

Surgical implantation of the CardioWest Total Artificial Heart

Vincenzo Tarzia¹, Edward Buratto^{1,2}, Michele Gallo¹, Giacomo Bortolussi¹, Jonida Bejko¹, Carlo Dal Lin¹, Gianluca Torregrossa¹, Roberto Bianco¹, Tomaso Bottio¹, Gino Gerosa¹

¹Cardiac Surgery Unit, Department of Cardiac, Thoracic and Vascular Sciences, University of Padua, Padua, Italy; ²Cardiac Surgery Unit, Department of Paediatrics, University of Melbourne, Australia

Correspondence to: Vincenzo Tarzia. Cardiac Surgery Unit, Department of Cardiac, Thoracic and Vascular Sciences, University of Padua, Via Giustiniani 2, 35128 Padova, Italy. Email: v.tarzia@gmail.com.



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Introduction

The CardioWest Total Artificial Heart (CW-TAH) is a pneumatically driven pump that completely replaces the patient's native ventricles orthotopically. The device weighs 160 g and consists of two artificial ventricles, four Medtronic Hall tilting disk valves, two membranes, and two drivelines tunneled through the skin, which connect the ventricles to an external console generating pulsatile flow (1). At maximum stroke volume (close to 70 mL), it delivers a cardiac output between seven and nine litres per minute. Variations in cardiac output are determined by variations in venous return and peripheral resistance linked to the patient's position and level of physical activity (2). The CW-TAH is indicated for use in patients with refractory cardiac failure as a bridge to transplantation, and when used for this indication, improves survival to transplant (3). Portable drivers have been approved in both Europe and the United States to allow stable patients to be discharged home while awaiting their transplant (4).

Surgical technique

The procedure is performed under general anesthesia in a supine position via median sternotomy. Aortic and bicaval cannulation is performed in the usual fashion and cardiopulmonary bypass (CPB) is instituted (*Video 1*).

The heart is excised in a manner somewhat different to that performed for heart transplantation, with efforts made to preserve the annuli of the atrioventricular (AV) valves. An incision is made on the ventricular side of the right ventricular AV groove, and is then extended anteriorly

across the right ventricular outflow tract just proximal to the pulmonary valve. Posteriorly it is extended across the interventricular septum on the left ventricular side of the AV groove. Excess leaflet tissue and chordae are trimmed away leaving a two mm rim of valve tissue. The atrial cuff consists of approximately one cm of residual muscle and fat which is left in situ. In the left ventricular outflow tract portion of the cuff, some residual anterior mitral leaflet and aortic tissue is left in situ as it provides strong tissue when anastomosing the inflow connectors.

The great vessels are then transected just above the valvular level and separated from one another. The left atrial appendage and the coronary sinus ostium are excluded by using prolene 4-0 running sutures.

The outer walls of the atrial cuff are reinforced by encircling stitches and either Teflon felt buttresses or residual mitral or tricuspid valve tissue. Atrial inflow connectors are inserted and anastomosed to the atrial cuff with 3-0 prolene. The same process is applied first for the left sided inflow connector and then the right-sided connector. The suture lines are then checked for leaks.

The outflow connectors are then anastomosed. The required length of the connectors is determined by placing the ventricles in the pericardium. The anastomosis of the pulmonary artery to the outflow connector is performed first with a continuous 4-0 prolene suture in an end to end fashion. The same process is then performed for the aortic outflow connector.

The left ventricle is placed first and connected as it determines the orientation of the whole device. The right ventricle is subsequently connected. The atrial connection is made first, then pulmonary outflow connection, taking

care to ensure no kinking or twisting has occurred.

The patient is placed in a steep Trendelenburg position and vents are placed in the highest part of the aorta and the aortic outflow connector for de-airing. Once totally de-aired, full flow of the CW-TAH can be commenced and CPB can be weaned off.

Comments

TAH is indicated for the treatment of patients with refractory biventricular failure. It produces high cardiac output regardless of the patient's clinical condition (even with elevated systemic or pulmonary vascular resistance) and hence improves end-organ perfusion, allowing organ recovery in the INTERMACS level 1 patient. The current indication for implanting the TAH is as a bridge to transplant in patients with end-stage congestive heart failure and/or concomitant contra-indication to left ventricular assist devices (LVADs) or biventricular assist devices (BiVADs) including: aortic regurgitation, refractory malignant arrhythmias, left ventricular thrombus, a complex post-infarction ventricular septal defect, post-cardiac transplant graft failure and irreversible biventricular failure requiring high pump outputs (3,5).

The CW-TAH has been shown to improve survival to transplant and 1-year survival in patients with biventricular failure when compared with medical therapy, albeit in a non-randomized trial (3). Worldwide, over 1,100 TAHs have been implanted (5), with the 6th INTERMACS annual report including 239 patients treated with TAH since 2006. Among these patients, 66 were implanted in the most recent 12 months (6). The one-year survival rate reported for TAH is 59%, which is comparable to continuous BiVADs (57% one-year survival), and superior to results achieved with pulsatile flow BiVADs (45% one-year survival).

With the availability of portable drivers, home discharge of patients supported by the CW-TAH has become a goal, and is associated with an acceptable safety profile and quality of life (7). Therefore, with the increasing availability of portable drivers, increasing numbers of centers implanting the device and the ongoing shortage of donors, utilization of the device will increase. However, the requirement for patients to have a body surface area of greater than 1.7 m², the high rate of infection associated with its bulky percutaneous driveline and the noise still represent limiting factors for the wider use of the CW-TAH (5,7).

Future efforts will need to focus on the development of a smaller, totally implantable TAH, with a transcutaneous

energy transfer system avoiding a percutaneous driveline and hence reducing infection risk, and noise. Furthermore, in the current era of donor shortage, a TAH that could be used for long-term support as destination therapy with a good quality of life should be the aim (8).

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