An evaluation of the outcomes associated with peritoneal catheter use in neonates undergoing cardiac surgery: A multicenter study

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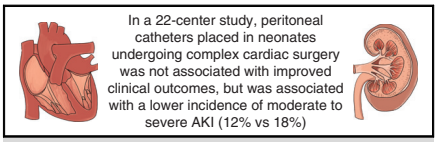
ABSTRACT

Objective: The study objective was to determine if intraoperative peritoneal catheter placement is associated with improved outcomes in neonates undergoing high-risk cardiac surgery with cardiopulmonary bypass.

Methods: This propensity score–matched retrospective study used data from 22 academic pediatric cardiac intensive care units. Consecutive neonates undergoing Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery category 3 to 5 cardiac surgery with cardiopulmonary bypass at centers participating in the NEonatal and Pediatric Heart Renal Outcomes Network collaborative were studied to determine the association of the use of an intraoperative placed peritoneal catheter for dialysis or passive drainage with clinical outcomes, including the duration of mechanical ventilation.

Results: Among 1490 eligible neonates in the NEonatal and Pediatric Heart Renal Outcomes Network dataset, a propensity-matched analysis was used to compare 395 patients with peritoneal catheter placement with 628 patients without peritoneal catheter placement. Time to extubation and most clinical outcomes were similar. Postoperative length of stay was 5 days longer in the peritoneal catheter placement cohort (17 vs 22 days, $P = .001$). There was a 50% higher incidence of moderate to severe acute kidney injury in the no-peritoneal catheter cohort (12% vs 18%, $P = .02$). Subgroup analyses between specific treatments and in highest risk patients yielded similar associations.

Conclusions: This study does not demonstrate improved outcomes among neonates with placement of a peritoneal catheter during cardiac surgery. Outcomes were similar apart from longer hospital stay in the peritoneal catheter cohort. The no-peritoneal catheter cohort had a 50% higher incidence of moderate to severe acute kidney injury (12% vs 18%). This analysis does not support indiscriminate peritoneal catheter use, although it may support the utility for postoperative fluid removal among neonates at risk for acute kidney injury. A multicenter controlled trial may better elucidate peritoneal catheter effects. (JTCVS Open 2024;19:275-95)



Neonates with PCs placed during cardiac surgery had better renal outcomes.

CENTRAL MESSAGE

Among neonates undergoing complex cardiac surgery, intraoperative PC placement is not associated with better outcomes, although it may be associated with less AKI.

PERSPECTIVE

This 22-center propensity-matched study assessed the outcomes associated with intraoperative PC placement in neonates undergoing complex cardiac surgery. Outcomes were not improved in those undergoing catheter placement except for a decrease in moderate to severe kidney injury. This argues against universal placement of catheters except for those at high risk of kidney injury.

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Abbreviations and Acronyms

AKI	= acute kidney injury
CICU	= cardiac intensive care unit
CPB	= cardiopulmonary bypass
NEPHRON	= NEonatal and Pediatric Heart Renal Outcomes Network
PC	= peritoneal catheter
PC^4	= Pediatric Cardiac Critical Care Consortium
POD	= postoperative day
STAT	= Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery
VIS	= vasoactive inotrope score

Disorders of fluid balance and the pathologic state of fluid overload are well-described complications among neonates undergoing cardiac surgery and have been associated with adverse outcomes, including acute kidney injury (AKI), prolonged mechanical ventilation, and mortality.[1-6] To prevent fluid overload in the highest risk neonates, some centers place peritoneal catheters (PCs) at the time of cardiac surgery to perform prophylactic peritoneal dialysis or passive drainage. It remains unknown if this practice is associated with improved outcomes.

To date, there have been several single-center observational studies and 1 single-center randomized controlled trial of prophylactic peritoneal dialysis or peritoneal drainage in neonates after cardiac surgery.[7-13] Many of these studies show an association with improved fluid balance, shorter duration of mechanical ventilation, lower mortality, or other improved outcomes.[7-13] However, other studies have failed to demonstrate benefit.[14,15] The absence of formative data leads to wide variation in the use of PC among centers, because center-specific dogma dictates practice.[16] To date, there remains a paucity of multicenter data describing the potential effects associated with PC placement and use after neonatal cardiac surgery. A better understanding of these practices may serve to inform the

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development of clinical practice guidelines, clinical trials, and ultimately optimize PC use.

To better understand fluid overload and AKI after cardiac surgery in infants, a 22-center collaborative, the Neonatal and Pediatric Heart Renal Outcomes Network (NEPHRON), was established.[17] The current report is a planned NEPHRON secondary study aimed at determining whether the use of an intraoperatively placed PC plus drainage or dialysis was associated with shorter duration of mechanical ventilation and other improved secondary clinical outcomes in high-complexity neonatal cardiac surgery with cardiopulmonary bypass (CPB). Given the results of single-center studies, we hypothesized that neonates with PC placement and subsequent drainage or prophylactic peritoneal dialysis would have shorter duration of mechanical ventilation and other improved outcomes, including shorter duration of inotropic support and hospital length of stay, when compared with neonates without intraoperative placement of a PC.

MATERIAL AND METHODS

This 22-center retrospective, propensity score–matched analysis used data from the NEPHRON dataset to determine the benefits associated with PC use in neonates undergoing high-complexity congenital cardiac surgery.

Data Source

Data were collected from the NEPHRON supplemental module within the Pediatric Cardiac Critical Care Consortium (PC^4) registry. This supplemental module included renal-specific information on all consecutive neonates (age $\leq$30 days) undergoing an index cardiac surgery between September 2015 and January 2018 at 22 pediatric cardiac centers with a maximum enrollment of 150 patients per center. Full details and participating centers of the dataset have been published.[17] Nonrenal study data were extracted from the PC^4 registry. PC^4 is a quality improvement collaborative that collects data on all patients with cardiac disease admitted to the cardiac intensive care unit (CICU) at participating hospitals and currently has more than 70 participating centers.[18] The PC^4 dataset has high integrity with comprehensive site education and data validation established through regular audits.[19,20] The University of Michigan Institutional Review Board provided oversight for the PC^4 Data Coordinating Center and has reviewed and approved this study for waived consent given the retrospective nature of the study. The University of Alabama at Birmingham Institutional Review Board approved this project as the NEPHRON Data Coordinating Center (X151002002, December 18, 2015).

Population

The NEPHRON dataset includes all neonates undergoing cardiac surgery with and without CPB. This secondary study included a subpopulation with a perceived higher risk of fluid overload, composed of neonates undergoing Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery (STAT) category 3 to 5 surgery[21] with CPB who were admitted to the CICU receiving mechanical ventilation. Epidemiologic data on this cohort have been published.[16]

Exposure Definitions

Patients were assigned to 2 cohorts: those with intraoperative placement and use of a PC (OR-PC) and those without intraoperative PC placement (No-PC). The OR-PC cohort was further divided into 2 subcohorts: those undergoing "prophylactic" peritoneal dialysis and those undergoing passive drainage. Prophylactic peritoneal dialysis was defined as all patients who received dialysate dwells in the first 24 postoperative hours. Any patient who initially received prophylactic peritoneal dialysis was classified as dialysis even if the catheter was later used for passive drainage, because dialysis was the original intent of therapy. Data were not captured on postoperative placement of a PC for drainage; thus, patients who received a postoperative PC were included in the No-PC cohort.

All aspects of operative and postoperative care were performed as per individual institutional practice. Although peritoneal dialysis protocols differ among centers, they share similar initial therapy prescriptions, with low-volume (10 mL/kg) dextrose containing dialysate (DIANEAL, Baxter Pharmaceuticals) dwells with hourly cycles and subsequent modification as appropriate per patient status.[7,11] The decision to start dialysis and the dextrose percentage were driven by local practice guidelines.

Outcomes

The primary outcome was duration of mechanical ventilation, defined as the time (hours) from arrival to the CICU after the index operation to initial successful extubation (extubated >24 hours). Secondary outcomes of interest included postoperative inotrope support duration, respiratory support duration, vasoactive inotrope score, fluid balance metrics, AKI incidence, length of stay, and adverse events. Inotrope support time was defined as the number of days until initial cessation of all inotropic medications (including milrinone), and respiratory support time was days until cessation of any form of noninvasive positive pressure ventilation or high-flow nasal cannula. Vasoactive inotrope score (VIS) was previously defined.[22]

The postoperative day (POD) cumulative fluid balance (daily percent fluid overload) was calculated as 100 $\times$ cumulative net daily postoperative fluid balance/preoperative weight and represents the daily change in fluid balance adjusted to weight on that individual POD.[17] Cumulative fluid balance does not include intraoperative fluid balance. AKI was defined using serum creatinine component of the modified neonatal Kidney Diseases: Improving Global Outcomes criteria, such that moderate AKI was defined as stage 2 and severe AKI was defined as stage 3 AKI.[23,24] Urine output was determined using each day's mean hourly urine output rate (mL/kg/h). Major complications were included as defined by PC^4. Adverse events reported to PC^4 and potentially related to a PC were collected, including necrotizing enterocolitis, unplanned gastrointestinal surgery, and surgical site infection.[16]

Analysis

Outcomes of the No-PC cohort were compared with the OR-PC cohort, as well as with those with prophylactic peritoneal dialysis and peritoneal drainage individually. Descriptive data are presented as frequency (%) and median [interquartile range] for categorical and continuous variables, respectively. Univariate analyses assessed associations between PC placement (Yes/No) and patient demographic, preoperative and intraoperative clinical variables, and PC placement by comparing characteristics between groups using Pearson's chi-square, Fisher exact, Wilcoxon rank-sum testing, or Kruskal–Wallis testing as appropriate. Time to first extubation among groups was presented graphically using Kaplan–Meier curves, and statistical significance was assessed using clustered log-rank test. Sensitivity analysis was performed on the subset of STAT-5 patients. *P* values do not adjust for multiple outcomes, because these analyses were exploratory in nature and therefore need careful interpretation and subsequent follow-up.

