Türk Göğüs Kalp Damar Cerrahisi Dergisi 2017;25(1):7-15
http://dx.doi.org/doi: 10.5606/tgkdc.dergisi.2017.12354

Original Article / Özgün Makale

Peritoneal dialysis in children undergoing congenital cardiac surgery under three years of age

Doğuştan kalp ameliyatı geçiren üç yaş altı çocuklarda periton diyalizi

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ABSTRACT

Background: This study aims to investigate the incidence, risk factors, and outcomes of peritoneal dialysis in children undergoing congenital cardiac surgery under three years of age.

Methods: We included a total of 36 patients aged three years and below who underwent open heart surgery for congenital heart disease and peritoneal dialysis between December 2007 and April 2013. Demographic data, intraoperative variables, risk factors, and outcome data were retrospectively analyzed.

Results: Recovery of renal functions was reported in 18 patients (50%) after peritoneal dialysis. Mortality was 72.2% (n=26). Eight of the patients with mortality were in the recovery group, while 18 patients were in the non-recovery group. The non-survivors (n=26, 72.3%) had a longer cardiopulmonary bypass time (101±30 vs 83±52 min, p=0.042), longer cross-clamp time (80.6±33.9 vs 56±34.7 min, p=0.033), postoperative longer time to initiate peritoneal dialysis (1.4±1.0 vs 0.6±2.0 days, p=0.048), higher mean inotrope score onset of peritoneal dialysis (34±9.8 vs 22±10.6, p<0.002), and higher Risk Adjustment for Congenital Heart Surgery-1 scores (2.9±0.8 vs 2.4±0.7, p<0.044) than the survivors (n=10, 27.7%). However, in the subgroup analysis, there was no statistically significant difference between recovery (n=18, %50) and non-recovery (n=18, %50) of the renal function groups.

Conclusion: Peritoneal dialysis is a major complication associated with longer length of hospital stay and higher in-hospital mortality. Appropriate management of peritoneal dialysis, which is ideal for neonates, infants, and young children following congenital cardiac surgery may improve the prognosis.

Keywords: Acute renal insufficiency; congenital heart surgery; pediatric patient; peritoneal dialysis.

ÖZ

Amaç: Bu çalışmada doğuştan kalp ameliyatı geçiren üç yaş altındaki çocuklarda periton diyalizinin sıklığı, risk faktörleri ve sonuçları araştırıldı.

Çalışma planı: Aralık 2007 - Nisan 2013 tarihleri arasında doğuştan kalp hastalığı nedeniyle açık kalp cerrahisi geçiren ve periton diyalizine giren üç yaş ve altında toplam 36 hasta çalışmaya alındı. Demografik veriler, ameliyat sırası değişkenler, risk faktörleri ve sonuçlar retrospektif olarak incelendi.

Bulgular: Periton diyalizi sonrası renal fonsiyonlarda düzelme 18 hastada (%50) bildirildi. Mortalite oranı %72.2 idi (n=26). Mortalite görülen hastaların sekizi renal fonksiyonları düzelen grupta iken, 18'i renal fonksiyonları düzelmeyen grupta idi. Sağ kalamayanlara kıyasla (n=10, 27.7%), sağ kalanlarda (n=26, %72.2) daha uzun kardiyopulmoner bypass süresi (83±52 dk.'ye kıyasla 101±30 dk., p=0.042), daha uzun kros klemp süresi (56±34.7 dk.'ye kıyasla 80.6±33.9 dk., p=0.033), daha uzun ameliyat sonrası periton diyalizine başlama zamanı (0.6±2.0 güne kıyasla 1.4±1.0 gün, p=0.048), periton diyalizi başlangıcında daha yüksek inotrop skoru (22±10.6'ya kıyasla 34±9.8, p<0.002) ve daha yüksek Doğuştan Kalp Cerrahisinde Risk Ayarlaması-1 skoru kaydedildi. Ancak, alt grup analizinde, renal fonksiyonlarda düzelme olan (n=18, %50) ve olmayan (n=18, %50) gruplar arasında istatiksel olarak anlamlı bir fark yoktu.

