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Peritoneal dialysis during congenital heart surgery admissions: insights from a large database

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Abstract

Background: The management of fluid overload after congenital heart surgery has been limited to diuretics, fluid restriction, and dialysis. This study was conducted to determine the association between peritoneal dialysis and important clinical outcomes in children undergoing congenital heart surgery. *Methods:* A retrospective review was conducted to identify patients under 18 years of age who underwent congenital heart surgery. The data were obtained over a 16-year period (1997–2012) from the Kids' Inpatient Database. Data analysed consisted of demographics, diagnoses, type of congenital heart surgery, length of stay, cost of hospitalisation, and mortality. Logistic regression was performed to determine factors associated with peritoneal dialysis. *Results:* A total of 46,176 admissions after congenital heart surgery were included in the study. Of those, 181 (0.4%) utilised peritoneal dialysis. The mean age of the peritoneal dialysis group was 7.6 months compared to 39.6 months in those without peritoneal dialysis. The most common CHDs were atrial septal defect (37%), ventricular septal defect (32.6%), and hypoplastic left heart syndrome (18.8%). Univariate analyses demonstrated significantly greater length of stay, cost of admission, and mortality in those with peritoneal dialysis. Regression analyses demonstrated that peritoneal dialysis was independently associated with significant decrease in cost of admission (−$57,500) and significant increase in mortality (odds ratio 1.5). *Conclusions:* Peritoneal dialysis appears to be used in specific patient subsets and is independently associated with decreased cost of stay, although it is associated with increased mortality. Further studies are needed to describe risks and benefit of peritoneal dialysis in this population.

Fluid overload is frequently noted in children after congenital heart surgery requiring cardiopulmonary bypass.[1] Fluid overload in this setting is likely secondary to a pro-inflammatory state induced by cardiopulmonary bypass, haemodilution, and exposure of blood to a non-endothelialised circuit surface.[2] In addition, fluid overload could be caused by oliguria in patients with acute kidney disease, low cardiac output, and excessive fluid for haemodynamic stabilisation or resuscitation.[3,4]

Fluid overload has been associated with increased risk of acute kidney injury, and both fluid overload and acute kidney injury have been documented to increase duration of mechanical ventilation, increase length of hospital stay, and increase mortality in the post-operative setting.[5–7]

The management of fluid overload remains challenging in this patient population. Some of the strategies to manage fluid overload are fluid restriction, diuretics, and peritoneal dialysis.[8] No consensus has been reached as to whether or not, one of these strategies is the optimal treatment for fluid overload in children after congenital heart surgery.[9] A randomised controlled trial comparing peritoneal dialysis versus furosemide concluded that peritoneal dialysis allows superior fluid management with better clinical outcomes, especially in patients with high risk of developing acute kidney injury and fluid overload.[10] Peritoneal dialysis has been used in the post-operative setting in children since the 1970s.[11] Many centres prophylactically place peritoneal dialysis catheters in neonates or patients felt to be at high risk for fluid overload.[12] Peritoneal dialysis offers the following theoretical benefits: fluid removal, fluid clearance, and relief of intra-abdominal venous congestion. All of these may improve renal function.[13] This study aimed to determine the effect of peritoneal dialysis on hospital length of stay, cost of hospitalisation, and mortality utilising a large national inpatient database.

Materials and methods

Institutional review board approval was not necessary as this study utilises deidentified data from a national database. This cross-sectional study follows the Helsinki declaration.

Kids' Inpatient Database

The Kids' Inpatient Database, made available by the Healthcare Cost Utilization Project by the Agency for Healthcare Research and Quality, is a large database designed to capture data from community, non-rehabilitation hospital admissions in the United States of America. Community hospitals are defined differently by the database when compared to the definition used by some healthcare providers. The definition used by the database is as follows: "All non-Federal, short-term, general, and other specialty hospitals". Freestanding and non-freestanding children's hospitals are both included as are teaching and non-teaching hospitals. Discharges of patients less than 20 years of age are included in the database. Rehabilitation and long-term acute care hospitals are excluded from this database. Patients from all regions of the United States of America with a variety of payer types are captured in this database. Data from a total of 44 states are captured.