To reduce the selection bias of PC placements and derive a reasonably balanced population for comparisons of the outcomes between groups, we assembled a balanced cohort through propensity score matching. Propensity scores were estimated by performing multivariable logistic regression for the outcome PC placement (Yes/No) using covariates likely to influence the PC placement selection as covariates in the model and with exact

matching on STAT category. In the propensity score matching, a caliper width of 0.10 was used to choose at most 2 controls for each case (PC placements: yes).[25,26] We assessed postmatch balance of covariates by absolute standardized difference with the difference less than 0.2 indicating small or negligible imbalance between groups.[27-29] To take into account clustered nature data (subjects within propensity matched set), we used generalized linear models with generalized estimating equation to obtain robust SE and make inference.

RESULTS

Among the 2240 neonates in the NEPHRON dataset, 582 were excluded for not undergoing CPB during cardiac surgery, 132 were excluded for undergoing STAT 1 or 2 surgery, and 36 were excluded for extubation in the operating room. The remaining 1490 patients met study criteria and were included and eligible for matching. The median age at surgery was 6 (4-10) days, and the average weight was 3.23 kg (Table 1). Many patients underwent high-complexity surgery, including 57% STAT 4 and 25% STAT 5 with an overall median CPB time of 134 (97-172) minutes. Median time to extubation was 92 (51-162) hours, and inpatient mortality was 3.8% (57/1490). Only 4% developed severe AKI, and 15% developed moderate or severe AKI.

Intraoperative placement of a PC (OR-PC) was performed in 471 (32%) neonates. There was variability in the use of PC by center (Figure E1); PC placement ranged from 0% at 6 (27%) centers to more than 90% at 4 (18%) centers. Four (18%) centers performed prophylactic peritoneal dialysis on a subset of patients. Table 1 shows the univariable comparison between the No-PC and OR-PC cohorts. The OR-PC cohort had a higher severity of illness with greater frequency of preoperative mechanical ventilation, increased proportion of single-ventricle physiology, higher STAT category surgery, and longer durations of CPB and aortic crossclamp. Postoperatively, the OR-PC cohort had higher median admission lactate and higher VIS, and received more packed red blood cell transfusions. The OR-PC cohort had longer median durations of mechanical ventilation, respiratory support, inotropic support, and hospital length of stay compared with the No-PC group. There were no differences in postoperative infections or complications, including AKI, necrotizing enterocolitis, unplanned gastrointestinal surgery, or peak fluid overload, although PC use was associated with decreased urine output.

Propensity-Matched Analyses

OR-PC versus No-PC. A total of 395 patients in the OR-PC cohort were matched to 628 patients in the No-PC cohort. Figure E2 shows the standardized mean differences between the prematched and matched cohorts, demonstrating effectiveness of the matching process with respect to key risk factors (Table 2). There was no difference in duration of mechanical ventilation between patients with and without a PC. Figure 1 shows Kaplan–Meier analysis for time to first extubation for the 2 cohorts with no difference noted.

Durations of total respiratory support and inotropic support were not different between cohorts; however, postoperative hospital length of stay was a median of 5 days longer in the OR-PC cohort after propensity matching (17 [11-31] vs 22 [12-34] days, $P = .001$). There was no difference in major complications or mortality. There was a 50% higher incidence of moderate to severe AKI in the No-PC cohort (12% vs 18%, $P = .02$). Urine output was lower in the first 6 PODs in the OR-PC, as was diuretic use. The No-PC cohort had clinically small, but statistically more negative daily and cumulative fluid balance on several PODs; however, there was no difference in time to first net negative daily fluid balance or peak cumulative fluid balance (Table 2).

STAT 5 category. Subgroup analysis was performed to compare neonates undergoing STAT 5 surgery. Among 378 patients undergoing STAT 5 surgery, propensity score matching was used to compare 100 patients with intraoperative PC placement with 149 patients without. Table E1 shows the comparisons between the cohorts. There was no difference in mechanical ventilation duration. As in the overall cohort, the median hospital length of stay was longer in the OR-PC cohort by approximately 4 days (27 [18-46] vs 31 days [26-54], $P = .02$). Those without PCs had higher diuretic use and correspondingly higher urine output, but similar incidence of AKI, fluid balance metrics, and other outcomes.

Prophylactic Peritoneal Dialysis Versus Passive Peritoneal Drainage

Of the 471 patients who received a PC in the operating room, 177 received prophylactic peritoneal dialysis and 294 had passive peritoneal drainage only. Among those receiving peritoneal dialysis, the median time to initiation was 3 [1-5] hours, and the median duration of use was 56 [37-90] hours. In propensity-matched analysis, 117 patients receiving prophylactic dialysis were compared with 156 patients undergoing passive peritoneal drainage (Table 3). The dialysis cohort had a lower median VIS on CICU admission (10 [7-14] vs 8 [5-12], $P < .001$) and on POD 1 (10 [7-13.5] vs 8 [5-12.5], $P = .01$). Cohorts did not differ in postoperative duration of mechanical ventilation. Durations of respiratory support, postoperative hospital length of stay, and inotropic support were similar, as were incidence of moderate and severe AKI and peak cumulative fluid overload. Urine output was significantly lower on the first 3 PODs in the dialysis cohort. Cumulative fluid balance was lower on all days in the drainage cohort as was the time to first negative fluid balance, although daily fluid balance was only lower on the first POD (−3.8 [−6.6 to 0.1] vs −0.8 [−3.6 to 1.5], $P < .001$). Mortality was lower in the dialysis cohort (13/156 [8%] vs 2/117 [2%], $P = .01$).

TABLE 1. Unadjusted comparison of patients with and without peritoneal catheter placement

Variable	Overall (n = 1490)	No PC (n = 1019)	Operative PC (n = 471)	*P* value
Gender (female)	583 (39.1)	397 (39)	186 (39.5)	.84
Race				
Non-Hispanic White	854 (57.3)	586 (57.5)	268 (56.9)	.86
Non-Hispanic Black	195 (13.1)	137 (13.4)	58 (12.3)	
Hispanic	254 (17)	172 (16.9)	82 (17.4)	
Other/multiracial	187 (12.6)	124 (12.2)	63 (13.4)	
Age at surgery (d)	6 [4-10]	6 [4-10]	7 [4-10]	.08
Weight at surgery, kg (mean [SD])	3.23 [0.58]	3.24 [0.58]	3.21 [0.57]	.33
Preterm (<37 wk)	151 (10.1)	103 (10.1)	48 (10.2)	.43
Chromosomal syndrome	245 (16.4)	169 (16.6)	76 (16.1)	.6
Extracardiac anomalies	243 (16.3)	164 (16.1)	79 (16.8)	.8
Preoperative mechanical ventilation	447 (30)	265 (26)	182 (38.6)	<.001
Preoperative serum creatinine (mg/dL)	0.49 [0.4-0.6]	0.5 [0.4-0.6]	0.47 [0.4-0.59]	.11
STAT category				
3	269 (18)	207 (20.2)	62 (13.2)	.001
4	843 (56.6)	579 (56.8)	264 (56.1)	
5	378 (25.4)	233 (22.9)	145 (30.8)	
Single-ventricle physiology	420 (28.2)	262 (25.7)	158 (33.5)	.002
Modified ultrafiltration (y/n)	900 (60.4)	650 (63.8)	250 (53.1)	<.001
CPB time (min)	134 [97-172]	130 [91-164]	145 [111-185]	<.001
Aortic crossclamp (y/n)	1376 (92.3)	930 (91.3)	446 (94.7)	.03
Aortic crossclamp time (min)	66 [45-99]	64 [43-92]	74 [49-111]	<.001
Deep hypothermic circulatory arrest (y/n)	603 (40.5)	386 (37.9)	217 (46.1)	.003
Postoperative lactate (mmol/mL)	4.1 [2.7-5.6]	4 [2.6-5.6]	4.4 [3.1-5.8]	.002
Postoperative VIS	9 [5-13]	8 [5-13]	10 [6-13]	.02
POD 1 VIS	9 [5-13]	8 [5-13]	9 [6-13]	.5
Delayed sternal closure (y/n)	659 (44.2)	454 (44.6)	205 (43.5)	.75
PRBC administration (y/n)	520 (34.9)	313 (30.7)	207 (43.9)	<.001
Outcomes				
Hospital mortality	57 (3.8)	35 (3.4)	22 (4.7)	.31
Postoperative hospital stay (d)	18 [11-32]	16 [11-31]	22 [13-34]	<.001
Postoperative CICU stay (d)	9.9 [6.1-17]	9 [6-16.1]	11.2 [7-18.1]	<.001
Mechanical ventilation duration (h)	92 [51-162]	89 [49-153]	95 [65-170]	.002
Respiratory support duration (d)	6 [4-12]	6 [3-11]	7 [4-13]	.001
Inotrope support duration (d)	5 [3-9]	5 [3-8]	6 [4-10]	.001
Any major complication	273 (18.3)	179 (17.6)	94 (20)	.43
Postoperative surgical site infection	26 (1.7)	19 (1.9)	7 (1.5)	.69
Postoperative necrotizing enterocolitis	39 (2.6)	26 (2.6)	13 (2.8)	.95
Moderate/severe AKI	217 (14.9)	159 (15.6)	58 (12.3)	.09
Severe AKI	58 (3.9)	48 (4.7)	10 (2.1)	.02
Daily fluid balance (%)				