Sonuç: Periton diyalizi hastanede daha uzun yatış süresi ve yüksek hastane mortalitesi ile ilişkili önemli bir komplikasyondur. Doğuştan kalp cerrahisi sonrası yenidoğan, bebek ve küçük çocuklarda ideal olan periton diyalizinin uygun yönetimi prognozu düzeltebilir.

Anahtar sözcükler: Akut böbrek yetmezliği; doğuştan kalp cerrahisi; pediyatrik hasta; periton diyalizi.

Available online at
www.tgkdc.dergisi.org
doi: 10.5606/tgkdc.dergisi.2017.12354
QR (Quick Response) Code

Received: September 04, 2015 *Accepted:* June 07, 2016

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Acute renal failure (ARF) affects over 10% of children who undergo cardiopulmonary bypass (CPB).[1-3] Despite progress in cardiac surgery and intensive care techniques, the mortality rate still remains high (ranging from 20 to 79%) in this group of patients.[2,4]

Peritoneal dialysis (PD) is the most widely available form of renal replacement therapy used in neonates, infants, and children.[5,6] The possible advantages and potential limitations of PD should be considered in the management of patients with ARF.

In this study, we aimed to investigate the incidence, risk factors, and outcomes of PD in children and to evaluate the effect of PD on morbidity and mortality rates undergoing congenital cardiac surgery under three years of age.

PATIENTS AND METHODS

The hospital records of a total of 36 patients who underwent open heart surgery for congenital heart disease and PD between December 2007 and April 2013 were retrospectively analyzed.

Exclusion criteria were as follows: PD for less than one day (n=1), previous renal insufficiency (loss of kidney function, n=2), or incomplete data (n=2). Three patients who died within 72 hours after congenital cardiac surgery were also excluded from the study.

Demographic data of the patients, cardiac diagnoses, perioperative data, and outcomes were collected. Physiological variables including blood urea nitrogen (BUN) and serum creatinine before the initiation of PD and after the end of PD, preoperative mechanical ventilatory support, presence of syndrome disorders, indications and complications of dialysis, timing of PD catheter insertion, time from surgery to PD, and duration of PD were also recorded. Surgical complexity was assessed by the Risk Adjustment for Congenital Heart Surgery (RACHS-1) risk categories (range, 1 to 6).[7] Renal function prior to PD catheter placement was assessed according to the Pediatric-Modified Risk of renal failure, Injury to the kidney, Failure of kidney function, Loss of kidney function, and End-stage renal failure (pRIFLE) criteria.[8] The patients with a RIFLE score were included; however, patients whose PD catheters were placed preoperatively due to the loss of kindey function and end-stage kidney disease were excluded. The inotropic score (IS)[9] and vasoactive-inotropic score (VIS)[10] were also calculated.

IS=Dopamine (μg/kg/min) + dobutamine (μg/kg/min) + 100 × epinephrine (μg/kg/min), VIS= IS + 10 x milrinone dose (μg/kg/min) + 10,000 x vasopressin dose (U/kg/min) + 100 x norepinephrine dose (μg/kg/min). In addition, the mean arterial blood pressure (MAP), central venous blood pressure (CVP), perioperative urine output, fluid balance before initiation of PD, diuresis after PD, intensive care unit (ICU), and length of hospital stay (LOS) were obtained from the medical records.

A peritoneal catheter was inserted percutaneously through a paraumbilical left-sided approach in the intensive care unit at the bedside using general anesthesia. The semi-rigid catheter inserted using a trocar was the most commonly used catheter. We used a closed irrigation/drainage system in all patients. Dialysis solution was a potassium-free bicarbonate solution containing variable glucose concentrations. The dextrose concentration varied from 1.5 to 4.5% and the choice of dextrose concentration depended on the presence of serum hyperglycemia. Dialysis was initiated with a 1.5 g/dL solution. Then, PD was started with a dwell volume of 10 mL/kg, a dextrose concentration of 1.5%, a fill time of 10 minutes, a dwell time of 30 minutes, and a drainage time of 20 minutes. The dwell time varied from 1 to 2 hours. The cycle length and dialysis solution were adapted to the clinical and biochemical status of the patient. Trained nurses changed the dialysate bags every 24 hours.

