Journal of Clinical & Experimental Cardiology

Sehgal and Ahluwalia, J Clin Exp Cardiolog 2017, 8:5
DOI: 10.4172/2155-9880.1000516

Commentary Open Access

Ventricular Assist Devices in Patients with Systemic Right Ventricular Failure due to Congenitally Corrected Transposition of the Great Arteries

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Received date: March 31, 2017; **Accepted date:** May 04, 2017; **Published date:** May 10, 2017

Abstract

Congenitally corrected transposition of the great arteries is increasingly recognized as an adult congenital heart problem. Although early atrial switch surgical repairs resulted in improved overall survival, these patients are further predisposed to systemic ventricular failure in their fourth and fifth decades of life. Early diagnosis and management of systemic ventricular dysfunction are often challenging. Ventricular assist devices may become a mainstay end-stage treatment option for these patients as a destination therapy or a bridge to heart transplantation.

Keywords: Ventricular assist device; Systemic right ventricle; Adult congenital heart disease; D-transposition of the great arteries; Congenitally corrected transposition of the great arteries; Right ventricular failure; Heart transplantation

Abbreviations:

Dextro-Transposition of the Great Arteries: d-TGA; Right Ventricle: RV; Congenitally Corrected Transposition of the Great Arteries: cc-TGA; Left Ventricle: LV; Ventricular Assist Device: VAD.

Introduction

Dextro-transposition of the great arteries (d-TGA) is the most common cyanotic congenital heart defect. Atrial switch operations e.g. Mustard and Senning procedures developed in the 1950s were the preferred surgical technique for d-TGA [1,2], which resulted in good short-term and immediate-term outcomes with improved overall survival [3-8]. The creation of a systemic right ventricle (RV) with the atrial switch surgical approach, however, leads to long-term complications as these patients are predisposed to RV dysfunction and failure, and pulmonary hypertension [9]. RV failure can occur in up to 44% of these patients and can be challenging to manage [9,10]. Although medical and surgical therapies target early RV dysfunction, heart transplantation remains the only long-term solution for ventricular failure. Due to limited donor availability, patients may require mechanical support devices to survive. This commentary will focus on the current clinical challenges seen in congenitally corrected transposition of the great arteries (cc-TGA), and the management of systemic RV failure with mechanical circulatory support.

Congenitally corrected- transposition of the great arteries

In d-TGA, the aorta arises from the anatomical RV, located rightward and anterior to the pulmonary artery (PA), which arises from the left ventricle (LV). This leads to a ventriculo-arterial discordance. An atrial switch operation helps by connecting the left atrium to the RV and the right atrium to the LV using a baffle, resulting in the formation of a systemic RV. This leads to atrio-ventricular discordance. Although the technique allows the pulmonary and systemic circulations to work in parallel, improving survival, these patients develop serious late complications [11,12]. Management of cc-TGA patients is challenging due to both complex anatomy and physiology, and limited options are available for systemic RV support.

The systemic right ventricle

RV dysfunction typically manifests in the fourth and fifth decades of life, and is one of the most common causes of death in such patients, along with fatal tachyarrhythmias. The systemic ventricular function is often difficult to assess owing to the morphological changes that the ventricle undergoes. These changes include high afterload leading to eccentric hypertrophy, enlargement of RV chamber with interventricular septal shift towards the LV, thickening and dysfunction of trabeculae, and tethering of papillary muscles [12]. This is not accompanied by augmented coronary blood flow as the native blood supply provided by the right coronary artery does not account for an increase in RV size and function. RV dilation leads to tricuspid valve annular dilatation and tricuspid regurgitation. Other cc-TGA-associated cardiac lesions can be seen in up to 80% of cases, which include conduction abnormalities, ventricular arrhythmias, pulmonary stenosis and ventricular septal defects, further worsening RV dysfunction [10,13]. Together, these factors play an important role in the development of late RV dysfunction and failure.

Medical and device therapy

Evaluation of RV dysfunction and timing of initiation of therapies are imperative. Although there are no randomized control trials in this patient population, evidence based therapies in heart failure with reduced ejection fraction have been applied, which include angiotensin converting enzyme inhibitor or angiotensin II receptor blocker and beta-blocker therapies [14-19]. There is no evidence for digoxin; however, it can be used. Caution should be used with digoxin and beta-blocker as this may predispose patients to bradyarrhythmias or atrioventricular nodal conduction abnormalities. Intraventricular

conduction delays and ventricular dyssynchrony have been described in cc-TGA patients primarily due to systemic ventricular hypertrophy. Cardiac resynchronization therapy promotes the movement of systemic RV free wall and the septum together, which has been shown to improve RV mechanical function as well as functional capacity in a small number of patients [20,21].

