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Factors affecting the clinical outcomes in pediatric post-cardiotomy patients requiring perioperative peritoneal dialysis

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SUMMARY

OBJECTIVE: Fluid overload is associated with increased mortality and morbidity in pediatric cardiac surgery. In the pediatric age group, peritoneal dialysis might improve postoperative outcome with avoiding fluid overload and electrolyte imbalance. It preserves hemodynamic status with the advantage of passive drainage. In this study, we are reporting our results of peritoneal dialysis after cardiac surgery.

METHODS: In this retrospective study, we evaluated the patients who underwent pediatric cardiac surgery in our hospital between December 2010 and January 2020. Patients who required peritoneal dialysis during hospitalization period were included in the study. Patients' clinical status and outcomes were evaluated.

RESULTS: Peritoneal dialysis was performed to 89 patients during the study period. The age varies from the newborn to 4 years old. The indication of peritoneal dialysis was prophylactic in 68.5% (n=61) and for the treatment in 31.5% (n=28). There were 31 mortalities. The risk factors for the mortality were preoperative lower age, longer cardiopulmonary bypass time, lengthened intubation, lengthened inotropic support, and requirement of extracorporeal membrane oxygenation (p<0.0001).

CONCLUSION: Earlier initiation of peritoneal dialysis in pediatric cardiac surgery helps maintain hemodynamic instability by avoiding fluid overload, considering the difficulty in the treatment of electrolyte imbalance and diuresis.

KEYWORDS: Congenital heart defects. Renal insufficiency. Dialysis.

INTRODUCTION

In pediatric patients, the risk of renal failure after cardiopulmonary bypass (CPB) varies between 20% and 64%[1, 2]. CPB causes fluid overload, hemodilution, capillary leakage, and release of pro-inflammatory mediators during the cardiac surgery. Fluid overload and edema, which are associated with the increased morbidity and mortality, might develop after the cardiac surgery even in the absence of renal dysfunction in pediatric patients[3, 4].

Renal replacement therapy might be initiated as soon as possible in the patients with acute kidney injury (AKI), who had undergone cardiac surgery[5]. The indications of the renal replacement therapy included fluid overload, prevention of fluid overload, acute renal failure, electrolytic abnormality, metabolic acidosis, oliguria, and increasing of urea[6-8]. In the postoperative period, fluid restriction and keeping the general balance negative contribute to recovery. In cases where there is no response to these treatments, continuous renal replacement therapy might be performed to gain hemodynamic stability, remove toxins, and control fluid balance[4].

In the pediatric age group, peritoneal dialysis catheter might be applied for renal replacement therapy[3]. Peritoneal dialysis is a low-cost, easy-to-apply method with a low risk of hemodynamic instability and is effective in reducing fluid overload[9]. It treats uremia and electrolyte imbalance via passive drainage[1]. It provides an opportunity for optimal ultrafiltration in newborns without affecting the hemodynamic status[3]. Early peritoneal dialysis reduces the need for vasoactive drugs and mechanical ventilation[1]. In some centers, prophylactic usage was reported to decrease the risk of acute renal injury[2]. It was reported that peritoneal dialysis is superior to diuretics in providing diuresis in the postoperative period in infants[10]. In this retrospective study, clinical outcomes of pediatric post-cardiotomy patients in which peritoneal dialysis was performed and the factors affecting these outcomes were investigated.

METHODS

Patients who underwent congenital heart surgery in our hospital between December 2010 and January 2020 (n=1404) were retrospectively investigated. The study was initiated after the approval of the institutional review board. Patients who underwent peritoneal dialysis during the perioperative period

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were included in the study. Demographic information, operative information, and laboratory results of the patients were obtained from the patient records. Mortality and morbidity rates were examined in patients who underwent peritoneal dialysis by examining the records of the patients.