The recovery of the urine output was defined as a urine output >1 mL/kg/hour, and the recovery of serum creatinine was defined as a decline in serum creatinine to preoperative levels. Indications for terminating PD included the return of sufficient of urine output to maintain or achieve negative fluid balance and normalization of serum electrolytes and acid-base status.

The study protocol was approved by the local Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Statistical analysis

Statistical analysis was performed using IBM SPSS version 22.0 for Windows software (IBM Corporation, Armonk, NY, USA). Data were expressed in the mean ± standard deviation or median (range). Univariate analysis was performed to compare the demographic data. The distribution of variables was analyzed by the Kolmogorov-Smirnov test. The chi-square and Fisher's exact tests were used to compare categorical variables between the groups. Continuous variables between groups were assessed using the Mann-Whitney U-test. Non-conditional logistic regression was used to explore the associated risk factors of recovery of renal function

and survey. A *p* value less than 0.05 was considered statistically significant.

RESULTS

The type of congenital heart defect and operation are shown in Table 1. The median age of the patients at surgery was 10.1 months (range, 0.1 to 36 months) with a median body weight of 6.7 kg (range, 3 to 12.5 kg). Recovery of renal function was reported in 18 patients (50%). The median RACHS-1 score was 3. There was no significant difference in the RIFLE categories between survivors/non-survivors and recovery/non-recovery groups (p=0.317 and p=0.371, respectively). The pRIFLE categories are shown in Table 2. These findings showed that the pRIFLE-based renal function was not related to postoperative complications.

Mortality was 72.2% (n=26). Among the total of 26 patients, eight patients (44.4%) were in recovery of renal function group and 18 patients were in (100%) non-recovery of renal function group. In-hospital mortality is presented in Table 2. The causes of death were pump failure in 13 (congestive heart failure or extensive myocardial injury), sepsis in five (pneumonia in four and PD-associated peritonitis in one), arrhythmia in two, pulmonary hypertension crisis in two, sudden cardiac arrest without obvious cause in two, pulmonary hemorrhage in one, and cerebral hemorrhage in one.

Table 3 and 4 shows the number of patients for each indication and complications for PD. Primary peritonitis developed in only one patient (2.7%). This patient died of uncontrolled sepsis and multi-organ failure. Replacement related to peritoneal catheter dysfunction was required in two patients (5.5%). Minor complications related to the PD such as hyperglycemia, electrolyte imbalance, catheter site leakage or difficult drainage were noted.

The data of 36 patients, 18 in the recovery group, and 18 in the non-recovery group, and 10 in the survivor group and 26 in the non-survivor group were analyzed. The clinical and laboratory comparisons between the groups (recovery/non-recovery and survivors/non-survivors) are shown in Table 2. The non-survivors (n=26, 72.3%) and non-recovery of renal function group (n=18, 50%) had a longer CPB time (101±30 vs 83±52 min, p=0.042; 106±31 vs 86±41 min, p=0.037), longer cross-clamp time (80.6±33.9 vs 56±34.7 min, p=0.033; 83.6±31 vs 61.4±43.3 min, p=0.038), postoperative longer time to initiate PD (14.3±12.1 vs 24.±9.3 hours, p=0.039; 12.2±7.5 vs 20.4±11.0 hours, p=0.044), higher mean inotrope score onset of PD (34±9.8 vs 22±10.6, p<0.002; 36.1±6.3 vs 25.3±12.7, p<0.003) and higher RACHS-1 score (2.9±0.8 vs 2.4±0.7, p<0.044; 3.1±0.8 vs 2.6±0.6, p<0.027) than the survivors (n=10, 27.7%) and recovery of renal function group (n=18, 50%).

Furthermore, the survivors had a higher mean MAP (50.5±5.1 vs 60±7.6 mmHg, p=0.036), lower mean CVP (14.6±2.2 vs 11±2 mmHg, p=0.045), higher perioperative urine output (6.8±4.5 vs 4.0±2.7 mL/kg/h, p=0.022), and higher diuresis after PD (1.6±0.2 vs 0.4±0.6 mL/kg/h, p<0.001) than non-survivors. Additionally, lower pre-PD BUN and serum creatinine values, lower time interval between surgery and PD and lower fluid balance before PD were associated with survival.