(Continued)

TABLE 1. Continued

Variable	Overall (n = 1490)	No PC (n = 1019)	Operative PC (n = 471)	*P* value
POD 0	1.5 [−2.2 to 5.3]	1.7 [−2.3 to 5.9]	1 [−2.1 to 4.2]	.02
POD 1	−3.2 [−6.7 to 0.6]	−3.6 [−7.2 to 0.4]	−2.2 [−5.7 to 1]	<.001
POD 2	−2.5 [−6.1 to 0.6]	−2.7 [−6.4 to 0.6]	−2.2 [−5.5 to 0.7]	.16
POD 3	−1 [−4.4 to 2]	−1 [−4.3 to 2]	−1.1 [−4.7 to 2]	.96
POD 4	0.4 [−2.6 to 3]	0.5 [−2.4 to 3.1]	0.2 [−2.6 to 2.9]	.24
POD 5	1.6 [−1.3 to 4]	1.7 [−1.1 to 4.1]	1.3 [−1.6 to 3.6]	.02
Cumulative fluid balance (%)				
POD 0	1.5 [−2.2 to 5.3]	1.7 [−2.3 to 5.9]	1 [−2.1 to 4.2]	.02
POD 1	−1.9 [−7.3 to 4.2]	−2.2 [−7.8 to 4.7]	−1.5 [−6.4 to 3.2]	.5
POD 2	−4.3 [−10.5 to 1.9]	−4.7 [−10.8 to 2.3]	−3.8 [−9.6 to 1.1]	.34
POD 3	−5.5 [−12.4 to 1.3]	−5.7 [−12.4 to 0.9]	−5.2 [−12.4 to 1.8]	.37
POD 4	−5.3 [−12.7 to 2.2]	−5.7 [−12.7 to 1.9]	−5 [−12.7 to 2.7]	.56
POD 5	−4.4 [−12.5 to 4.2]	−4.5 [−12.3 to 4]	−4 [−13 to 4.4]	.97
Diuretic use				
POD 0	782 (52.6)	577 (56.8)	205 (43.5)	<.001
POD 1	1302 (87.7)	965 (95.3)	337 (71.5)	<.001
POD 2	1373 (92.5)	978 (96.5)	395 (83.9)	<.001
POD 3	1377 (92.9)	964 (95.3)	413 (87.7)	<.001
POD 4	1372 (92.7)	956 (94.7)	416 (88.3)	<.001
POD 5	1355 (92.7)	936 (94.3)	419 (89.3)	.002
POD 6	1298 (90.3)	900 (92.2)	398 (86.3)	.001
Time to first negative fluid balance (d)				
1	586 (39.6)	394 (38.9)	192 (41.2)	.26
2	592 (40)	422 (41.6)	170 (36.5)	
3	208 (14.1)	141 (13.9)	67 (14.4)	
4	46 (3.1)	30 (3)	16 (3.4)	
5	12 (0.8)	5 (0.5)	7 (1.5)	
6	5 (0.3)	3 (0.3)	2 (0.4)	
Peak cumulative percent fluid overload	4.4 [0.1-9.9]	4.6 [0-10.2]	3.7 [0.1-8.6]	.13
Operating room urine output (mL/kg/h)	7.6 [2.5-19.1]	9.1 [3-23.1]	5.7 [1.6-12.6]	<.001
Urine output (mL/kg/h)				
POD 0	1.8 [1.1-3]	2 [1.2-3.2]	1.4 [0.9-2.2]	<.001
POD 1	2.8 [1.2-4.9]	3.3 [1.7-5.4]	1.6 [0.8-3.6]	<.001
POD 2	5.1 [3.3-6.8]	5.6 [3.9-7.2]	4 [2-5.7]	<.001
POD 3	5.2 [3.7-6.6]	5.4 [4-6.8]	4.6 [3-6.1]	<.001
POD 4	4.7 [3.3-6.1]	5 [3.4-6.2]	4.4 [3-5.8]	<.001
POD 5	4.3 [2.9-5.6]	4.4 [3.1-5.6]	4.2 [2.8-5.4]	.04
POD 6	4 [2.7-5.3]	4 [2.7-5.3]	4 [2.7-5.4]	.82

PC, Peritoneal catheter; *CPB*, cardiopulmonary bypass; *VIS*, vasoactive inotrope score; *POD*, postoperative day; *PRBC*, packed red blood cells; *CICU*, cardiac intensive care unit; *AKI*, acute kidney injury.

Subgroup Analysis

Propensity-matched analysis comparing 129 patients receiving prophylactic dialysis with 227 patients without PC placement (Table E2) demonstrated similar median postoperative duration of mechanical ventilation and other clinical outcomes, including AKI, peak fluid balance, and time to negative daily fluid balance.

Propensity-matched analysis comparing 260 patients receiving passive drainage with 455 patients without PC placement (Table E3) also demonstrated similar duration of mechanical ventilation; however, those with passive peritoneal drainage had a lower incidence of moderate/severe AKI (20% vs 11%; $P = .001$) and had a lower peak cumulative percent of fluid overload (5 [0-11] vs 3 [−1 to 8]; $P = .014$). Other clinical outcomes were similar.

DISCUSSION

This propensity score–matched multicenter study demonstrated discrepant outcomes associated with PC use in neonates undergoing complex cardiac surgery.

TABLE 2. Propensity-matched comparison of patients with and without peritoneal catheter placement

Variable	No PC (n = 628)	Operative PC (n = 395)	*P* value
Gender (female)	249 (40%)	155 (39%)	.9
Race			
Non-Hispanic White	368 (59%)	224 (57%)	1
Non-Hispanic Black	81 (13%)	53 (13%)	
Hispanic	111 (18%)	71 (18%)	
Other/multiracial	68 (11%)	47 (12%)	
Age at surgery (d)	6 (4-10)	7 (4-10.5)	.3
Weight at surgery, kg (mean [SD])	3.22 (0.6)	3.20 (0.55)	.5
Preterm (<37 wk)	71 (11%)	43 (11%)	.8
Chromosomal syndrome	103 (16%)	67 (17%)	.8
Extracardiac anomalies	100 (16%)	65 (16%)	.8
Preoperative mechanical ventilation	208 (33%)	141 (36%)	.4
Preoperative serum creatinine (mg/dL)	0.5 (0.4-0.6)	0.47 (0.4-0.59)	.2
STAT category			
3	99 (16%)	57 (14%)	.8
4	361 (57%)	232 (59%)	
5	168 (27%)	106 (27%)	
Single-ventricle physiology	183 (29%)	122 (31%)	.6
Modified ultrafiltration (y/n)	368 (59%)	221 (56%)	.4
CPB time (min)	136 (100-174)	137 (106-176)	.3
Aortic crossclamp (y/n)	582 (93%)	372 (94%)	.4
Aortic crossclamp time (min)	64 (41-92)	64 (43-100)	.5
Deep hypothermic circulatory arrest (y/n)	253 (40%)	174 (44%)	.2
Postoperative lactate (mmol/mL)	4.2 (2.9-5.9)	4.3 (3-5.6)	.8
Postoperative VIS	9 (5-13)	9 (6-13)	.7
POD 1 VIS	9 (6-13)	9 (6-13)	.6
Delayed sternal closure (y/n)	303 (48%)	182 (46%)	.5
PRBC administration (y/n)	189 (30%)	161 (41%)	<.001
Outcomes			
Hospital mortality	23 (4%)	16 (4%)	.8
Postoperative hospital stay (d)	17 (11-31)	22 (13-34)	.001
Postoperative CICU stay (d)	9 (6-18)	11 (7-19)	.02
Mechanical ventilation duration (h)	92 (55-164)	95 (65-171)	.2
Respiratory support duration (d)	6 (4-12)	7 (4-13)	.06
Inotrope support duration (d)	5 (4-8)	6 (4-10)	.06
Any major complication	113 (18%)	73 (18%)	.8
Postoperative surgical site infection	24 (4%)	16 (4%)	.9

(Continued)