In our clinic, peritoneal dialysis is initiated prophylactically in the operating room as well as in the intensive care unit (ICU) for the treatment. The indications of prophylactic peritoneal dialysis are longer than 90 min CPB time and perioperative oliguria. In case of prolonged CPB and intraoperative fluid overload, we place the peritoneal dialysis catheter prophylactically in the operating room. In intensive care follow-ups, we place peritoneal dialysis catheter in cases of oliguria (<0.5 mL/kg/h for more than 4 h), fluid overload, electrolyte imbalance, and creatinine value above 1.2 mg/dL. We considered edema, weight gain, and positive overall balance as signs of fluid overload.

The data were evaluated by using the Analyse-it version 4.20.1 program. Categorical variables were expressed as numbers and percentages, and continuous variables were expressed as mean±standard deviation.

RESULTS

Peritoneal dialysis was performed to 89 patients during the study period. The preoperative demographic and laboratory findings of the patients are shown in Table 1. Different surgical procedures were performed based on the underlying pathologies. The diagnoses of the patients and the surgical procedures are detailed in Table 2.

Peritoneal dialysis was used as prophylactic in 61 patients and for the treatment in 28 patients. There were 31 mortality rates in the follow-up period; dialysis was initiated in 19 patients as prophylactic, and in 12 patients for the treatment. There is no statistically significance for indications of dialysis, i.e., for the mortality (p=0.282). Preoperative lower age, lower body surface area (BSA), lower weight, longer CPB time, lengthened intubation period, and lengthened inotropic support were found statistically significant for the mortality (p<0.0001). Extracorporeal membrane oxygenation (ECMO) was performed in 18 patients. Mortality rate in patients undergoing ECMO was 89% (p<0.0001). In 11 of 16 mortality with ECMO, dialysis was initiated prophylactically.

Table 1. Preoperative variables in 89 patients with peritoneal dialysis.

Variable	Values
Age (months)	11.7 ± 37.6
BSA (m^2)	0.25 ± 0.2
Weight (g)	4971 ± 4698
Preoperative Hb (g/dL)	13.6 ± 3
Preoperative Htc (%)	40.1 ± 9
Preoperative creatinine (mg/dL)	0.47 ± 0.2
Preoperative SaO_2 (%)	88.6 ± 9.1
Preoperative PaO_2 (mmHg)	54.5 ± 48.3

BSA: body surface area; Hb: hemoglobin; Htc: hematocrit; PaO_2: partial pressure of arterial oxygen; SaO_2: oxygen saturation.

DISCUSSION

Preoperative cyanosis, polycythemia, congestive heart failure, prolonged CPB, hypothermia, and low cardiac output are the increasing risk factors for AKI in congenital cardiac surgery[8]. Fluid overload and usage of nephrotoxic drugs are the other risk factors that increase the risk of tubular damage[11]. In this study, we found that lower age, lower BSA, lower weight, longer CPB time, lengthened intubation period, and lengthened inotropic support are the risk factors for the mortality in the patients who needs dialysis. In these patients, increased inflammatory response to prolongation of CPB, low cardiac output, and inotropic drugs increased the necessity of the renal replacement therapy.

It was reported that the risk of renal injury increased seven times when the CPB duration exceeds 2 h[12]. In case of CPB duration longer than 90 min and total circulatory arrest longer than 60 min, insertion of a peritoneal catheter is suggested[8]. In our study, we started peritoneal dialysis prophylactically in the patients who had longer than 90 min CPB time. Mortality rates of the patients according to the indications of dialysis were similar. We can predict that earlier initiation of peritoneal dialysis in the lengthened CPB time decreases the risk of AKI and related complications during the congenital cardiac surgery.

Myocardium is extremely sensitive to fluid overload, electrolyte imbalance, and acid-base imbalance in the postoperative period of cardiac surgery[8]. Prevention of fluid overload is important to preserve myocardial functions. Fluid overload and AKI are associated with increased mortality and morbidity. Fluid overload is an independent risk factor that negatively affects congenital cardiac surgery[2]. There are different methods such as ultrafiltration, peritoneal dialysis, and fluid restriction in the treatment of fluid overload[2]. The first option for the treatment of postoperative fluid overload is intravenous diuretic administration[11]. Continuous renal replacement therapy is required in patients whose renal function does not improve with diuretics[13]. In our clinical approach, we started

Table 2. Cardiac pathology and surgical procedures.