According to logistic regression analysis, the following factors were found to be independently associated with survey: perioperative urine output [odds ratio (OR)=0.818; 95% confidence interval (CI)=0.653-1.024; p=0.048], time interval between surgery and PD [OR=0.991; 95% CI=0.964-1.019; p=0.044], mean MAP before PD [OR=0.836; 95% CI=0.724-0.965; p=0.015], mean CVP before PD [OR=1.418; 95% CI=0.977-2.058; p=0.033], mean

Table 1. Congenital heart defects and operations in patients requiring peritoneal dialysis

Diagnosis category	No	Operation	RACHS-1
Ventricular septal defect + atrial septal defect	3	Repair	2
Ventricular septal defect + pulmonary banding	2	Repair	2
Transposition of great arteries	6/1	Arterial switch/Senning	4
Complete atrioventricular septal defect	8	Repair	3
Truncus arteriosus	3	Repair	4
Total anomalous pulmonary venous return	4	Repair	4
Tetralogy of Fallot	4	Repair	2
Aortic incompetence	1	Konno procedure	4
Double-outlet right ventricle	3	Repair	3
ALCAPA	1	Repair	3

RACHS: Risk adjustment in congenital heart surgery severity score; ALCAPA: Anomalous left coronary artery from the pulmonary artery.

Table 2. Comparison in clinical variables of patients requiring peritoneal dialysis

	Renal function												
	Recovery (n=18)			Non-recovery (n=18)				Survivors (n=10)			Non-survivors (n=26)			
	n	%	Mean±SD	n	%	Mean±SD	*p*	n	%	Mean±SD	n	%	Mean±SD	*p*
Age at surgery (months)			9.5±8.3			10.1±9.9	0.895			7.9±5.8			10.4±9.3	0.785
Gender														0.244
Female	10	56		10	56		1.000	4	40		16	62		
Male	8	44		8	44			6	60		10	38		
Weight at surgery (kg)			6.6±2.5			6.8±3.4	0.773			6.8±2.3			6.6±3.2	0.865
Body surface area (m^2)			0.3±0.1			0.4±0.1	0.645			0.4±0.1			0.3±0.1	0.740
Syndrome disorder	3	17		4	22		0.674	2	20		5	19		1.000
Preoperative mechanical ventilatory support	1	6		2	11		1.000	1	10		2	8		1.000
Preoperative SCr (mg/dL)			0.36±0.1			0.37±0.1	0.941			0.35±0.1			0.38±0.1	0.628
Preoperative BUN (mg/dL)			31.3±8.4			30.1±12.5	0.733			29.7±9.6			31.1±11	0.723
CPB time (min)			86±41			106±31	0.037			83±52			101±30	0.042
Cross-clamp time (min)			61.4±43.3			83.6±31	0.038			56±34.7			80.6±33.9	0.033
K+(mmol/L) after CPB			3.9±0.7			4.4±0.8	0.081			4±0.8			4.2±0.8	0.359
Perioperative urine output (mL/kg/h)			5.5±3.8			3.4±2.9	0.183			6.8±4.5			4±2.7	0.022
Before PD BUN (mg/dL)			88±33			108±35	0.008			80±23			106±34	0.006
Before PD SCr (mg/dL)			0.7±0.4			1.4±0.3	<0.001			0.6±0.3			1.2±0.4	<0.001
RIFLE														0.317
R	-	-					0.371	-	-					
I	4	22		2	11			3	30		3	12		
F	14	78		16	89			7	70		23	88		
L	-	-		-	-									
E	-	-		-	-									
Fluid balance before PD (mL/kg/h)			+2.6±3.8			+2.9±2.4	0.789			+1.5±0.9			+2.8±3.5	0.063
Time interval between surgery and PD (h)			14.3±12.1			24.1±9.3	0.039			12.2±7.5			20.4±11	0.044
Duration of PD (day)			4.1±1.1			-	-			4.3±1.3			3.9±0.9	0.573
Duration of mechanical ventilation (days)			6.8±4.1			7.3±3.2	0.308			4.4±4.2			6.7±4	0.222
Mean MAP before PD (mmHg)			51.5±4.7			47±6.3	0.161			60±7.6			50.5±5.1	0.036
Mean CVP before PD (mmHg)			12.9±2.4			15.4±2	0.207			11±2			14.6±2.2	0.045
Mean inotropic score onset of PD			25.3±12.7			36.1±6.3	0.003			22±10.6			34±9.8	0.002
Mean VIS onset of PD			28.6±8.3			42.2±7.7	<0.001			24.3±8.1			43.1±5.9	<0.001
After PD BUN (mg/dL)			45.3±13.5			-	-			38.3±4.8			54.1±15.9	0.012
After PD SCr (mg/dL)			0.5±0.2			-	-			0.5±0.2			0.6±0.1	0.315
Diuresis after PD (mL/kg/h)			1.4±0.3			-	-			1.6±0.2			0.4±0.6	<0.001
ICU LOS (days)			11.2±5.3			7.3±3.2	0.014			10.8±6.2			8.2±4	0.037
Hospital LOS (days)			14.2±6			7.3±3.2	<0.001			15.9±6.9			8.8±4	<0.001
Hospital mortality	8	44,4		18	100		<0.001		-	-	26	72,2		-