Patient identification

Data regarding hospital admissions were obtained from all six available iterations of the database, spanning from 1997 to 2012. Patients with CHD having undergone congenital heart surgery were included in the final analysis. The determination of CHD and congenital heart surgery were made based using International Classification of Diseases-9 coding as delineated below. Primary and secondary diagnosis fields were used to collect these data. Only patients under 18 years of age were included in this analysis.

Data identification and collection

Demographic information including gender and race were collected for each admission. Admission characteristics such as admission month, length of stay, and cost of stay were collected as well. Information regarding co-morbid conditions was also collected. Overweight or obese patients were identified using 278.00, 278.01, and 278.02. Acute kidney injury was identified using 584.9. Heart failure was identified using 428.0 to 428.9. Arrhythmias were identified using codes 427.0 to 427.42 as well as 426.0 to 426.13.

CHD was identified using several International Classification of Diseases-9 codes: double-outlet right ventricle using 745.11, atrioventricular septal defect using 745.60, partial anomalous pulmonary venous connection using 747.42, total anomalous pulmonary venous connection using 747.41, transposition of the great arteries using 745.10, congenitally corrected transposition using 745.12, hypoplastic left heart syndrome using 746.7, atrial septal defect using 745.61, ventricular septal defect using 745.5, pulmonary atresia with ventricular septal defect using 746.01, tricuspid atresia using 746.1, Ebstein anomaly using 746.2, truncus arteriosus using 745.0, and coronary artery anomaly using 746.85.

Congenital heart surgery was identified using the following codes: codes 35.10 through 35.14 for valvuloplasty with no valve replacement, 35.20 through 35.28 for valvuloplasty with replacement, codes 35.50 through 35.73 for septal defect repair (including atrioventricular septal defect repair), 35.81 for complete repair of tetralogy of Fallot, 35.82 for pulmonary venous repair, 35.83 for complete repair of common arterial trunk, 35.84 for arterial switch operation for transposition, 35.91 for atrial switch operation for transposition, 35.92 for right ventricle to pulmonary artery conduit, 39.22 for Blalock–Tausig shunt, and 37.51 for heart transplant. Pulmonary stenosis was identified using 746.02. Peritoneal dialysis was identified using 54.98.

Statistical analysis

A cross-sectional study was conducted. Continuous variables are reported using mean and standard deviation, while categorical variables are reported using absolute frequency and percentages. Continuous variables were analysed using a student t-test or Mann–Whitney U-test as appropriate with categorical variables being analysed using Chi-square test. Baseline characteristics, cardiac morphology, congenital heart surgery, and other co-morbidities were compared between those with and without peritoneal dialysis.

A regression was then performed to determine factors associated with peritoneal dialysis using this as the dependent variable. Next, logistic regression analysis was conducted to determine risk factors for increased length of hospitalisation, cost of hospitalisation, and inpatient mortality. While these served as dependent variables in separate regression analyses, the independent variables included peritoneal dialysis, peritonitis, and other variables. The other variables included were co-morbidities and cardiac diagnoses that had a significant p value in univariate analysis. Due to the non-parametric nature of some of the included variables, non-parametric regression analyses were conducted. Cost of stay used represents the total charges recorded for the admission. Figures were adjusted for inflation using 2018 as the reference year for easier understanding of numerical figures by readers. All statistical analysis was done using SPSS Version 20.0 (Chicago, Illinois, United States of America).

