Use of a Long Term Ventricular Assist Device with a Modified Circuit for Short Term Extracorporeal Support in an Infant with Single Ventricle Physiology

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Abstract
The approach to mechanical device support in the pediatric heart failure population, particularly those with congenital heart disease, is rapidly evolving. At our institution we have chosen to use the TandemHeart ventricular assist device with a modified circuit as the primary mode of circulatory support for our congenital heart patient population. In this case report, we describe the use of this TandemHeart modified circuit in a less than 5 kg infant for post-cardiotomy heart failure as well as after cardiac arrest as a mode of resuscitation. To the best of our knowledge, our case represents the smallest and youngest patient supported on this circuitry and demonstrates a novel technique for the management of heart failure in the pediatric population.

Abbreviations: VAD: ventricular assist device; ECMO: Extracorporeal Membrane Oxygenation; CPR: Cardiopulmonary Resuscitation; CPB: Cardiopulmonary Bypass; RV: Right Ventricle

Keywords: ventricular assist device, TandemHeart, neonate, single ventricle physiology, heart failure.

Introduction
Mechanical support for heart failure is an evolving, blossoming field. As the patient population grows, so too does the need for medical and mechanical support. The industry of supportive mechanical devices has the added pressure of needing to produce products that are reliable, durable, cost effective, and require low maintenance and oversight. In the pediatric population, mechanical support for patients with congenital heart disease is an ongoing challenge. Support can range from days to weeks and in some instances, may extend to months. The formal development of a sole purpose, pediatric, Ventricular Assist Device (VAD) has lagged behind the demand. Issues regarding thrombosis and bleeding can complicate the use of VADs in patients with complex congenital heart disease. To date, traditional extracorporeal membrane oxygenation (ECMO) has been the mode of choice for most pediatric patients in need of circulatory support. At our institution we have chosen to use the TandemHeart VAD and a modified circuit as the primary mode of circulatory support for our congenital heart patient population.

The TandemHeart (Cardiac Assist, Pittsburgh, PA) VAD is a centrifugal pump that is currently approved by the FDA for clinical use in adults. However, it has been used off-label in pediatric population with a modified circuit as a bridge to heart transplant [1-4]. We have elected to use the TandemHeart VAD with further modified circuit in order to provide full circulatory support, oxygenation, and ultrafiltration for neonates, infants and children. Our modifications involve an inline oxygenator on the outflow limb of the circuit as well as an ultrafiltrator coming off the oxygenator returning to the venous line via a recirculation shunt (Figure 1).

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Case Description

The patient is a 2 month old female infant (weight- 4.7 kg) born at 35 weeks of gestation with double outlet right ventricle, hypoplastic right ventricle (RV) and hypoplastic RV outflow tract. A two-ventricle repair including VSD patch repair and RV outflow tract augmentation was not achievable given the anatomy and the patient underwent central shunt placement, over sewing of the tricuspid valve and atrial septectomy as part of single ventricle palliation. Separation from cardiopulmonary bypass was not initially possible, and the patient was placed on mechanical support with the use of the modified circuit via central cannulation (common atrium, aorta). A flow between 130-140 ml/kg/min, with the shunt partially occluded allowed for adequate systemic and pulmonary perfusion. Cardiac function improved significantly. After 48 hours the echocardiogram showed mildly diminished left ventricular (LV) function with an LV ejection fraction (LVEF) of 57% and patient was weaned off support with debanding of the shunt.

The chest was closed 2 days later and the patient was extubated on post-operative day 10. LV function remained mild to moderately diminished (LVEF 38-44%) on subsequent echocardiograms. Post-TandemHeart course was significant for a small intracranial hemorrhage noted on routine head ultrasound, later confirmed by computer tomography of head. However, the patient remained neurologically stable and required no intervention. She was weaned off oxygen, afterload reduction and diuretics were titrated and she being evaluated for oral feeding as part of discharge planning.

On postoperative day 30 (3 months old, 6 kg), patient acutely decompensated with bradycardia and hypotension followed by a cardiac arrest during a routine echocardiogram. E-CPR was initiated and patient was once again placed on mechanical circulatory support via neck cannulation after a total of 35 minutes of CPR. Echocardiogram just prior to cardiac arrest showed severely diminished LV function with an LVEF of 27% and severe mitral regurgitation. During the second run, the TandemHeart pump was used to provide higher flows (150-160 ml/kg/min) because the shunt caliber was unable to be reduced. The course was uneventful from a hemodynamic standpoint and once again there was a significant improvement in cardiac function (LVEF 38-44%). After four days, the patient was weaned off circulatory support. She currently remains stable on diuretics, afterload reduction (angiotensin converting enzyme inhibitors) and minimal ventilator support via tracheostomy.

Discussion

Innovative work by others in the field of pediatric mechanical circulatory support [1-4] has provided our group with the platform to design a circuit to suit our patient population. The pediatric population is challenging due to variability in size, age, etiology and length of time for support. The variation in patient age and size makes stocking a variety of devices cumbersome and potentially financially cost prohibitive for the hospital. The pediatric heart failure population encompasses a broad spectrum of patients including those with post- cardiotomy heart failure, post resuscitative heart failure, and dilated cardiomyopathy. The need for reliable, versatile, and easy to deploy circulatory support device in this patient population is critical.

The TandemHeart is an adult ventricular assist device that others have been able to successfully modify for pediatric patients in heart failure awaiting heart transplantation [4]. Our design is unique in that we elected to choose a device that is designed for durability, low oversight, simplicity of deployment, portability, and versatility and added circuit modifications allows for full mechanical support while also providing the added benefit of oxygenation and ultrafiltration. Furthermore, while providing full support to the patient, we benefit from the low oversight model of care (1 patient: 1 nurse) that is customary with the deployment of traditional VADs. Traditional ECMO requires the involvement of multiple team members (primer, a specialist and a nurse), longer deployment times and a larger team to manage which in turn increases cost and complexity.

We successfully deployed our TandemHeart modified circuit in a less than 5 kg infant for post-cardiomyotomy heart failure population is critical.
failure as well as after cardiac arrest as a mode of resuscitation. To the best of our knowledge, our case represents the smallest and youngest patient supported on this circuitry and is a novel technique for the management of heart failure in the pediatric population. Our TandemHeart modified circuit is simple in applicability, can be used for a variety of patient sizes, is cost effective, and with its circuit modifications can be an attractive alternative to VADs or traditional ECMO support.

References