Diagnosis	n	Surgical procedure
Aorta stenosis	1	Valvuloplasty
Aorta stenosis + hypoplastic arcus aorta	1	Valvuloplasty + repair of hypoplastic arcus aorta
CAVSD	5	Repair of CAVSD
CAVSD + hypoplastic arcus aorta	1	Repair of hypoplastic arcus aorta + pulmonary artery banding
CAVSD + PS		BCPC + pulmonary valvuloplasty
CAVSD + TOF	2	Repair of CAVSD + pulmonary valvuloplasty
CAVSD + TOF	1	BT shunt
DORV + PS	1	RVOTR
DORV + PS	1	Rastelli procedure
DORV + PS	1	BCPC
Hypoplastic arcus aorta	1	Repair of hypoplastic arcus aorta + VSD repair
Hypoplastic arcus aorta	1	Repair of hypoplastic arcus aorta + pulmonary banding
Hypoplastic right ventricle + PS	1	Central shunt
Hypoplastic right ventricle + TAPVC	1	BCPC + TAPVC Repair
Hypoplastic left heart syndrome	10	Norwood I procedure
Hypoplastic left heart syndrome	2	Repair of hypoplastic arcus aorta + pulmonary banding
Hypoplastic left heart syndrome	1	Pulmonary banding
Interrupted arcus aorta	1	Repair of hypoplastic arcus aorta + pulmonary banding
Interrupted arcus aorta	1	Repair of hypoplastic arcus aorta + VSD Repair
Interrupted arcus aorta + VSD	1	Norwood I procedure
PS	1	RVOTR
Pulmonary venous stenosis	1	Pulmonary venous reconstruction
TAPVC	1	Correction of TAPVC
TGA	21	Arterial switch
TGA	2	Senning procedure
TGA	1	Rastelli procedure
TGA	1	Arterial switch+ VSD repair
TGA + DORV	1	Senning procedure + VSD repair
TGA + hypoplastic arcus aorta	1	Repair of hypoplastic arcus aorta + pulmonary banding
TGA + PS	1	Senning procedure
TGA + VSD + interrupted arcus aorta	1	Repair of arcus aorta + pulmonary banding
TOF	1	BT Shunt
TOF	10	Total correction of TOF
TOF	2	RVOTR
TOF	1	BCPC
Tricuspid atresia	1	Closure of pulmonary artery
Tricuspid atresia	1	Fontan procedure
Truncus arteriosus	1	Rastelli procedure
VSD + coarctation of aorta	1	Repair of VSD and coarctation
VSD + coarctation of aorta	1	Repair of hypoplastic arcus aorta and VSD
VSD + coarctation of aorta	1	Repair of hypoplastic arcus aorta and VSD + pulmonary banding
VSD + pulmonary band	1	Repair of VSD + pulmonary debanding

BCPC: bidirectional cavopulmonary connection; BT: Blalock-Taussig; CAVSD: complete atrioventricular septal defect; DORV: double-outlet right ventricle; PS: pulmonary stenosis; RVOTR: right ventricle outflow reconstruction; TAPVC: total anomalous pulmonary venous connection; TGA: transposition of great artery; TOF: tetralogy of Fallot; VSD: ventricular septal defect.

renal replacement therapy with peritoneal dialysis, who has insufficient reply to diuretics and volume overload.