TABLE 2. Continued

Variable	No PC (n = 628)	Operative PC (n = 395)	*P* value
Postoperative necrotizing enterocolitis	16 (3%)	11 (3%)	.8
Moderate/severe AKI	112 (18%)	49 (12%)	.02
Severe AKI	34 (5%)	10 (3%)	.02
Daily fluid balance (%)			
POD 0	2 (−2 to 7)	1 (−2 to 4)	.002
POD 1	−3.7 (−7.4 to 0.6)	−2.1 (−5.7 to 1.1)	<.001
POD 2	−3.4 (−7.2 to −0.1)	−2.2 (−5.5 to 0.7)	.001
POD 3	−1.4 (−4.7 to 1.5)	−1.2 (−4.7 to 1.9)	.3
POD 4	0.1 (−2.9 to 2.7)	0.1 (−2.8 to 2.7)	.8
POD 5	1.6 (−1.3 to 4.2)	1.2 (−1.7 to 3.5)	.04
Cumulative fluid balance (%)			
POD 0	2 (−2 to 7)	1 (−2 to 4)	.002
POD 1	−2 (−8 to 6)	−1 (−6 to 4)	.9
POD 2	−5 (−12 to 3)	−4 (−9 to 1)	.13
POD 3	−6 (−14 to 1)	−5 (−12 to 2)	.05
POD 4	−7 (−14 to 2)	−5 (−13 to 3)	.07
POD 5	−6 (−13 to 3)	−4 (−13 to 4)	.3
Diuretic use			
POD 0	334 (53%)	179 (45%)	.008
POD 1	587 (94%)	284 (72%)	<.001
POD 2	601 (96%)	331 (84%)	<.001
POD 3	596 (96%)	347 (88%)	<.001
POD 4	595 (96%)	351 (89%)	<.001
POD 5	585 (95%)	348 (89%)	.001
POD 6	570 (93%)	333 (86%)	<.001
Time to first negative fluid balance (d)			
1	226 (36%)	158 (41%)	.5
2	265 (42%)	146 (37%)	
3	96 (15%)	57 (15%)	
4	20 (3%)	13 (3%)	
5	3 (1%)	7 (2%)	
6	2 (0%)	1 (0%)	
Peak cumulative percent fluid overload	5 (0-11)	4 (0-9)	.2
Operating room urine output (mL/kg/h)	9 (3-23)	6 (2-13)	<.001
Urine output (mL/kg/h)			
POD 0	1.8 (1.1-3)	1.5 (1-2.4)	<.001
POD 1	3 (1.4-5.2)	1.7 (0.8-3.7)	<.001
POD 2	5.5 (3.8-7.2)	4 (1.9-5.7)	<.001
POD 3	5.6 (4.3-7)	4.6 (3-6.1)	<.001
POD 4	5.1 (3.7-6.6)	4.5 (3-5.9)	<.001
POD 5	4.5 (3.3-5.7)	4.23 (2.9-5.5)	.02
POD 6	4.2 (2.9-5.4)	4.1 (2.8-5.5)	.6

Propensity matching is 1 case to maximum 2 control match. Covariates included in the propensity score matching model: Cardsurgaged+Surgwtkg+Underweight+Gender+RaceGroup+PretermYN+ChromSyndYN+ExtraCardAnomYN+PreOpFeedYN+PreOpVISyn+PreOpVentYN+ScrBsln+PGEyn+STATcat+SingleVyn+MUFyn+CPBtm+XclampTm+DHCATm+PostOpLactVal+PostOpVIS+OpenChestYN, with exact matching on STAT category. *PC*, Peritoneal catheter; *CPB*, cardiopulmonary bypass; *VIS*, vasoactive inotrope score; *POD*, postoperative day; *PRBC*, packed red blood cells; *CICU*, cardiac intensive care unit; *AKI*, acute kidney injury.

Although this study demonstrated no difference in duration of mechanical ventilation and longer length of stay in those with PC use, the cohort without PC placement had a 50% higher incidence of moderate to severe AKI (12% vs 18%). These results remained similar whether the PC was used for drainage or prophylactic dialysis, as

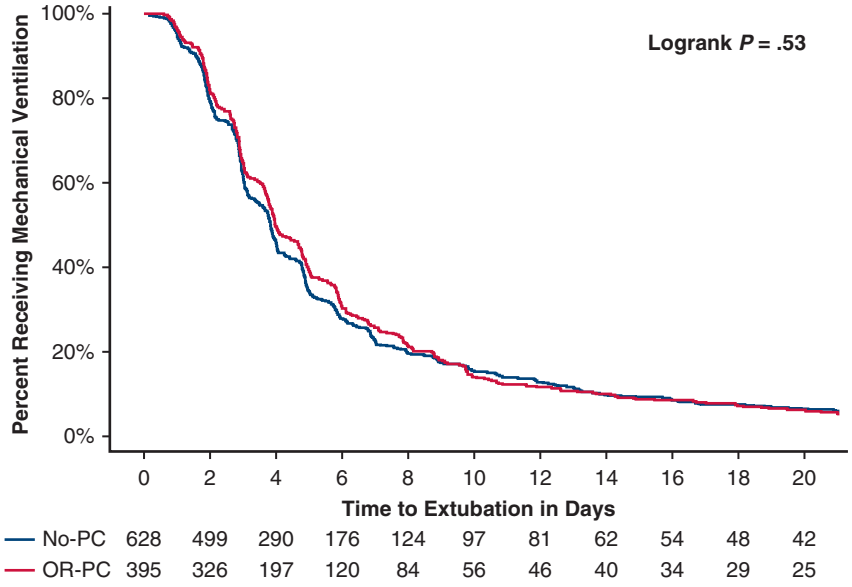

FIGURE 1. Kaplan–Meier curve analysis demonstrating time to first successful extubation attempt comparing the propensity-matched cohorts of patients with intraoperative placement and use of a PC (OR-PC), and those without intraoperative peritoneal catheter placement (No-PC). Time to extubation was not different among cohorts as assessed using log-rank testing.

well as among the subgroup analysis of the highest risk cohort. This analysis can be used to support PC use as an alternative source of postoperative fluid removal. However, limitations of the study design and dataset highlight the need for further prospective investigation. Until definitive prospective data are available, the authors of this article would strongly consider PC use in neonates at high risk of postoperative AKI including those with impaired baseline renal function or fluid overload and those undergoing Norwood palliation or other surgeries requiring prolonged CPB.

Neonates are at high risk for fluid accumulation after cardiac surgery, including the development of ascites.[15,30] Postoperative tissue and extravascular fluid accumulations may cause worsening organ function, including AKI, which may subsequently cause worse fluid balance.[2,31] The proposed benefit of early or "prophylactic" PC use is to prevent fluid accumulation, rather than waiting to treat pathologic fluid overload, because this condition is associated with morbidity and mortality. Additionally, PC may mitigate the need for intake restriction to facilitate earlier nutrition. PC use has the potential to remove deleterious inflammatory cytokines, which have been associated with kidney and other organ injuries after neonatal cardiac surgery.[11,32] Our study did not show any clear benefit of PC regarding fluid balance or time to negative fluid balance, although it is clear from uncontrolled analysis that despite significantly more risk factors and higher acuity of illness, the PC cohort did not have more fluid accumulation.

Patients with PC use had longer lengths of CICU and hospital stay, even within subanalyses. Given similar duration of mechanical ventilation, we do not believe that PC use caused delayed deintensification and that differences in duration of stay are secondary to center-specific variation in de-escalation and discharge practice given clustering of PC use at relatively few centers. Multiple single-center retrospective studies have found PC use to be associated with improved outcomes, including shorter duration of mechanical ventilation, shorter CICU duration, improved fluid balances, and lower incidence of mortality.[8-13,33-35] A meta-analysis describing many of these reports demonstrates that every included study showed a shorter duration of mechanical ventilation and CICU stay among infants undergoing peritoneal dialysis initiation in the first POD after cardiac surgery.[36] A single-center randomized trial that assigned infants with early postoperative oliguria to a standard course of furosemide or peritoneal dialysis demonstrated infants treated with prophylactic dialysis were less likely to have prolonged duration of mechanical ventilation, had shorter duration of inotropic medication use, and were less likely to experience fluid overload.[7] The use of PC and prophylactic peritoneal dialysis has also been demonstrated to not add additional hospital expenses.[8,13] That said, our study cannot conclude there is no delayed deintensification directly or indirectly caused by the presence of a PC."

