**Novel use of an ultrafiltration device as an alternative method for fluid removal in critically ill pediatric patients with cardiac disease: a case series**

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**Abstract**

Fluid overload (FO) is a common complication for pediatric patients in the intensive care unit. When conventional therapy fails, hemodialysis or peritoneal dialysis is classically used for fluid removal. Unfortunately, these therapies are often associated with cardiovascular or respiratory instability. Ultrafiltration, using devices such as the Aquadex™ system (Baxter Healthcare, Deerfield, IL, USA), is an effective tool for fluid removal in adult patients with congestive heart failure. As compared to hemodialysis, ultrafiltration can be performed using smaller catheters, and the extracorporeal volume and minimal blood flow rates are lower. In addition, there is no associated abdominal distension as is seen in peritoneal dialysis. Consequently, ultrafiltration may be better tolerated in critically ill pediatric patients. We present three cases of challenging pediatric patients with FO in the setting of congenital heart disease in whom ultrafiltration using the Aquadex™ system was successfully utilized for fluid removal while cardiorespiratory stability was maintained.

**Introduction**

Fluid overload (FO) associated with acute kidney injury (AKI) is common in critically ill pediatric patients, and it is associated with poor outcomes.1,2 When conventional therapies fail to achieve a negative fluid balance, early initiation of renal replacement therapy (RRT) has been shown to decrease mortality.3,4 Traditional modes of RRT, including peritoneal dialysis (PD) and hemodialysis (HD), are highly effective at fluid removal, but they are often poorly tolerated in critically ill patients. Several studies have demonstrated advanced ultrafiltration (UF) devices, such as the Aquadex™ system (Baxter Healthcare, Deerfield, IL, USA), to be effective at achieving fluid removal while maintaining hemodynamic stability in adults with congestive heart failure.5-9 UF using the Aquadex™ system can be performed using smaller catheters and the extracorporeal volume and minimal blood flow rates are lower than those required for HD. In addition, there is no associated abdominal distension as is seen in PD. We describe the successful use of the Aquadex™ system for fluid removal via UF in three critically ill pediatric patients with congenital heart disease.

**Case Report #1**

Case report #1 is a 11-year-old, 25 kg male with heterotaxy syndrome of the asplenia type with transposition of the great arteries, unbalanced right dominant atrioventricular canal defect, pulmonary atresia, and total anomalous pulmonary venous connection, who underwent multiple palliative procedures in infancy and subsequently underwent a bidirectional superior cavopulmonary anastomosis at two years of age. Due to persistent pulmonary vein stenosis, he was not felt to be a candidate for a Fontan palliation. The patient presented to our institution with cyanosis. He underwent repair of his atrioventricular canal defect, mitral valve replacement, left ventricle to aortic baffle, and placement of a right vane to pulmonary artery conduit. The patient’s post-operative course was complicated by a low cardiac output syndrome and tachyarrhythmia causing AKI and acute respiratory failure secondary to significant FO.

After initial treatment with conventional diuretics and fenoldopam failed to produce a negative fluid balance, alternative modalities of fluid removal were considered. Conventional forms of RRT using continuous veno-venous hemofiltration (CVVH) or PD were deemed unsuitable secondary to the patient’s tenuous hemodynamic status and high UF needs. UF using the Aquadex™ system was thought to be feasible due to its low flow capacity. A 6 French, double lumen, reinforced, peripherally inserted central catheter (PICC) was placed in the right lower extremity. After consent was obtained from the parents, UF was initiated. Notably, the patient was anticoagulated with heparin for mechanical valve thrombophrophaxis, and this was adequate for the Aquadex™ system.

The initial blood flow rate was 10 mL/minute and this was gradually increased to 40 mL/minute. UF was started at 10 mL/hour and was gradually increased. The patient initially experienced mild hypotension requiring fluid administration and a slight increase in vasopressor support. Over the 9-day course of treatment, UF rates were gradually increased to 150 mL/hour and the patient tolerated negative fluid balances of greater than 750 mL/day. There was steady improvement in the patient’s clinical condition allowing for weaning of vasopressor and ventilatory support.

Although UF therapy facilitated a significant improvement in the patient’s clinical status, he continued to have oliguria. After 9 days of UF, once his hemodynamics had improved, he was transitioned to CVVH. He was ultimately discharged home on PD.

**Case Report #2**

Full term male infant of a diabetic mother with severe hypertrophic cardiomyopathy, respiratory distress syndrome, and persistent pulmonary hypertension of the newborn, who was transferred to our institution with acute respiratory failure. The patient was placed on high frequency oscillatory ventilation, pulmonary vasodilators, and esmolol, but he had persistent severe hypoxemia requiring veno-venous...
Case Report

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Case Report #3

Female infant with pre-natal diagnosis of Ebstein’s anomaly with severe tricuspid regurgitation, pulmonary valve atresia, and significant cardiomegaly with severe lung hypoplasia. The patient was delivered via C-section for hydrops fetalis and non-reassuring fetal heart tracing at 36 weeks gestation. Her post-natal course was complicated by severe hypoxemia and respiratory and metabolic acidosis, as well as atrioventricular re-entrant tachycardia. The patient’s condition stabilized with high frequency oscillation ventilation, fluid resuscitation, correctional of metabolic acidosis, inotropic support, vasopressor support, and arrhythmia control. Nonetheless, the patient had AKI with FO despite attempts at diuresis with conventional diuretic therapy and treatment with fenoldopam. Due to declining respiratory status, a peritoneal drain was placed on day of life five with drainage of ascites. PD was attempted, but this was not tolerated due to hypoxemia and hypotension associated with abdominal distension. Consequently, consent was obtained and the decision was made to proceed with UF. Notably, head ultrasound was normal. Patient underwent placement of a 6 French reinforced double lumen PICC via tran-
shown that UF membranes, such as those used in the Aquadex™ system, allow passage of small molecules, including pro-inflammatory cytokines, which may cause myocardial depression and are implicated in the systemic inflammatory response that is observed in infants and children after congenital heart surgery.\textsuperscript{5,20} We speculate that removal of these substances by UF in the post-operative period may have contributed to the overall improvement in our first patient’s clinical status.

The mechanism of UF is by convection, eliminating iso-osmolar extracellular fluid. A potential benefit is that significant electrolyte abnormalities may be avoided, but until lately, this has precluded the use of the Aquadex™ system in patients with significant electrolyte derangements or uremia.\textsuperscript{6,9} Askenazi and colleagues recently published their favorable experience using a modified Aquadex™ machine to perform CVVH in twelve critically ill infants and young children.\textsuperscript{21} Similarly, the CARPEDIEM and Nidus systems have been developed in Europe specifically for the purpose of providing RRT to newborns and young infants with weights ranging from 800 grams to 8 kilograms. All three of these tools offer small extracorporeal circuit volumes, low minimal blood flow rates, and improved UF accuracy. Early reports of the use of these novel devices suggest that the prognosis for this fragile group of patients requiring dialysis may be improving.\textsuperscript{21,22}

Similar to CVVH, UF using the Aquadex™ system requires systemic anticoagulation. As a result, this therapy is contraindicated in patients who are at significant risk of bleeding, and hemorrhagic complications may occur, as was seen in our third patient.

Conclusions

There are few reports of the use of UF therapy with the Aquadex™ system in pediatric patients with congenital heart disease. We were successful in achieving a significant net negative fluid balance in a timely fashion in three very complex patients without compromising hemodynamic stability. Further studies are required to assess the utility of this therapy for treatment of FO in a broader population of critically ill pediatric patients.

References