

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

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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.

References

- Mustard WT, Keith JD, Trusler GA, Fowler R, Kidd L (1964) The Surgical Management of Transposition of the Great Vessels. *J Thorac Cardiovasc Surg* 48: 953-958.
- Senning A (1959) Surgical correction of transposition of the great vessels. *Surgery* 45: 966-980.
- Ruys TP, van der Bosch AE, Cuypers JA, Witsenburg M, Helbing WA, et al. (2013) Long-term outcome and quality of life after arterial switch operation: a prospective study with a historical comparison. *Congenit Heart Dis* 8: 203-210.
- Junge C, Westhoff-Bleck M, Schoof S, Danne F, Buchhorn R, et al. (2013) Comparison of late results of arterial switch versus atrial switch (mustard procedure) operation for transposition of the great arteries. *Am J Cardiol* 111: 1505-1509.
- Vejlstrup N, Sørensen K, Mattsson E, Thilén U, Kvidal P, et al. (2015) Long-Term Outcome of Mustard/Senning Correction for Transposition of the Great Arteries in Sweden and Denmark. *Circulation* 132: 633-638.
- Hörner J, Herrmann F, Schreiber C, Cleuziou J, Prodan Z, et al. (2007) How well are patients doing up to 30 years after a mustard operation? *Thorac Cardiovasc Surg* 55: 359.
- Oechslin E, Jenni R (2000) 40 years after the first atrial switch procedure in patients with transposition of the great arteries: long-term results in Toronto and Zurich. *Thorac Cardiovasc Surg* 48: 233.
- Wilson NJ, Clarkson PM, Barratt-Boyes BG, Calder AL, Whitlock RM, et al. (1998) Long-term outcome after the mustard repair for simple transposition of the great arteries. 28-year follow-up. *J Am Coll Cardiol* 32: 758-765.
- Moons P, Gewillig M, Sluysmans T, Verhaaren H, Viart P, et al. (2004) Long term outcome up to 30 years after the Mustard or Senning operation: a nationwide multicenter study in Belgium. *Heart* 90: 307-313.
- Wallis GA, Debich-Spicer D, Anderson RH (2011) Congenitally corrected transposition. *Orphanet J Rare Dis* 6: 22.
- Kral Kollars CA, Gelehrter S, Bove EL, Ensing G (2010) Effects of morphologic left ventricular pressure on right ventricular geometry and tricuspid valve regurgitation in patients with congenitally corrected transposition of the great arteries. *Am J Cardiol* 105: 735-739.
- Gelatt M, Hamilton RM, McCrindle BW, Connelly M, Davis A, et al. (1997) Arrhythmia and mortality after the Mustard procedure: a 30-year single-center experience. *J Am Coll Cardiol* 29: 194-201.
- Gatzoulis MA, Walters J, McLaughlin PR, Merchant N, Webb GD, et al. (2000) Late arrhythmia in adults with the mustard procedure for transposition of great arteries: a surrogate marker for right ventricular dysfunction? *Heart* 84: 409-415.
- Doughan AR, McConnell ME, Book WM (2007) Effect of beta blockers (carvedilol or metoprolol XL) in patients with transposition of great arteries and dysfunction of the systemic right ventricle. *Am J Cardiol* 99: 704-706.
- Giardini A, Lovato L, Donti A, Formigari R, Gargiulo G et al. (2007) A pilot study on the effects of carvedilol on right ventricular remodelling and exercise tolerance in patients with systemic right ventricle. *Int J Cardiol* 114: 241-246.
- Bouallal R, Godart F, Francart C, Richard A, Foucher-Hossein C, et al. (2010) Interest of β^2 -blockers in patients with right ventricular systemic dysfunction. *Cardiol Young* 20: 615-619.
- Dore A, Houde C, Chan KL, Ducharme A, Khairy P et al. (2005) Angiotensin receptor blockade and exercise capacity in adults with systemic right ventricles: a multicenter, randomized, placebo-controlled clinical trial. *Circulation* 112: 2411-2416.
- van der Bom T, Winter MM, Bouma BJ, Groenink M, Vliegen HW, et al. (2013) Effect of valsartan on systemic right ventricular function: a double-blind, randomized, placebo-controlled pilot trial. *Circulation* 127: 322-330.
- Therrien J, Provost Y, Harrison J, Connelly M, Kaemmerer H, et al. (2008) Effect of angiotensin receptor blockade on systemic right ventricular function and size: a small, randomized, placebo-controlled study. *Int J Cardiol* 129: 187-192.
- Diller GP, Okonko D, Uebing A, Ho SY, Gatzoulis MA, et al. (2006) Cardiac resynchronization therapy for adult congenital heart disease patients with a systemic right ventricle: analysis of feasibility and review of early experience. *Europace* 8: 267-272.
- Dubin AM, Janousek J, Rhee E, Strieper MJ, Cecchin F, et al. (2005) Resynchronization therapy in pediatric and congenital heart disease patients: an international multicenter study. *J Am Coll Cardiol* 46: 2277-2283.
- Bautista-Hernandez V, Marx GR, Gauvreau K, Mayer JE Jr, Cecchin F, et al. (2006) Determinants of left ventricular dysfunction after anatomic repair of congenitally corrected transposition of the great arteries. *Ann Thorac Surg* 82: 2059-2065.
- Gaies MG, Goldberg CS, Ohye RG, Devaney EJ, Hirsch JC, et al. (2009) Early and intermediate outcome after anatomic repair of congenitally corrected transposition of the great arteries. *Ann Thorac Surg* 88: 1952-1960.
- Gaies MG, Goldberg CS, Ohye RG, Devaney EJ, Hirsch JC, et al. (2009) Early and intermediate outcome after anatomic repair of congenitally corrected transposition of the great arteries. *Ann Thorac Surg* 88: 1952-1960.
- Hiramatsu T, Matsumura G, Konuma T, Yamazaki K, Kurosawa H, et al. (2012) Long-term prognosis of double-switch operation for congenitally corrected transposition of the great arteries. *Eur J Cardiothorac Surg* 42: 1004-1008.
- Langley SM, Winlaw DS, Stumper O (2003) Midterm results after restoration of the morphologically left ventricle to the systemic circulation in patients with congenitally corrected transposition of the great arteries. *J Thorac Cardiovasc Surg* 125: 1229-1241.