These single-center studies have limitations, including those of generalizability and selection bias, which ideally would be addressed with this multicenter study. However, differing selection bias in this multicenter study prevented it from being fully controlled. Peritoneal dialysis use was clustered in 4 of the 22 centers. Center-specific variation in PC patient selection, surgical performance, sedation

TABLE 3. Propensity-matched comparison of patients undergoing passive peritoneal drain to those undergoing peritoneal dialysis

Variable	Peritoneal drain (n = 156)	Prophylactic peritoneal dialysis (n = 117)	*P* value
Gender (female)	63 (40%)	47 (40%)	1
Race			
Non-Hispanic White	77 (49%)	61 (52%)	.7
Non-Hispanic Black	21 (13%)	13 (11%)	
Hispanic	33 (21%)	29 (25%)	
Other/multiracial	25 (16%)	14 (12%)	
Age at surgery (d)	6 (4-10)	6 (5-9)	>.9
Weight at surgery, kg (mean [SD])	3.21 (0.58)	3.23 (0.47)	.4
Preterm (<37 wk)	15 (10%)	11 (9%)	1
Chromosomal syndrome	29 (19%)	22 (19%)	1
Extracardiac anomalies	31 (20%)	20 (17%)	.6
Preoperative mechanical ventilation	62 (40%)	50 (43%)	.6
Preoperative serum creatinine (mg/dL)	0.48 (0.4-0.59)	0.47 (0.4-0.6)	1
STAT category			
3	13 (8%)	8 (7%)	.9
4	96 (62%)	73 (62%)	
5	47 (30%)	36 (31%)	
Single-ventricle physiology	51 (33%)	42 (36%)	.9
Modified ultrafiltration (y/n)	77 (49%)	49 (42%)	.2
CPB time (min)	149 (108-180)	145 (117-207)	.4
Aortic crossclamp (y/n)	148 (95%)	114 (97%)	.4
Aortic crossclamp time (min)	74 (51-109)	80 (52-118)	.3
Deep hypothermic circulatory arrest (y/n)	75 (48%)	57 (49%)	1
Postoperative lactate (mmol/mL)	4.5 (3.1-6)	5 (3.2-6.1)	.3
Postoperative VIS	10 (7-14)	8 (5-12)	<.001
POD 1 VIS	10 (7-13.5)	8 (5-12.5)	.01
Delayed Sternal Closure (y/n)	66 (42%)	45 (38%)	.5
PRBC administration (y/n)	80 (51%)	48 (41%)	.1
Outcomes			
Hospital mortality	13 (8%)	2 (2%)	.01
Postoperative hospital stay (d)	20 (13-32)	22 (16-35)	.07
Postoperative CICU stay (d)	11 (7-18)	12 (8-20)	.05
Mechanical ventilation duration (h)	90 (53-188)	96 (69-144)	.5
Respiratory support duration (d)	6 (4-14)	7 (4-12)	.2
Inotrope support duration (d)	5 (4-10)	6 (4-9)	.8
Any major complication	35 (22%)	20 (17%)	.3
	2 (1.3%)	0 (0%)	.5

(Continued)

TABLE 3. Continued

Variable	Peritoneal drain (n = 156)	Prophylactic peritoneal dialysis (n = 117)	*P* value
Postoperative surgical site infection			
Postoperative necrotizing enterocolitis	4 (3%)	2 (2%)	.7
Moderate/severe acute AKI	16 (10%)	16 (14%)	.38
Severe AKI	1 (1%)	3 (3%)	1
Daily fluid balance (%)			
POD 0	0.1 (−3.5 to 4.7)	0.9 (−0.8 to 3.3)	.2
POD 1	−3.8 (−6.6 to 0.1)	−0.8 (−3.6 to 1.5)	<.001
POD 2	−1.9 (−5.2 to 0.8)	−1.8 (−4.7 to 0.9)	.5
POD 3	−1.2 (−4.1 to 2.3)	0 (−3.3 to 2.8)	.2
POD 4	1.1 (−2.6 to 3.4)	0.6 (−2.1 to 2.9)	>.9
POD 5	2.2 (−1.4 to 4.4)	1.9 (−0.5 to 3.8)	.8
Cumulative fluid balance (%)			
POD 0	0.1 (−3.5 to 4.7)	0.9 (−0.8 to 3.3)	.2
POD 1	−4 (−8 to 2)	1 (−4 to 4)	<.001
POD 2	−6 (−12 to 1)	−2 (−6 to 3)	<.001
POD 3	−7 (−15 to 2)	−2 (−7 to 4)	<.001
POD 4	−6 (−17 to 3)	−1 (−7 to 5)	.002
POD 5	−4 (−13 to 5)	−1 (−6 to 7)	.005
Diuretic use			
POD 0	72 (46%)	52 (44%)	.2
POD 1	129 (83%)	59 (50%)	<.001
POD 2	137 (88%)	86 (74%)	<.001
POD 3	138 (88%)	99 (85%)	.3
POD 4	139 (89%)	100 (85%)	.3
POD 5	136 (88%)	101 (86%)	.4
POD 6	128 (85%)	100 (86%)	.7
Time to first negative fluid balance (d)			
1			
2	75 (49%)	43 (37%)	.02
3	55 (36%)	43 (37%)	
4	11 (7%)	20 (17%)	
5	8 (5%)	3 (3%)	
6	1 (1%)	5 (4%)	
Peak cumulative percent fluid overload	3 (−1 to 10)	4 (1-9)	.2
Operating room urine output (mL/kg/h)	6 (2-14)	5 (1-10)	.03
Urine output (mL/kg/h)			
POD 0	1.7 (1.2-2.8)	1 (0.7-1.4)	<.001
POD 1	3.1 (1.4-4.8)	0.9 (0.6-1.6)	<.001
POD 2	4.8 (3.7-6.4)	2.4 (1.3-3.9)	<.001
POD 3	4.7 (3-6.3)	4.1 (2.4-5.5)	.013
POD 4	4.4 (2.7-5.9)	4 (2.8-5.2)	.3
POD 5	3.6 (2.4-5.3)	4.3 (3.2-5.1)	.13
POD 6	3.3 (2.1-4.8)	4.3 (3.2-5.5)	<.001

Propensity matching is 1 case to maximum 2 control match. Covariates included in the propensity score matching model: Cardsurgaged+Surgwtkg+Underweight+Gender+RaceGroup+PretermYN+ChromSyndYN+ExtraCardAnomYN+PreOpFeedYN+PreOpVISyn+PreOpVentYN+ScrBsln+PGEyn+STATcat+SingleVyn+MUFyn+CPBtm+XclampTm+DHCATm+PostOpLactVal+PostOpVIS+OpenChestYN STAT. *CPB*, Cardiopulmonary bypass; *VIS*, vasoactive inotrope score; *POD*, postoperative day; *PRBC*, packed red blood cells; *CICU*, cardiac intensive care unit; *AKI*, acute kidney injury.

protocols, fluid administration variation, mechanical ventilation variation, transfer/discharge practice variation, and other unmeasured CICU variables likely had important influence on measured outcomes. Given the high density of peritoneal dialysis at a small number of centers, even with propensity matching, statistical control of these variables is less effective given high collinearity of the treatment and center variables. Although peritoneal drainage was performed at a greater number of centers (16/22), there were likely unmeasurable patient selection biases that determined whether a drain was placed. A patient with an uncomplicated preoperative and intraoperative course is less likely to require a drain, and some surgeons only place a drain if there is already the collection of ascites, a potential harbinger of postoperative fluid balance problems. Although risk factors such as CPB time and STAT category were used in propensity matching, there are likely uncaptured variables that dictated why some patients received a catheter and others did not.

We have previously shown that urine output is lower in those with PC use (with dialysis lower than passive drainage), likely due to less frequent use of diuretics and the normal physiologic response of the kidneys to the alternative mode of interstitial fluid removal.[16] That said, this current controlled analysis demonstrated a 50% decrease in the incidence of moderate to severe AKI in PC patients even in the setting of a higher acuity cohort. Potential renoprotective mechanisms include improved kidney perfusion due to lower intrabdominal pressure via prevention of ascites, decreased diuretic use, decreased organ edema, and decreased inflammatory cytokines. Although peritoneal dialysis provides solute clearance and a resulting decrease in creatinine level, only 15% of the cohort used dialysis beyond POD 3 and the association with lower creatinine was seen through POD 6. Additionally, an association was seen among the cohort with drainage alone, an intervention not associated with solute clearance. It is unknown if this renal protection translates to longer-term changes in kidney function or AKI incidence in subsequent surgery. Certainly, PC as a potential strategy to prevent postoperative AKI in high-risk patients warrants further study. It was notable that the AKI benefit differed from other similar clinical outcomes in this study. It is possible that the treatment effect of PC use on renal protection was strong enough to overpower other confounders, unlike a potentially weaker treatment effect on other outcomes.

To fully understand the potential benefit of PC placement or peritoneal dialysis use in neonates undergoing cardiac surgery, a multicenter randomized trial that minimizes other perioperative variability and delineates treatment intention is necessary. It is notable that the incidence of moderate to severe AKI in this study was only 15%. Although this is not different from prior reports,[37-39] it does demonstrate that this therapy is being used in a population who largely has adequate postoperative renal function. A randomized trial may benefit from an intraoperative risk assessment and stratification of treatments, potentially using an early biomarker of renal injury such as neutrophil gelatinase-associated lipocalin.[40,41] This would allow treatment to be randomized in a population who may be more vulnerable to fluid overload and more likely to benefit from the treatment effect, if present.

Study Limitations

There were further study limitations that should be considered. This study was designed to determine the effect of intraoperative placement of peritoneal drains and did not identify catheters placed postoperatively. Common use of a catheter placed early in the postoperative period could minimize perceived treatment effect in the peritoneal drainage group. There was variability in the prescription of dialysis by centers. Although an initial dialysis regimen is relatively similar across centers, the choice of initial dialysate composition and subsequent adjustments, modification of cycle time, and volumes is likely variable and not described by the variables collected.