Results

Cohort characteristics, univariate analyses

A total of 46,176 admissions with congenital heart surgery under 18 years of age were included in the final analyses. Of these, 181 (0.4%) utilised peritoneal dialysis. The mean age was lower in those with peritoneal dialysis at 7.6 months compared to 39.6 months in the group without peritoneal dialysis (Table 1). In regard to co-morbidities, heart failure, tachyarrhythmias, and peritonitis were more prevalent in those with peritoneal dialysis. The following cardiac lesions were noted with greater prevalence in those with peritoneal dialysis: double-outlet right ventricle, total anomalous pulmonary venous connection, hypoplastic left heart syndrome, transposition, and common arterial trunk (Table 1). The following cardiac surgeries were more prevalent in those with peritoneal dialysis: valvuloplasty with valve replacement, septal defect repair, common arterial trunk, pulmonary venous connection repair, arterial switch, Blalock–Taussig, and Fontan (Table 1).

Hospital admission characteristics, univariate analyses (Table 1)

Median length of admission was greater in those with peritoneal dialysis (39.6 days versus 13.0 days, $p < 0.001$). Median cost of admission was also greater in those with peritoneal dialysis ($449,780 versus $149,418, $p < 0.001$). Inpatient mortality was 32.6% in those with peritoneal dialysis which was greater than the 2.5% inpatient mortality noted in those without peritoneal dialysis (odds ratio 19.2; 95% confidence interval 14.0, 26.3; $p < 0.001$).

Impact of peritoneal dialysis on admission characteristics, regression analysis (Table 2)

Admissions with peritoneal dialysis were independently associated with increased odds of mortality (odds ratio 1.5, 95% confidence interval 1.1, 2.2, $p = 0.026$). Other factors in the regression that were significantly associated with increasing the odds of mortality

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Table 1. Characteristics of admissions with congenital heart surgery where peritoneal dialysis was and was not utilised

	No peritoneal dialysis (n = 45,995)	Peritoneal dialysis (n = 181)	Odds ratio (95% confidence interval)	p Values
Age (months)	34.2 (1–214)	3.2 (1–208)	–	<0.001
Heart failure	8706 (18.9%)	44 (24.3%)	1.3 (0.9–1.9)	0.065
Acute kidney injury	975 (2.1%)	128 (70.7%)	111.5 (80.4–154.5)	<0.001
Arrhythmia (not including atrioventricular block)	1135 (2.5%)	11 (6.1%)	2.5 (1.3–4.7)	0.006
Atrioventricular block	907 (2.0%)	1 (0.6%)	0.2 (0.1–1.9)	0.275
Peritonitis	28 (0.1%)	1 (0.6%)	9.1 (1.2–67.3)	0.008
Cardiac lesion				
Double-outlet right ventricle	2475 (5.4%)	22 (12.2%)	2.4 (1.5–3.8)	<0.001
Atrioventricular septal defect	4753 (10.3%)	26 (14.4%)	1.4 (0.9–2.2)	0.081
Partial anomalous pulmonary venous connection	838 (1.8%)	3 (1.7%)	0.9 (0.2–2.8)	0.869
Total anomalous pulmonary venous connection	1124 (2.4%)	22 (12.2%)	5.5 (3.5–8.6)	<0.001
Coronary artery anomaly	719 (1.6%)	5 (2.8%)	1.7 (0.7–4.3)	0.213
Atrial septal defect	18,697 (40.7%)	67 (37.0%)	0.8 (0.6–1.1)	0.363
Tetralogy of Fallot	4784 (10.4%)	20 (11.0%)	1.0 (0.6–1.7)	0.728
Ventricular septal defect	13,485 (29.3%)	59 (32.6%)	1.1 (0.8–1.5)	0.328
Pulmonary atresia	1168 (2.5%)	3 (1.7%)	0.6 (0.2–2.0)	0.635
Tricuspid atresia	1639 (3.6%)	8 (4.4%)	1.2 (0.6–2.5)	0.542
Ebstein anomaly	354 (0.8%)	0 (0.0%)	–	0.652
Hypoplastic left heart syndrome	3442 (7.5%)	34 (18.8%)	2.8 (1.9–4.1)	<0.001
Transposition	1554 (3.4%)	12 (6.6%)	2.0 (1.1–3.6)	0.023
Congenitally corrected transposition	330 (0.7%)	0 (0.0%)	–	0.644
Common arterial trunk	758 (1.6%)	9 (5.0%)	3.1 (1.5–6.1)	0.003
Cardiac surgery				
Valvuloplasty, no valve replacement	3345 (7.3%)	8 (4.4%)	0.5 (0.2–1.1)	0.152
Valvuloplasty with valve replacement	3776 (8.2%)	3 (1.7%)	0.1 (0.1–0.5)	<0.001
Septal defect repair	23,284 (50.6%)	73 (40.3%)	0.6 (0.4–0.8)	0.006
Tetralogy of Fallot, complete repair	3373 (7.3%)	10 (5.5%)	0.7 (0.3–1.4)	0.473
Common arterial trunk, complete repair	453 (1.0%)	9 (1.9%)	5.2 (2.6–10.3)	<0.001
Pulmonary venous connection repair	1218 (2.6%)	23 (12.7%)	5.3 (3.4–8.3)	<0.001
Transposition repair, arterial switch	614 (1.3%)	9 (5.0%)	3.8 (1.9–7.5)	<0.001
Transposition, atrial switch	224 (0.5%)	1 (0.6%)	1.1 (0.1–8.1)	0.588
Right ventricle to pulmonary artery conduit	1561 (3.4%)	8 (4.4%)	1.3 (0.6–2.6)	0.408
Blalock–Tausig shunt	96 (0.2%)	2 (1.1%)	5.3 (1.3–21.8)	0.009
Glenn	3902 (8.5%)	9 (5.0%)	0.5 (0.2–1.1)	0.107
Fontan	3508 (7.6%)	23 (12.7%)	1.7 (1.1–2.7)	0.016
Heart transplant	644 (1.4%)	3 (1.7%)	1.1 (0.3–3.7)	744
Length of hospital stay	13.0 (0–291)	39.6 (1–122)	–	<0.001
Cost of hospitalisation (median US dollars)	143,322	472,829	–	<0.001
Inpatient mortality	1128 (2.5%)	59 (32.6%)	19.2 (14.0–26.3)	<0.001