SD: Standard deviation; SCr: Serum creatinine; BUN: Blood urea nitrogen; RIFLE: Risk of renal failure, Injury to the kidney, Failure of kidney function, Loss of kidney function, and End-stage renal failure; CPB: Cardiopulmonary bypass; PD: Peritoneal dialysis; MAP: Mean arterial blood pressure; CVP: Central venous pressure; VIS: Vasoactive inotropic score; ICU: Intensive care unit; LOS: Length of stay.

Table 3. Indications for peritoneal dialysis

	Renal function Recovery (n=18)		Renal function Non-recovery (n=18)
	Survivors (n=10)	Non-survivors (n=8)	Non-survivors (n=18)
Oliguria	5	1	3
Anuria	4	6	11
Hyperpotassemia	1	3	6
Metabolic acidosis	6	3	8

Table 4. Complications for peritoneal dialysis

	Renal function Recovery (n=18)		Renal function Non-recovery (n=18)
	Survivors (n=10)	Non-survivors (n=8)	Non-survivors (n=18)
Hyperglycemia	1	2	1
Electrolyte imbalance	1	1	1
Difficult drainage	0	2	0
Catheter site leakage	0	1	2
Peritonitis	0	0	1
Peritoneal catheter dysfunction	1	0	1

inotropic score onset of PD [OR=1.125; 95% CI=1.028-1.230; p=0.010], mean VIS onset of PD [OR=1.582; 95% CI=1.389-1.689; p=0.014], hospital LOS [OR=0.755; 95% CI=0.610-0.935; p=0.010]. No significant difference in the remaining variables was seen (Table 5).

In addition, as shown in Table 6, time interval between surgery and PD, mean MAP before PD, mean inotropic score onset of PD, mean VIS onset of PD, ICU LOS and hospital LOS contributed as the independent risk factors for recovery of renal function ($p<0.05$).

DISCUSSION

Acute renal failure is common in pediatrics undergoing complex congenital cardiac surgery. However, the use of renal replacement therapy (RRT) in this patients may vary among adults due to associated conditions causing ARF, variable patient weights,[11] and non-renal indications for RRT such as the postoperative period of patients with congenital heart defects.[12] Peritoneal dialysis is the first-line RRT modality which is relatively easy to employ, effective, and has a low complication rate to be used for ARF in these patients.[1,4,13,14]

Several studies have attempted to identify the risk factors of ARF requiring RRT in pediatric patients undergoing congenital cardiac surgery.[2,7,14] In consistent with previous studies,[15-17] patients who showed recovery of renal function following PD with associated lower CPB and CC times, RACHS-1 category and inotrope scores, BUN and SCr values before PD and a lower time interval between surgery and PD had lower mortality. Additionally, in the present study, higher MAP and CVP scores before PD, late beginning of PD, lower perioperative urine output, and lower diuresis after PD were significant risk factors for increased mortality. A higher RACHS-1 category was significantly associated with the development of ARF and higher mortality rates.[18] We also confirmed that the RACHS-1 score and complexity of surgery associated with it was a significant risk factor. We also demonstrated that increasing mortality and failure of PD was associated with lower MAP and higher CVP before PD. Analysis of these risk factors can reduce mortality and morbidity. Furthermore, with appropriate assessment of these factors will lead to a better outcome of PD in postoperative period. This may be due to lower time interval between surgery and PD in the recovery and survivor groups, whereas most other groups started PD later.[2,4] In the current

study, the renal function normalized after PD in all surviving patients, and this rate was in consistent with the previous studies.[1,19]

