long been established in kidney dysfunction[23] and are mostly attributed to uremic-induced platelet dysfunction.[24,25] The comparatively higher serum urea nitrogen levels observed in patients receiving PD as opposed to those receiving HD can be worrisome to practitioners and may lead to conversion to HD to decrease the risk of periprocedural bleeding. We did not observe a difference in intraoperative bleeding because both groups required the same amount of blood transfusion (2 units on average). This is supported by studies demonstrating no correlation between serum urea nitrogen levels and the bleeding time,[26] and the association of HD with transient worsening in platelet dysfunction.[27]

Deep sternal wound infections are also a significant concern in patients undergoing cardiac surgery because the highest rate is observed in patients undergoing combined CABG or valvular surgery.[28] Although rare overall, this

Box 1. Key Learning Points

- Dialysis patients are more likely to undergo invasive cardiac revascularization procedures but experience higher mortality after cardiac surgery.
- The evidence in the current literature examining the outcomes of these patients when stratified by dialysis modality (peritoneal dialysis [PD] vs hemodialysis [HD]) is scarce and conflicted.
- A significant number of patients receiving PD are converted to HD perioperative without an absolute indication, potentially exposing these patients to unnecessary procedures.
- Short-term mortality appears to be similar in dialysis patients receiving PD or HD.
- Patients receiving PD have comparable and possibly better outcomes when measuring pericardial effusions, external sternal wound infections, bleeding risk, and so on.
- Recent policies in the United States aim to increase the number of dialysis patients receiving PD given its benefits over HD; as the use of PD increases, it will be crucial for providers to become more comfortable managing PD in critical periods.
- Converting patients receiving PD to HD perioperatively should be limited with efforts undertaken to adjust the PD prescription in concordance with clinical needs.

complication is feared because it is associated with significant comorbid condition and an increased risk of both in-hospital mortality and decreased long-term survival.[28] Vascular calcification is well established in dialysis patients,[29,30] is often linked to hyperphosphatemia,[31] and is a significant risk factor for deep sternal wound infections.[28] Our study did not find a difference in deep sternal wound infection rates in the PD and HD groups (Fig 2). This was despite patients receiving PD undergoing more CABG and combined CABG or valve surgeries.

Sixteen patients receiving PD (∼26%) were converted to HD postoperatively. The most cited reason for the conversion was hemodynamic instability and the use of vasopressors (43.75%). Although about 19% were converted owing to PD catheter malfunction, clinician preference accounted for 25% of the patients converted to HD. We maintain that PD to HD conversion is most appropriate when unable to safely perform PD. This is supported by studies showing a higher rate of dialysis-related complications (bacteremia, bleeding, and thrombosis) in HD as opposed to PD in patients newly started on kidney replacement therapy.[32-34]

Strengths of our analysis include a large patient population with data spanning over 10 years. Data were collected from a quaternary center with a diverse patient population. The diversity of our patient population strengthens the generalizability of our findings, increasing the external validity of the study. While we sampled about 10 times more patients receiving HD, our group distribution mirrors the current use of these modalities in the United States because PD is estimated to hold around 10% of the market share.[35]

We recognize that retrospective analyses are prone to residual confounding. Although we included several variables that could affect mortality, we lacked details about nutritional data. Additionally, we used the length of intensive care unit stay as a surrogate for volume status control, but we lacked invasive hemodynamic monitoring, or time to extubation, as perhaps a more accurate proxy for volume status. Furthermore, our patients have been followed in a single health care system, and hence, these data might not be applicable to community-dwelling adults with kidney failure.

In conclusion, there was no difference in outcomes examined between patients receiving PD and HD undergoing a major cardiac surgery. Furthermore, when examining the 4 inpatient composite outcomes of death, cardiac arrest, pericardial effusions, and sternal wound infections, patients receiving PD appeared to do better. Based on these findings, PD appears to be as safe as intermittent HD, and switching modalities should be restricted to absolute indications. This is very pertinent considering the recent "Advancing American Kidney Health" initiative with a set goal of fewer Americans receiving in-center hemodialysis. More data are needed given the projected increase in patients receiving PD pursuant to this initiative, and providers should become more comfortable with the use of PD in acute settings including after surgery.

SUPPLEMENTARY MATERIALS

Supplementary File (PDF)

Figure S1: The study flowchart.

Table S1: Missing Data by Group: Baseline Characteristics.

Table S2: Missing Data by Group: Perioperative Characteristics by HD Versus PD.

Table S3: Missing Data by Group: Outcomes by HD Versus PD.

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