were age less than 1 year, arrhythmia, acute kidney injury, double-outlet right ventricle, total anomalous pulmonary venous connection, transposition, hypoplastic left heart syndrome, and peritonitis. The other independent variables in the regression analysis were significantly associated with decreased total charges (−$57,500, p = 0.002). Length of stay was also assessed in the regression analysis but was not significantly associated with decreased length of stay (−2.1 days, p = 0.221).

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Table 2. The independent effect or odds ratio of peritoneal dialysis on length of stay, cost of stay, and inpatient mortality based on results of regression analysis with model taking into account: age, arrhythmia, acute kidney injury, transposition, double-outlet right ventricle, hypoplastic left heart syndrome, total anomalous pulmonary venous connection, and peritonitis

	Effect size or odds ratio	p Values[a]
Length of stay	−2.1 days	0.221
Cost of stay	−$57,500	0.002
Mortality	Odds ratio 1.5 (1.1–2.2)[b]	0.026

[a]p value < 0.05. p Values were performed using Chi-square test.
[b]In parenthesis, 95% confidence interval of the odds ratio.

Discussion

Fluid overload and acute kidney injury are serious complications in children after congenital heart surgery, with a documented prevalence as high as 45%.[14] No consensus has been reached as to how to best prevent fluid overload or acute kidney injury or how to manage these conditions if they develop. Peritoneal dialysis appears as a reasonable strategy to help manage fluid removal and clearance from a physiological point of view, but limited data exist to demonstrate that this provides benefit when compared to fluid restriction and dieresis.[15] The current study demonstrated an independent association of peritoneal dialysis with increased mortality. Yet to be defined are the concrete indications of peritoneal dialysis, its complications and the technical particularities such as timing, content of solutions, and volume for prophylactic management of fluid overload and acute kidney injury in this population.[16] For example, Bojan and colleagues demonstrated that initiating peritoneal dialysis earlier (first 24 hours) was significantly associated with a decrease in mortality, compared to those with delayed dialysis (after 24 hours).[17]