In addition, the incidence of postoperative ARF can be as high as 42% with an incidence of 1 to 17% for dialysis and a mortality rate of 20 to 100%.[12,15,16,19,20] The incidence of ARF, which required PD and mortality rate following congenital cardiac surgery in our study population, were 7.9% and 72.2%, respectively. The development of ARF is often related to the results of CPB with the associated complexity of the operation (RACHS-1 category) in pediatric patients.[15] Patients with non-recovery of renal functions after PD still have a higher mortality than patients with recovery of renal function. The mortality rate was 44.4% (n=8) in 18 patients with recovery of renal function and 100% in 18 patients without recovery of renal function. Our study also demonstrated an association between more complex surgical procedures as defined by higher RACHS-1 scores and higher mortality rates in patients with postoperative PD who underwent congenital heart surgery. These patients had significantly higher RACHS-1 scores, longer CPB time, cross-clamp time, and ICU and hospital LOS. In the light of these findings, we can conclude that ARF constitutes an important predictor of mortality and morbidity. Despite improved renal functions, a significant number of these patients with of ARF supported by RRT still dies.

In the present study, the main factor of mortality in the patients with recovery of renal function was the presence of sepsis. The mortality-related factors may be directly linked to sepsis associated with ICU problems, such as ventilator-associated pneumonia.[21] Mortality was found to be significantly increased in

Table 5. Single-factor logistic regression analyses of the risk factors for survey

					95% CI	
	Regression coefficient	Wald χ^2 value	*p*	OR value	Lower limit	Higher limit
Gender	-0.875	1.323	0.250	0.417	0.094	1.852
Age at surgery (months)	0.037	0.679	0.410	1.037	0.951	1.132
Weight at surgery (kg)	-0.054	0.165	0.684	0.947	0.730	1.230
Body surface area (m^2)	-1.126	0.118	0.732	0.324	0.001	202.536
Syndrome disorder	-0.049	0.003	0.958	0.952	0.153	5.942
Preoperative mechanical ventilatory support	-0.288	0.050	0.823	0.750	0.060	9.319
Preoperative SCr (mg/dL)	2.146	0.250	0.617	8.549	0.002	38496.726
Preoperative BUN (mg/dL)	0.013	0.134	0.714	1.013	0.944	1.088
Cardiopulmonary bypass time (min)	0.015	1.429	0.232	1.015	0.991	1.039
Cross-clamp time (min)	0.008	0.412	0.521	1.008	0.984	1.032
K+(mmol/L) after cardiopulmonary bypass	0.473	0.875	0.349	1.605	0.596	4.326
Perioperative urine output (mL/kg/h)	-0.201	3.076	0.048	0.818	0.653	1.024
Before PD BUN (mg/dL)	0.039	3.715	0.058	1.040	0.999	1.082
Before PD SCr (mg/dL)	1.205	0.518	0.472	3.336	0.125	88.766
RIFLE	1.190	1.659	0.198	3.286	0.538	20.081
Fluid balance before PD (mL/kg/h)	0.508	2.224	0.136	1.662	0.852	3.242
Time interval between surgery and PD (h)	-0.009	0.404	0.044	0.991	0.964	1.019
Duration of PD (day)	-0.387	0.667	0.414	0.679	0.268	1.719
Duration of mechanical ventilation (days)	0.129	1.500	0.221	1.137	0.926	1.397
Mean MAP before PD (mmHg)	-0.179	5.959	0.015	0.836	0.724	0.965
Mean CVP before PD (mmHg)	0.349	3.375	0.033	1.418	0.977	2.058
Mean inotropic score onset of PD	0.117	6.630	0.010	1.125	1.028	1.230
After PD BUN (mg/dL)	0.186	3.412	0.065	1.204	0.989	1.467
After PD SCr (mg/dL)	3.446	0.727	0.394	31.389	0.011	86596.775
Diuresis after PD (mL/kg/h)	-29.031	2.244	0.134	0.000	0.000	7752.522
ICU LOS (days)	-0.093	1.371	0.242	0.911	0.780	1.065
Hospital LOS (days)	-0.280	6.662	0.010	0.755	0.610	0.935