CONCLUSIONS

This is the first multicenter evaluation of the outcomes associated with PC placement during complex neonatal heart surgery. Although a benefit in most clinical outcomes was not demonstrated, there was potential benefit with respect to incidence of AKI. Dataset limitations and biases inherent in multicenter retrospective studies may have obfuscated other potential treatment effect. A multicenter clinical trial is necessary to determine potential benefit of PC use in this population.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: acute kidney injury, fluid overload, neonatal cardiac surgery, peritoneal catheter, peritoneal dialysis

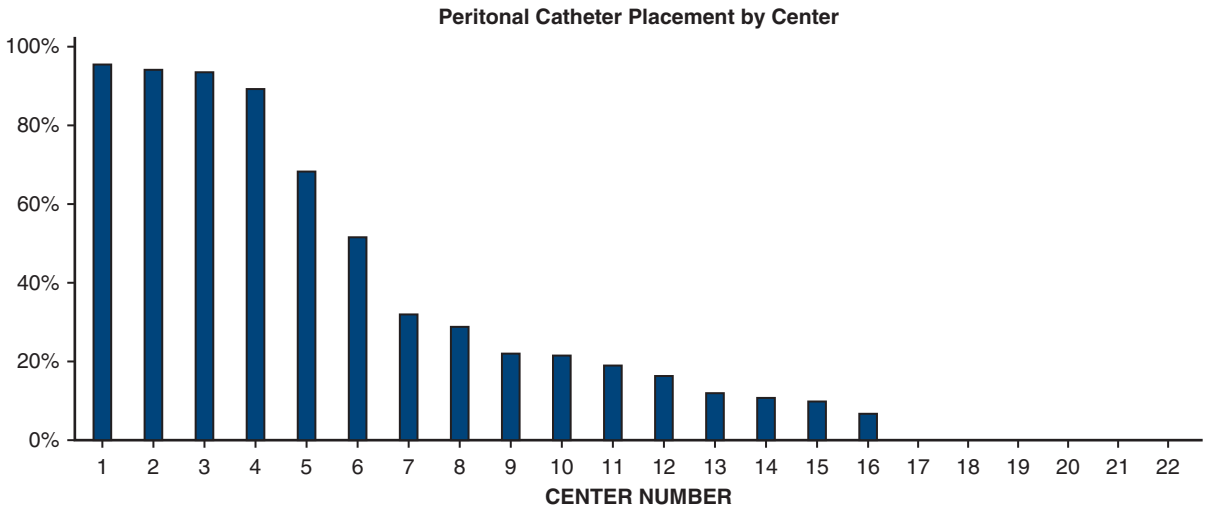

FIGURE E1. The incidence of PC placement varied by center. Six centers did not place an intraoperative catheter in any neonates, and 6 centers placed a catheter in more than half of studied neonates.

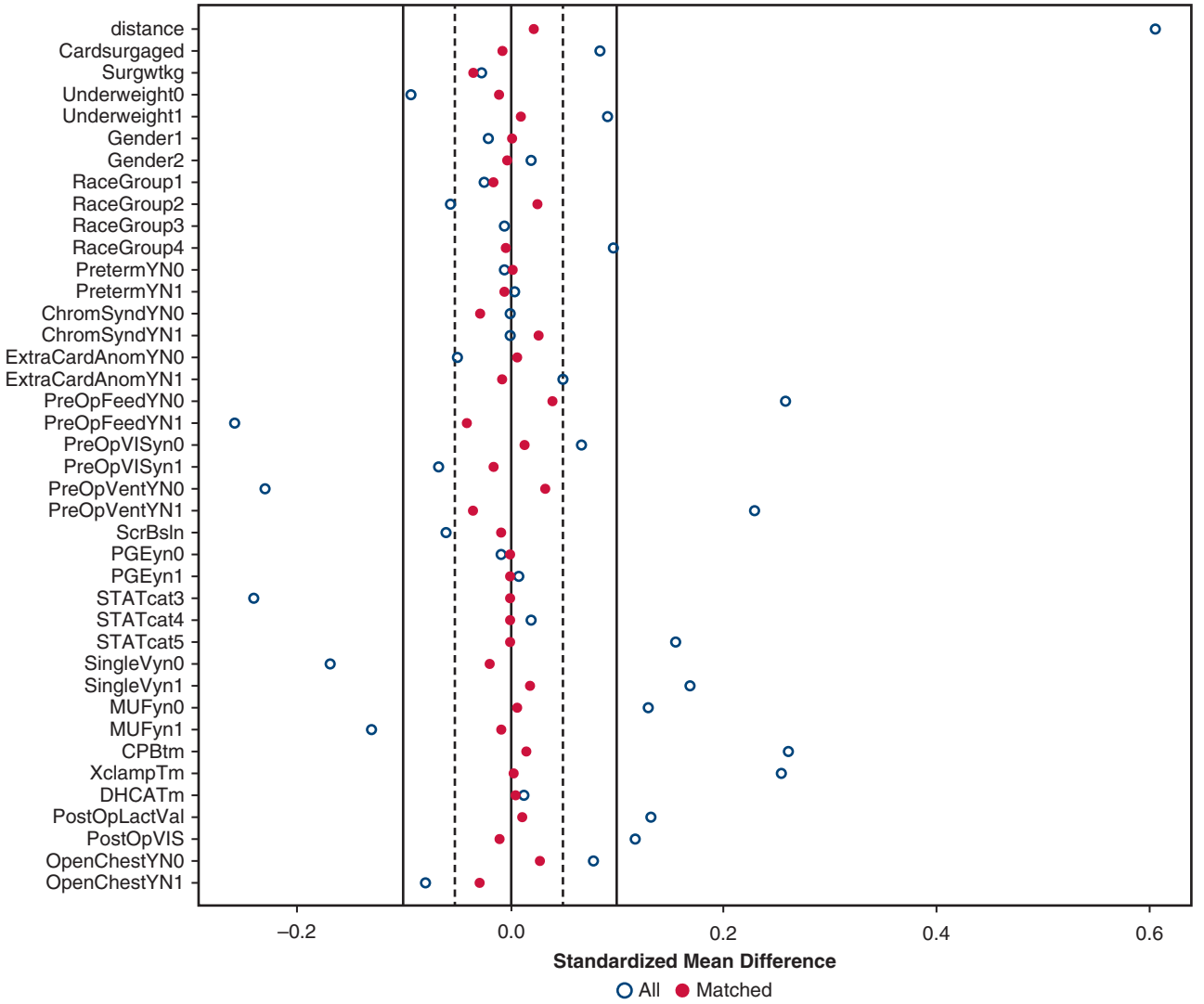

FIGURE E2. This balance plot demonstrates the postmatch balance of covariates by absolute standardized difference, with the difference less than 0.2 indicating small or negligible imbalance between groups for the propensity score match of the primary comparison (use of intraoperative placed PC vs no PC). A caliper width of 0.10 (solid line) was used to choose at most 2 controls for each case. *Dashed line* demonstrates a caliper width of 0.05. Cardsurgaged = age at surgery; Surgwtkg = weight at surgery; Underweight0/1 = underweight at time of surgery; ChromSyndYN0/1 = presence or absence of a chromosomal syndrome; ExtraCardAnomYN0/1 = presence or absence of an extracardiac anomaly; PreOpVentYN0/1 = presence or absence of preoperative mechanical ventilation; SCrBsLn = baseline serum creatinine; PGEyn0/1 = presence or absence of preoperative prostaglandin infusion; STATcat3/4/5 = Society of Thoracic Surgeons–European Association for Cardio-Thoracic Surgery (STAT) category; SingleVyn0/1 = single ventricle status (y/n); MUFyn0/1 = use of modified ultrafiltration; CPBtm = cardiopulmonary bypass time in minutes; XclampTm = crossclamp time in minutes; DHCATm = deep hypothermic circulatory arrest time in minutes; PostOpLactVal = postoperative lactate value.

TABLE E1. Propensity-matched comparison of STAT-5 patients with and without peritoneal catheter placement