Acute kidney injury after cardiac surgery is associated with prolonged ventilation and hospital stay and increased mortality. It increases the risk of mortality five times after cardiac surgery[11]. A 20% mortality has been reported in patients undergoing peritoneal dialysis after pediatric cardiac surgery[3, 8, 12]. Earlier treatment of the AKI improves postoperative outcome and avoids postoperative complications. The tendency to initiate the peritoneal dialysis in early postoperative period, in the patients at risk of being affected by rapid fluid change and those who do not response to diuretic therapy and prolonged CPB duration, was started in order to maintain fluid balance[11, 14]. Peritoneal dialysis is a safe and easy method to prevent postoperative AKI and fluid overload with the advantages of not requiring anticoagulation and vascular intervention[1, 2, 10]. Short-term and low-volume peritoneal dialysis (10 mL/kg every hour) might be performed safely with a low risk of hemodynamic instability[8]. Peritoneal dialysis prevents capillary leakage, which is one of the effects of CPB. It also drains the fluid accumulated in the extravascular area[10]. Peritoneal dialysis improves the electrolyte imbalance and reduces the need for mechanical ventilation and inotropic support by providing negative fluid balance in a short time. In a prospective, randomized controlled study, peritoneal dialysis is superior to diuretics in fluid management, controlling the electrolyte imbalance, and reducing the need for inotropic support and mechanical ventilation[10]. In our clinic, we aim to reduce postoperative morbidity and mortality by performing peritoneal dialysis as prophylactic in prolonged CPB duration in the operating room and as earlier treatment of fluid overload in intensive care follow-ups. When examined all of our patients who underwent congenital cardiac surgery, we observed that the patients with longer than 90 min CPB time underwent prophylactic peritoneal dialysis. There were patients whose CPB duration was longer than 90 min in the treatment group for dialysis indication. In these patients, we did not prefer to insert a catheter intraoperatively because of negative balance and without the signs of fluid overload. The mortality rate of our patients was 34.8%. It was 31.1% for prophylactically dialysis and 42.8% for the patients whose dialysis was initiated in the ICU.

Gist et al.[2] reported the prophylactic peritoneal dialysis avoids fluid overload after arterial switch operation. Prophylactic peritoneal dialysis after arterial switch operation reduces mechanical ventilation time by 42% and hospital stay by 34%, improving the postoperative recovery and reducing hospital cost[2]. We performed peritoneal dialysis prophylactically in all 22 patients who underwent arterial switch operation in our clinic, and our mortality rate was 13.5% (n:3) in these patients.

Patients under treatment of ECMO have a high risk of fluid overloading and renal damage due to the patient's primary disease (i.e., sepsis, ischemia, respiratory and cardiac failure, and vasopressor support). Acute renal damage occurs in 70–85% of the patients with ECMO, and 50% of these patients require renal replacement therapy[7]. Initiation of renal replacement therapy in the earlier period without fluid overloading in the patients with ECMO increases the rate of survival[15]. In the patients with peritoneal dialysis, base deficit, lower pH, and higher lactate levels increase the risk of mortality. Extracorporeal support systems might be beneficial in these patients[16]. In patients undergoing ECMO, the need for dialysis is an independent risk factor for mortality and increases mortality four times[9]. Peritoneal dialysis with ECMO is an effective and safe method to prevent fluid overload and electrolyte abnormality[7]. ECMO was required in 20% (n:18) of our patients who underwent peritoneal dialysis, and two of the patients with ECMO survived.

In this study, there is a lack of the nature of the retrospective studies and as a result no definitive conclusions can be drawn by these results. We included all patients with congenital cardiac defects in the study. Our study includes the patients in the age range from newborn to 288 months, and those weighing up to 12 kg were evaluated. Assessment of age- and weight-related dialysis requirement could not be done and therefore we could not suggest any risk value of age or weight for dialysis. Further prospective studies should be performed with sub-analyses in different age groups and according to diagnosis and treatment modalities.

CONCLUSION

Peritoneal dialysis is a safe and easy method to avoid fluid overloading and AKI after the pediatric congenital cardiac surgery. It might be initiated in earlier period in the operating room in the conditions of fluid overloading and lengthened CPB time. It improves postoperative outcomes with decreasing mechanical ventilation period, need of inotropic support, and length of hospital stay.

AUTHORS' CONTRIBUTIONS

AHA: Conceptualization, Data collection. **AHA, MU:** Methodology, Writing – original draft. **TA:** Software, Investigation. **HU:** Validation, Formal Analysis. **TA, HU:** Writing – review & editing.

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