Surgical repair

Anatomic correction aims at re-establishing LV as the systemic ventricle, thus protecting the deteriorating RV. A double switch (atrial-arterial switch) procedure may be performed in patients with cc-TGA when RV dysfunction is reversible and is accompanied by relatively well preserved LV and mitral valve function. This procedure is not feasible in patients with significant LV dysfunction, pulmonary valve abnormalities precluding its use as a neo-aortic valve, or uncontrollable arrhythmias. Although no randomized clinical trials exist, amongst the few case studies described, anatomic correction has been shown to have good long-term outcomes with 10 and 20 year-survival reported as 75% and 85%, respectively [22-27]. In patients without pulmonary hypertension or LV outflow tract obstruction, the LV may not have the ability to support systemic pressures after anatomic correction. These patients undergo a two-staged surgical procedure involving PA banding for preparing the LV to withstand systemic pressures, followed by the atrial switch (Mustard or Senning) combined with either arterial switch or a ventricular level repair (Rastelli procedure). PA banding has also been used as a palliative procedure in cc-TGA, as it increases LV afterload, preventing leftward septal shift and worsening of tricuspid regurgitation and thus preserving RV function [28,29].

Mechanical circulatory support

There have been an increasing number of case reports describing support of the systemic RV using a ventricular assist device (VAD) as a bridge to heart transplant (Table 1) [30-45]. Nearly all such patients presented with symptoms of advanced heart failure or pulmonary hypertension. VAD implant improves hemodynamics by unloading the RV, allowing it to recover by regression of cellular hypertrophy, leading to a leftward shift of end-diastolic pressure-volume relationship. VAD helps improve the deranged neuro-hormonal milieu of systemic RV failure. This, along with improved end-organ perfusion, helps create a more favorable option for heart transplantation. Operative challenges associated with VAD implantation include VAD inflow placement in the systemic RV apex site to ensure adequate flow, adjustment of the length of the cannulas to the RV instead of the usual LV implantation and optimization of the connection site. VADs remain the only treatment modality in patients with advanced systemic RV dysfunction and failure awaiting a donor heart, and in those who do not qualify for a surgical correction or heart transplantation. The longest reported duration of VAD support in these patients is 988 days [41-47].

Authors	Patients (n)	VAD type	Median age in years	Duration of VAD support	Survival	Heart transplantation (at last follow-up)
Wilkund et al. [30] 1999	1	Heartmate I	15	n/a	1-Jan	Awaiting
Stewart et al. [31] 2002	2	Heartmate I	15, 28	12 weeks, 8 months	2-Feb	n/a
Gregoric et al. [32] 2007	1	Heartware	53	8 months	1-Jan	Transplanted
George et al. [33] 2009	1	Heartmate II	17	13 months	1-Jan	Transplanted
Netuka et al. [34] 2009	1	Heartmate II	30	n/a	n/a	n/a
Joyce et al. [35] 2010	3	DeBakey VAD × 1, Heartmate II × 1	33	n/a	n/a	n/a
Akay et al. [36] 2012	1	Heartmate II	34	18 months	1-Jan	Awaiting
Jacobs et al. [37] 2012	1	Circulite	49	10 months	1-Jan	Awaiting
Mohite et al. [38] 2013	1	Heartmate II	53	n/a	n/a	unknown
Huang et al. [39] 2013	1	Heartware	63	24 months	1-Jan	n/a
Neely et al. [40] 2013	1	Heartmate II	41	Destination Therapy	n/a	Not eligible
Shah et al. [41] 2013	6	Heartmate I × 1, Heartmate II × 3, Jarvik 2000 × 1, Heartware × 3	41 (23 - 54)	171, 261, 27, 988, 577, 493 days	6-Apr	1/6 Transplanted, 1/6 Awaiting
Peng et al. [42] 2014	7	Heartware	36	232, 64, 685, 313, 640, 190, 30 days	7-May	3/7 Transplanted, 2/7 Awaiting

Maly et al. [43] 2015	5	Heartmate II	31.5 ± 1.8	284 ± 177 days	5-Mar	3/5 received
Sehgal et al. [44] 2015	1	Heartware	43	4 months	0/1	Not eligible
Tanoue et al. [45] 2016	1	Jarvik 2000	60	12 months	1-Jan	Awaiting

Table 1: Summary of cases of cc-TGA patients who underwent ventricular assist device implantation for systemic right ventricular support.

Conclusion

RV failure in patients with cc-TGA remains an emerging adult congenital problem, and is challenging to manage. Medical and surgical therapies may help with early RV dysfunction, but heart transplantation remains the only long-term solution for systemic ventricular failure. Due to limited donor heart availability, mechanical support with VADs may become a routine part of end-stage heart failure therapy for such patients. Hence, VAD implant is a life-saving measure that can delay the progression of systemic ventricular failure and can be used to improve morbidity and mortality in patients with cc-TGA.

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This article was originally published in a special issue, entitled: **"Atherosclerosis and Cardiovascular Risk Factors",** Edited by Sumita Mishra, Sphingolipid Signaling and Vascular Biology Lab, Department of Pediatrics Division of Medicine, Johns Hopkins Medical Institutions, USA