CI: Confidence intervals; χ^2: Chi-square; SCr: Serum creatinine; BUN: Blood urea nitrogen; RIFLE: Risk of renal failure, Injury to the kidney, Failure of kidney function, Loss of kidney function, and End-stage renal failure; PD: Peritoneal dialysis; MAP: Mean arterial blood pressure; CVP: Central venous pressure; ICU: Intensive care unit; LOS: Length of stay.

patients with sepsis associated with prolonged ICU stay in the present study. The mortality rate associated with sepsis was 50% (n=4) in eight patients with recovery of renal function and 5.5% (n=1) in 18 patients without recovery of renal function.

As the rate of PD peritonitis decreases, non-infectious complications of PD are proportionately increasing.[22] What is emerging, as an important cause of technical failure, is mechanical catheter complications. To reduce the risk of hyperglycemia, hyperinsulinemia and hyperleptinemia, the metabolic complications of PD and glucose-sparing strategies have also started to increasingly draw attention.[23] However, it should be kept in mind that complications which are associated with morbidity and technical failure can be prevented, recognized beforehand, and appropriately managed.[22,23]

Optimal timing and the criteria indicating PD are still controversial issues on debate. In some centers, peritoneal catheters are prophylactically placed in infants who are at a high risk of ARF and CPB following surgery, whereas these catheters are used by other centers, including ours, to serve as a continuous drain of the abdominal cavity, for the dialysis of persistent low urinary output, to correct electrolytes and metabolic status, or to remove fluid.[1] In a study conducted by Dittrich et al.,[24] in which the prophylactic and early use of PD was applied in the presence of risk factors for ARF, improved control of fluid balance and a more favorable patient outcomes with a mortality rate of 27% were reported.

The usual indications for the initiation of RRT in patients with acute kidney injury (AKI) include oliguria/anuria leading to refractory fluid overload, metabolic abnormalities such as hyperkalemia (K+>6.5 mEq/L) and severe metabolic acidosis (pH<7.1).[25] We introduced PD, if the patient had risk factors for ARF, based on the RIFLE criteria. Tables 1 and 2 show the indications for PD and RIFLE

Table 6. Single-factor logistic regression analyses of risk factors for recovery of renal function

	Regression coefficient	Wald χ^2 value	*p*	OR value	95% CI	
					Lower limit	Higher limit
Gender	0.000	0.000	1.000	1.000	0.269	3.724
Age at surgery (months)	0.014	0.176	0.675	1.014	0.949	1.085
Weight at surgery (kg)	-0.005	0.002	0.966	0.995	0.785	1.261
Body surface area (m^2)	1.425	0.226	0.635	4.157	0.012	1483.381
Syndrome disorder	0.357	0.176	0.675	1.429	0.270	7.549
Preoperative mechanical ventilatory support	0.754	0.350	0.554	2.125	0.175	25.775
Preoperative SCr (mg/dL)	0.291	0.006	0.939	1.338	0.001	2364.961
Preoperative BUN (mg/dL)	-0.011	0.125	0.724	0.989	0.928	1.053
Cardiopulmonary bypass time (min)	0.017	2.518	0.113	1.017	0.996	1.038
Cross-clamp time (min)	0.012	1.183	0.277	1.012	0.991	1.033
K+(mmol/L) after cardiopulmonary bypass	0.820	2.948	0.086	2.270	0.890	5.789
Perioperative urine output (mL/kg/h)	-0.145	1.738	0.187	0.865	0.698	1.073
Before PD BUN (mg/dL)	0.005	0.210	0.647	1.005	0.985	1.025
Before PD SCr (mg/dL)	0.687	0.217	0.641	1.988	0.111	35.681
RIFLE	0.827	0.773	0.379	2.286	0.362	14.431
Fluid balance before PD (mL/kg/h)	0.030	0.076	0.783	1.031	0.830	1.280
Time interval between surgery and PD (h)	-0.010	0.572	0.047	0.990	0.965	1.016
Duration of PD (day)	-0.105	1.461	0.227	0.900	0.759	1.068
Mean MAP before PD (mmHg)	-0.093	2.615	0.038	0.911	0.814	1.020
Mean CVP before PD (mmHg)	0.106	0.465	0.495	1.111	0.820	1.506
Mean inotropic score onset of PD	0.108	6.933	0.008	1.114	1.028	1.207
Mean VIS onset of PD	0.205	8.743	0.012	1.457	1.341	1.488
ICU LOS (days)	-0.238	5.243	0.022	0.788	0.643	0.966
Hospital LOS (days)	-0.428	8.715	0.003	0.652	0.491	0.866
Hospital mortality	22.014	0.000	0.999	36348.603	0.000	-