Variable	No PC (n = 149)	Operative PC (n = 100)	*P* value
Gender (female)	60 (40%)	39 (39%)	.8
Race			
Non-Hispanic White	94 (63%)	64 (64%)	1
Non-Hispanic Black	23 (15%)	15 (15%)	
Hispanic	22 (15%)	14 (14%)	
Other/multiracial	10 (6.7%)	7 (7%)	
Age at surgery (d)	6 (4-7)	6 (4-7)	.7
Weight at surgery, kg (mean [SD])	3.26 [0.56]	3.25 [0.43]	.6
Preterm (<37 wk)	12 (8.1%)	7 (7%)	.8
Chromosomal syndrome	20 (13%)	11 (11%)	.6
Extracardiac anomalies	26 (17%)	15 (15%)	.6
Preoperative mechanical ventilation	40 (27%)	30 (30%)	.6
Preoperative serum creatinine (mg/dL)	0.5 (0.4-0.6)	0.49 (0.4-0.6)	.5
Single-ventricle physiology	128 (86%)	89 (89%)	.5
Modified ultrafiltration (y/n)	97 (65%)	64 (64%)	.9
CPB time (min)	152 (129-192)	153 (133-186)	.5
Aortic crossclamp (y/n)	141 (95%)	99 (99%)	.09
Aortic crossclamp time (min)	61 (48-78)	58 (48-88)	1
Deep hypothermic circulatory arrest (y/n)	107 (72%)	69 (69%)	.6
Postoperative lactate (mmol/mL)	5.5 (4.1-6.9)	5 (3.9-7)	.4
Postoperative VIS	10 (7-16)	10 (8-14)	1
POD 1 VIS	10 (7-15)	10 (8-13)	.9
Delayed sternal closure (y/n)	114 (77%)	73 (73%)	.5
PRBC administration (y/n)	62 (42%)	47 (47%)	.4
Outcomes			
Hospital mortality	9 (6%)	4 (4%)	.5
Postoperative hospital stay (d)	27 (18-46)	31 (26-54)	.02
Postoperative CICU stay (d)	15 (9-26)	20 (13-28)	.02
Mechanical ventilation duration (h)	140 (90-232)	151 (95-218)	.3
Respiratory support duration (d)	9 (6-18)	12 (7-19)	.13
Inotrope support duration (d)	8 (6-16)	10 (6-16)	.2
Any AKI	39 (26%)	27 (27%)	.9
Postoperative surgical site infection	4 (2.7%)	2 (2%)	1
Postoperative necrotizing enterocolitis	8 (5.4%)	3 (3%)	.5
Moderate/severe AKI	27 (18%)	16 (16%)	.66
Severe AKI	11 (7%)	5 (5%)	.6
Daily fluid balance (%)			
POD 0	3 (−2 to 7)	2 (−1 to 4)	.05
POD 1	−3.5 (−7.2 to 1.7)	−2.4 (−6.2 to 0.9)	.8
POD 2	−4.7 (−7.8 to −0.9)	−3.1 (−8.4 to −0.4)	.3
POD 3	−3.1 (−7.5 to −0.3)	−2.2 (−6.2 to 0.7)	.13
POD 4	−1.1 (−3.7 to 1.4)	−1.3 (−3.2 to 1.5)	.8
POD 5	0.7 (−2.3 to 3.2)	0.4 (−2 to 3.1)	1
Cumulative fluid balance (%)			
POD 0	3 (−2 to 7)	2 (−1 to 4)	.05
POD 1	−1 (−8 to 9)	−2 (−7 to 4)	.4
POD 2	−5 (−12 to 4)	−5 (−14 to 2)	.5
POD 3	−7 (−15 to 0)	−8 (−17 to 1)	1

(Continued)

TABLE E1. Continued

Variable	No PC (n = 149)	Operative PC (n = 100)	*P* value
POD 4	−8 (−17 to 0)	−11 (−19 to 0)	.7
POD 5	−8 (−15 to 0)	−9 (−18 to 1)	.8
Diuretic use			
POD 0	72 (48%)	38 (38%)	.2
POD 1	136 (92%)	64 (64%)	<.001
POD 2	144 (97%)	84 (84%)	<.001
POD 3	143 (97%)	85 (85%)	.003
POD 4	141 (95%)	88 (88%)	.09
POD 5	141 (95%)	88 (88%)	.09
POD 6	138 (93%)	87 (87%)	.2
Time to first negative fluid balance (d)			
1	46 (31%)	37 (38%)	.3
2	32 (22%)	27 (28%)	
3	22 (15%)	9 (9%)	
4	18 (12%)	5 (5%)	
5	4 (3%)	1 (1%)	
6	6 (4%)	3 (3%)	
Peak cumulative percent fluid overload	5 (0-10)	3 (0-9)	.3
Operating room urine output (mL/kg/h)	8 (3-20)	5 (1-14)	.03
Urine output (mL/kg/h)			
POD 0	1.7 (1.1-2.9)	1.3 (0.8-2)	.02
POD 1	2.4 (1.1-4.8)	1.4 (0.6-2.5)	<.001
POD 2	5.5 (3.1-7.3)	4 (1.3-6.4)	<.001
POD 3	5.9 (4.3-7.4)	4.6 (2.8-6.5)	<.001
POD 4	5.5 (4.3-6.9)	4.5 (3-6.6)	.01
POD 5	4.9 (3.3-6)	4.6 (2.9-5.7)	.2
POD 6	4.4 (3.4-5.5)	4.1 (3-5.1)	.3

STAT 5 subgroup analysis. Propensity matching is 1 case to maximum 2 control match. Covariates included in the propensity score matching model: Cardsurgaged+Surgwtkg+Underweight+Gender+RaceGroup+PretermYN+ChromSyndYN+ExtraCardAnomYN+PreOpFeedYN+PreOpVISyn+PreOpVentYN+ScrBsln+PGEyn+SingleVyn+MUFyn+CPBtm+XclampTm+DHCATm+PostOpLactVal+PostOpVIS+OpenChestYN. *PC*, Peritoneal catheter; *CPB*, cardiopulmonary bypass; *VIS*, vasoactive inotrope score; *POD*, postoperative day; *PRBC*, packed red blood cells; *CICU*, cardiac intensive care unit; *AKI*, acute kidney injury.

TABLE E2. Propensity-matched comparison of patients undergoing peritoneal dialysis to those without catheter placement

Variable	No PC (n = 227)	Prophylactic peritoneal dialysis (n = 129)	*P* value
Gender (female)	88 (39%)	49 (38%)	.9
Race			
Non-Hispanic White	122 (54%)	67 (52%)	.9
Non-Hispanic Black	37 (16%)	20 (16%)	
Hispanic	48 (21%)	27 (21%)	
Other/multiracial	20 (8.8%)	15 (12%)	
Age at surgery (d)	6 (4-10)	7 (5-10)	.8
Weight at surgery, kg (mean [SD])	3.19 (0.64)	3.21 (0.51)	.6
Preterm (<37 wk)	31 (14%)	15 (12%)	.6
Chromosomal syndrome	39 (17%)	23 (18%)	.9
Extracardiac anomalies	55 (24%)	22 (17%)	.11
Preoperative mechanical ventilation	72 (32%)	50 (39%)	.2
Preoperative serum creatinine (mg/dL)	0.50 (0.40-0.61)	0.50 (0.40-0.60)	.8
STAT category			
3	15 (6.6%)	8 (6.2%)	.9
4	150 (66%)	88 (68%)	
5	62 (27%)	33 (26%)	
Single-ventricle physiology	70 (31%)	41 (32%)	.9
Modified ultrafiltration (y/n)	105 (46%)	55 (43%)	.5
CPB time (min)	144 (100-192)	137 (111-178)	.8
Aortic crossclamp (y/n)	217 (96%)	125 (97%)	.5
Aortic crossclamp time (min)	70 (48-107)	73 (50-109)	.6
Deep hypothermic circulatory arrest (y/n)	95 (42%)	61 (47%)	.3
Postoperative lactate (mmol/mL)	4.40 (2.95-6.00)	4.80 (3.20-6.10)	.3
Postoperative VIS	10 (5-13)	8 (5-11)	.014
POD 1 VIS	9.0 (5.0-13.0)	7.5 (5.0-12.2)	.06
Delayed sternal closure (y/n)	85 (37%)	50 (39%)	.8
PRBC administration (y/n)	71 (31%)	46 (36%)	.4
Outcomes			
Hospital mortality	8 (4%)	2 (2%)	.3
Postoperative hospital stay (d)	18 (11-32)	22 (14-34)	.042
Postoperative CICU stay (d)	10 (7-18)	12 (8-20)	.09
Mechanical ventilation duration (h)	88 (51-156)	92 (66-142)	.4
Respiratory support duration (d)	6 (4-12)	7 (4-12)	.2
Inotrope support duration (d)	5 (3-8)	6 (4-9)	.5
Any major complication	40 (18%)	19 (15%)	.5
Postoperative surgical site infection	8 (3.5%)	0 (0%)	.055
Postoperative necrotizing enterocolitis	8 (3.5%)	3 (2.3%)	.8
Moderate/severe AKI	42 (18.5%)	16 (12.4%)	.18
Severe AKI	12 (5.3%)	3 (2.3%)	.27
Daily fluid balance (%)			
POD 0	3 (−2 to 7)	1 (−1 to 4)	.017
POD 1	−3.6 (−6.9 to 0.6)	−0.7 (−3.3 to 1.7)	<.001
POD 2	−2.7 (−6.3 to 0.3)	−2.2 (−4.4 to 0.9)	.070
POD 3	−1.6 (−4.8 to 2.0)	0.4 (−3.1 to 2.9)	.034
POD 4	0.0 (−3.4 to 3.1)	0.3 (−2.1 to 3.3)	.2
POD 5	1.7 (−1.0 to 4.0)	1.7 (−0.7 to 4.0)	>.9
Cumulative fluid balance (%)			

(Continued)