This study included 46,176 paediatric congenital heart surgery admissions. Of these, 181 (0.4%) utilised peritoneal dialysis. While the percentage appears low, the absolute number of admissions in the peritoneal dialysis group represents the largest cohort that has been described in this specific setting.[18] Previously, the largest study was the one conducted by Madenci and colleagues in 2013 and included 28,259 patients.[19] Although several centres have reported the use of peritoneal dialysis for the treatment of fluid overload and acute kidney injury after congenital heart surgery,[20–25] this multi-centre cohort demonstrated that peritoneal dialysis is still utilised in a relatively low proportion of paediatric congenital heart surgery admissions.

While general physiologic states in which peritoneal dialysis may be advantageous have been identified, specific indications within these remain elusive.[21,23] Historically and currently, the prophylactic placement of a peritoneal dialysis catheter has depended on physician preference.[14,26] This decision is often based on thorough assessment of the likelihood that fluid overload or acute kidney injury may develop in the post-operative setting based on characteristics such as age, complexity of the congenital heart surgery, and duration of cardiopulmonary bypass.[27] Thus, disease severity or the perception of severity still appears to be the major factors for determining the use of peritoneal dialysis. This is likely the explanation for why the patients in the peritoneal dialysis cohort had a lower mean age of admission and had associated co-morbidities like heart failure, tachyarrhythmias, peritonitis, and acute kidney injury. Additionally, the prevalence was significantly higher with more complex cardiac surgeries such as the arterial switch, pulmonary venous connection repair, common arterial trunk repair, and placement of a Blalock–Taussig shunt.[28]

Data from previous studies would have led one to intuitively hypothesise that admissions utilising peritoneal dialysis would have a shorter length of stay, lower cost, and lower mortality; this, however, was not consistent with the findings of the current study. Regression analyses demonstrated that inpatient mortality was actually greater in the admissions with peritoneal dialysis, while length and cost of hospital stay were lower. This likely is a function of early post-operative death in the peritoneal dialysis group, which may be secondary to increased severity of illness in the peritoneal dialysis group. This is supported by the increased prevalence of a number of co-morbidities in the peritoneal dialysis admissions. Mahon et al also found a significant correlation between length of stay, costs of admission, and mortality in children with peritoneal dialysis.[29]

To our knowledge, this study is the largest retrospective study describing the associations of peritoneal dialysis in congenital heart surgery admissions. However, this study is not without its limitations. First and foremost, these data are prone to coding error. Diagnoses and procedures could only be identified as being present if they are coded and thus undercoding could present an issue. Also, errant coding could also lead to inappropriate attribution of a diagnosis or procedure. Nonetheless, even if the absolute frequencies are susceptible to this, the large numbers should help moderate the impact of this on the degree of associations noted. Additionally, not all International Classification of Diseases-9 codes have been validated in the paediatric population. The precise timing of peritoneal dialysis initiation cannot be determined. Nor can the indications of peritoneal dialysis be captured from the database. It is possible that the effect of peritoneal dialysis mortality may differ in those who received prophylactic peritoneal dialysis versus those who had a catheter placed and dialysis initiated after reaching a certain threshold of illness. Also, each centre differs in the technique for catheter placement, filtration rate, and other technical aspects of peritoneal dialysis itself. Such characteristics may also impact associated outcomes. It is also important to note that admissions without peritoneal dialysis may have consisted of various fluid restriction and diuresis strategies. Important to mention, due to International Classification of Diseases-10 code implementation in 2015, the data in this study were limited until 2012 to focus only on International Classification of Diseases-9 codes.

Conclusion

Congenital heart surgery admissions in which peritoneal dialysis was used differed in characteristics to those in which peritoneal dialysis was not utilised. Regression analyses demonstrated that peritoneal dialysis was independently associated with increased mortality which may be due to increased severity of illness in the peritoneal dialysis as demonstrated by higher prevalence of co-morbidities in this group. This study is limited due its design and highlights the need for additional future investigations.

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Conflicts of Interest. None.

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