CI: Confidence intervals; χ^2: Chi-square; SCr: Serum creatinine; BUN: Blood urea nitrogen; RIFLE: Risk of renal failure, Injury to the kidney, Failure of kidney function, Loss of kidney function, and End-stage renal failure; PD: Peritoneal dialysis; MAP: Mean arterial blood pressure; CVP: Central venous pressure; ICU: Intensive care unit; LOS: Length of stay.

categories. However, the adverse effects of fluid overload on the outcome of children with AKI were observed.[26] Fluid overload is also associated with a reduced likelihood of recovery of renal functions.[27] In the survivor group, fluid balance and mean CVP before PD was lower than in the non-survivors. Although there are large-scale retrospective reports on the timing of PD initiation, no criteria have been established from randomized-controlled trials, but rather based on historically held beliefs and practices of medical personnel worldwide.[28] In the present study, the time of beginning PD in the survivors and recovery of the renal function group was significantly earlier than non-survivors and non-recovery of the renal function group.

This modality does not require anticoagulation and is ideal for neonates, children with inadequate vascular access, and those who can tolerate slower fluid removal and electrolyte correction. The benefits of PD include ease and quickness of the catheter insertion, cost-efficacy compared to other modalities, and overall tolerance for the hemodynamic stability.[5] However, the increased risk of complications such as gastrointestinal perforation, peritonitis, catheter malfunction, and poor dialysate flow are the main limitations.[6] In pediatric patients, the rate of peritonitis is approximately one episode of peritonitis per catheter-year.[29] In the present study, primary peritonitis developed in only one patient (2.7%), and the complication rate is consistent with the previous studies.[1,24]

Nonetheless, our study has some limitations. The primary limitation was its small sample size and retrospective design. In addition, the RACHS score and indication of PD were unable to be standardized. Despite these drawbacks, we still believe that our findings were relevant.

In conclusion, despite the fact that peritoneal dialysis is an important renal replacement therapy modality for acute renal failure following cardiac surgery in young children, these patients are high-risk population with an in-hospital mortality of 72.2%. For such high-risk patients with possible detrimental effects of acute renal failure, peritoneal dialysis is effective and useful to achieve postoperative negative fluid balance and produce hemodynamic stability. In patients requiring peritoneal dialysis, preoperative, intraoperative, and postoperative cardiopulmonary status have a significant bearing on the total duration of peritoneal dialysis, mortality, and morbidity. Our study results showed that cardiopulmonary bypass and cross-clamp time, low cardiac output syndrome, time interval between surgery and peritoneal dialysis, fluid balance before peritoneal dialysis and peritoneal dialysis-related complications were the determinant factors for the prognosis of peritoneal dialysis in pediatric patients aged three years and below with acute renal failure undergoing congenital heart surgery. Furthermore, we found that higher inotrope scores, lower mean arterial blood pressure, and higher central venous blood pressure were associated with an increased morbidity and mortality. Although peritoneal dialysis is considered an optimal therapy for the management of acute renal failure, recovery of the renal functions alone may not be sufficient in these patients for survival. In addition, as the management of peritoneal dialysis in pediatric congenital cardiac surgery is complex, there are various demographics, intraoperative, and postoperative factors which contribute to clinical outcomes. Despite some of these factors are inclusive to the complex congenital cardiac surgery, early peritoneal dialysis administration is the most important part of the process to achieve positive outcomes in the early postoperative period. Therefore, this study further supports the need for additional prospective, randomized-controlled trials, including preventive approaches for the development of acute renal failure on cardiac surgical populations, specifically children under the age of three years.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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