TABLE E2. Continued

Variable	No PC (n = 227)	Prophylactic peritoneal dialysis (n = 129)	*P* value
POD 0	3 (−2 to 7)	1 (−1 to 4)	.017
POD 1	0 (−7 to 6)	1 (−3 to 4)	.3
POD 2	−4 (−10 to 3)	−2 (−6 to 3)	.018
POD 3	−5 (−12 to 2)	−2 (−7 to 4)	.002
POD 4	−6 (−13 to 3)	−2 (−7 to 6)	<.001
POD 5	−5 (−12 to 6)	0 (−6 to 7)	.004
Diuretic use			
POD 0	118 (52%)	55 (43%)	.11
POD 1	211 (93%)	62 (48%)	<.001
POD 2	216 (96%)	93 (72%)	<.001
POD 3	218 (96%)	109 (84%)	<.001
POD 4	214 (95%)	106 (82%)	<.001
POD 5	210 (94%)	108 (84%)	.002
POD 6	196 (89%)	106 (83%)	.15
Time to first negative fluid balance (d)			.11
1	78 (35%)	45 (35%)	
2	97 (43%)	48 (37%)	
3	31 (14%)	23 (18%)	
4	12 (5.3%)	3 (2.3%)	
5	2 (0.9%)	5 (3.9%)	
6	2 (0.9%)	0 (0%)	
Peak cumulative percent fluid overload	6 (1-13)	5 (1-9)	.2
Operating room urine output (mL/kg/h)	8 (2-19)	4 (1-9)	<.001
Urine output (mL/kg/h)			
POD 0	1.86 (1.13-3.25)	1.04 (0.67-1.37)	<.001
POD 1	3.00 (1.27-5.23)	0.88 (0.58-1.54)	<.001
POD 2	5.44 (3.67-7.11)	2.39 (1.11-3.96)	<.001
POD 3	5.47 (4.12-6.78)	4.17 (2.44-5.52)	<.001
POD 4	5.08 (3.34-6.22)	4.23 (3.18-5.27)	<.001
POD 5	4.43 (3.17-5.74)	4.39 (3.39-5.23)	.5
POD 6	4.23 (3.00-5.46)	4.40 (3.05-5.47)	.7

Propensity matching is 1 case to maximum 2 control match. Covariates included in the propensity score matching model: Cardsurgaged+Surgwtkg+Underweight+Gender+RaceGroup+PretermYN+ChromSyndYN+ExtraCardAnomYN+PreOpFeedYN+PreOpVISyn+PreOpVentYN+ScrBsln+PGEyn+STATcat+SingleVyn+MUFyn+CPBtm+XclampTm+DHCATm+PostOpLactVal+PostOpVIS+OpenChestYN,Plus STAT_cat exact match. *PC*, Peritoneal catheter; *CPB*, cardiopulmonary bypass; *VIS*, vasoactive inotrope score; *POD*, postoperative day; *PRBC*, packed red blood cells; *CICU*, cardiac intensive care unit; *AKI*, acute kidney injury.

TABLE E3. Propensity-matched comparison of patients undergoing passive peritoneal drain to those without catheter placement

Variable	No PC (n = 455)	Passive peritoneal drainage (n = 260)	*P* value
Gender (female)	183 (40%)	108 (42%)	.7
Race			
Non-Hispanic White	269 (59%)	155 (60%)	.9
Non-Hispanic Black	55 (12%)	29 (11%)	
Hispanic	75 (16%)	41 (16%)	
Other/multiracial	56 (12%)	35 (13%)	
Age at surgery (d)	6.0 (4.0-10.0)	7.0 (4.0-10.0)	.5
Weight at surgery, kg (mean [SD])	3.24 (0.60)	3.23 (0.60)	.5
Preterm (<37 wk)	43 (9.5%)	24 (9.2%)	.9
Chromosomal syndrome	84 (18%)	41 (16%)	.4
Extracardiac anomalies	81 (18%)	39 (15%)	.3
Preoperative mechanical ventilation	150 (33%)	96 (37%)	.3
Preoperative serum creatinine (mg/dL)	0.49 (0.39-0.60)	0.45 (0.40-0.52)	.3
STAT category			
3	85 (19%)	45 (17%)	.9
4	245 (54%)	143 (55%)	
5	125 (27%)	72 (28%)	
Single-ventricle physiology	142 (31%)	79 (30%)	.8
Modified ultrafiltration (y/n)	289 (64%)	160 (62%)	.6
CPB time (min)	139 (97-172)	138 (104-173)	.7
Aortic crossclamp (y/n)	413 (91%)	242 (93%)	.3
Aortic crossclamp time (min)	62 (39-88)	59 (37-98)	.8
Deep hypothermic circulatory arrest (y/n)	178 (39%)	110 (42%)	.4
Postoperative lactate (mmol/mL)	4.10 (2.70-5.70)	4.00 (3.00-5.40)	.9
Postoperative VIS	9.5 (5.0-13.0)	10.0 (7.0-13.6)	.026
POD 1 VIS	9.0 (5.0-13.2)	10.0 (7.0-13.0)	.14
Delayed sternal closure (y/n)	227 (50%)	130 (50%)	.9
PRBC administration (y/n)	132 (29%)	123 (47%)	<.001
Outcomes			
Hospital mortality	17 (3.7%)	14 (5.4%)	.3
Postoperative hospital stay (d)	17 (11-33)	20 (13-33)	.062
Postoperative CICU stay (d)	9 (6-17)	11 (7-17)	.3
Mechanical ventilation duration (h)	92 (52-167)	98 (62-188)	.3
Respiratory support duration (d)	6 (4-12)	6 (4-13)	.6
Inotrope support duration (d)	5 (3-9)	6 (4-11)	.081
Any major complication	84 (18%)	51 (20%)	.7
Postoperative surgical site infection	11 (2.4%)	6 (2.3%)	.9
Postoperative necrotizing enterocolitis	10 (2.2%)	7 (2.7%)	.7
Moderate/severe AKI	91 (20%)	28 (11%)	.001
Severe AKI	30 (6.6%)	5 (1.9%)	<.001
Daily fluid balance (%)			
POD 0	2 (−2 to 7)	1 (−3 to 4)	.003
POD 1	−3.5 (−7.3 to 0.5)	−3.7 (−6.8 to 0.3)	.8
POD 2	−3.3 (−7.1 to −0.1)	−2.5 (−6.1 to 0.5)	.13
POD 3	−1.1 (−4.9 to 1.7)	−1.5 (−5.1 to 1.5)	.8
POD 4	0.3 (−3.2 to 2.9)	0.0 (−3.0 to 2.5)	.4
POD 5	1.5 (−1.3 to 4.0)	0.9 (−2.1 to 3.4)	.025

(Continued)

TABLE E3. Continued

Variable	No PC (n = 455)	Passive peritoneal drainage (n = 260)	*P* value
Cumulative fluid balance (%)			
POD 0	2 (−2 to 7)	1 (−3 to 4)	.003
POD 1	−1 (−8 to 6)	−3 (−8 to 2)	.047
POD 2	−5 (−11 to 3)	−6 (−12 to 1)	.15
POD 3	−6 (−13 to 0)	−7 (−15 to 0)	.2
POD 4	−7 (−14 to 1)	−7 (−17 to 1)	.2
POD 5	−5 (−13 to 3)	−8 (−17 to 2)	.039
Diuretic use			
POD 0	231 (51%)	115 (44%)	.016
POD 1	425 (94%)	222 (85%)	<.001
POD 2	437 (97%)	235 (90%)	.002
POD 3	430 (95%)	234 (90%)	.012
POD 4	429 (95%)	236 (91%)	.03
POD 5	422 (95%)	233 (90%)	.038
POD 6	412 (93%)	220 (87%)	.012
Time to first negative fluid balance (d)	164 (36%)	115 (45%)	.2
1	198 (44%)	96 (38%)	
2	69 (15%)	30 (12%)	
3	11 (2.4%)	9 (3.5%)	
4	2 (0.4%)	2 (0.8%)	
5	3 (0.7%)	0 (0%)	
6	5 (1.1%)	3 (1.2%)	
Peak cumulative percent fluid overload	5 (0-11)	3 (−1 to 8)	.014
Operating room urine output (mL/kg/h)	10 (3-23)	6 (2-14)	.002
Urine output (mL/kg/h)			
POD 0	1.78 (1.08-2.95)	1.79 (1.22-3.06)	.3
POD 1	2.88 (1.40-5.04)	2.74 (1.27-4.51)	.2
POD 2	5.48 (3.74-7.25)	4.77 (3.43-6.40)	<.001
POD 3	5.57 (4.18-7.01)	4.86 (3.27-6.50)	<.001
POD 4	5.06 (3.60-6.59)	4.61 (2.90-6.10)	.011
POD 5	4.49 (3.38-5.71)	4.04 (2.55-5.57)	.006
POD 6	4.15 (2.86-5.42)	3.76 (2.36-5.27)	.038

Propensity matching is 1 case to maximum 2 control match. Covariates included in the propensity score matching model: Cardsurgaged+Surgwtkg+Underweight +Gender+RaceGroup+PretermYN+ChromSyndYN+ExtraCardAnomYN+PreOpFeedYN+PreOpVISyn+PreOpVentYN+ScrBsln+PGEyn+SingleVyn+MUFyn+CPBtm + XclampTm+DHCATm+PostOpLactVal+PostOpVIS+OpenChestYN, exact match on STAT category. *PC*, Peritoneal catheter; *CPB*, cardiopulmonary bypass; *VIS*, vasoactive inotrope score; *POD*, postoperative day; *PRBC*, packed red blood cells; *CICU*, cardiac intensive care unit; *AKI*, acute kidney injury.