27. Hraajka V, Mattes A, Haun C, Blaschczok HC, Photiadis J, et al. (2011) Functional outcome of anatomic correction of corrected transposition of the great arteries. *Eur J Cardiothorac Surg* 40: 1227-1234.
28. Murtuza B, Barron DJ, Stumper O (2011) Anatomic repair for congenitally corrected transposition of the great arteries: a single-institution 19-year experience. *J Thorac Cardiovasc Surg* 142: 1348-1357.
29. Cools B, Brown SC, Louw J, Heying R, Meyns B, et al. (2012) Pulmonary artery banding as 'open end' palliation of systemic right ventricles: an interim analysis. *Eur J Cardiothorac Surg* 41: 913-918.
30. Myers PO, del Nido PJ, Geva T, Bautista-Hernandez V, Chen P, et al. (2013) Impact of age and duration of banding on left ventricular preparation before anatomic repair for congenitally corrected transposition of the great arteries. *Ann Thorac Surg* 96: 603-610.
31. Bautista-Hernandez V, Myers PO, Cecchin F, Marx GR, Del Nido PJ (2013) left ventricular preparation before anatomic repair for congenitally corrected transposition of the great arteries. *Ann Thorac Surg* 96: 603-610.
32. Wiklund L, Svensson S, Berggren H (1999) Implantation of a left ventricular assist device, back-to-front, in an adolescent with a failing mustard procedure. *J Thorac Cardiovasc Surg* 118: 755-756.
33. Stewart AS, Gorman RC, Pocchetino A, Rosengard BR, Acker MA (2002) Left ventricular assist device for right side assistance in patients with transposition. *Ann Thorac Surg* 74: 912-914.
34. Gregoric ID, Kosir R, Smart FW (2005) Left Ventricular Assist Device Implantation in a Patient with Congenitally Corrected Transposition of the Great Arteries. *Tex Heart Inst J* 32: 567-569.
35. George RS, Birks EJ, Radley-Smith RC, Khaghani A, Yacoub M, et al. (2007) Bridge to transplantation with a left ventricular assist device for systemic ventricular failure after Mustard procedure. *Ann Thorac Surg* 83: 306-308.
36. Netuka I, Maly J, Szarszoi O, Novotny J (2009) Systemic right ventricle supported by implantable axial-flow assist device. *Eur J Cardiothorac Surg* 36: 403.
37. Joyce DL, Crow SS, John R, St Louis JD, Braunlin EA, et al. (2010) Mechanical circulatory support in patients with heart failure secondary to transposition of the great arteries. *J Heart Lung Transplant* 29: 1302-1305.
38. Akay MH, Cooley DA, Frazier OH (2012) Implantation of the heartmate II in a patient of 34 years after a Mustard procedure. *J Card Surg* 27: 769-770.
39. Jacobs S, Rega F, Burkhoff D, Meyns B (2012) The use of a CircuLite micro-pump for congenitally corrected transposition of the great arteries. *Eur J Cardiothorac Surg* 42: 741-743.
40. Mohite PN, Popov AF, Garcia D (2012) Ventricular assist device outflow graft in congenitally corrected transposition of great arteries - a surgical challenge. *J Cardiothorac Surg* 7: 93.
41. Huang J, Slaughter MS (2013) HeartWare ventricular assist device placement in a patient with congenitally corrected transposition of the great arteries. *J Thorac Cardiovasc Surg* 145: e23-e25.
42. Neely RC, Davis RP, Stephens EH, Takayama H, Khalpey Z, et al. (2013) Ventricular assist device for failing systemic ventricle in an adult with prior mustard procedure. *Ann Thorac Surg* 96: 691-693.
43. Shah NR, Lam WW, Rodriguez FH 3rd, Ermis PR, Simpson L, et al. (2013) Clinical outcomes after ventricular assist device implantation in adults with complex congenital heart disease. *J Heart Lung Transplant* 32: 615-620.
44. Peng E, O'Sullivan JJ, Griselli M, Roysam C, Crossland D, et al. (2014) Durable ventricular assist device support for failing systemic morphologic right ventricle: early results. *Ann Thorac Surg* 98: 2122-2129.
45. Maly J, Netuka I, Besik J, Dorazilova Z, Pirk J, et al. (2015) Bridge to transplantation with long-term mechanical assist device in adults after the Mustard procedure. *J Heart Lung Transplant* 34: 1177-1181.
46. Sehgal S, Ramachandran S, Leff JD (2015) HeartWare Ventricular Assist Device Placement in a Patient with Corrected Dextro-Transposition of Great Arteries: A Case Report and Its Clinical Challenges. *Semin Cardiothorac Vasc Anesth* 19: 243-247.
47. Tanoue Y, Jinzai Y, Tominaga R (2016) Jarvik 2000 axial-flow ventricular assist device placement to a systemic morphologic right ventricle in congenitally corrected transposition of the great arteries. *J Artif Organs* 19: 97.

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