Horizon Scanning Technology
Prioritising Summary

CardioWest Total Artificial Heart

September
2005
© Commonwealth of Australia [2005]

This work is copyright. You may download, display, print and reproduce this material in unaltered form only (retaining this notice) for your personal, non-commercial use or use within your organisation. Apart from any use as permitted under the Copyright Act 1968, all other rights are reserved. Requests and inquiries concerning reproduction and rights should be addressed to Commonwealth Copyright Administration, Attorney General’s Department, Robert Garran Offices, National Circuit, Canberra ACT 2600 or posted at http://www.ag.gov.au/cca

Electronic copies can be obtained from http://www.horizonscanning.gov.au

Enquiries about the content of the report should be directed to:

HealthPACT Secretariat
Department of Health and Ageing
MDP 106
GPO Box 9848
Canberra ACT 2606
AUSTRALIA

DISCLAIMER: This report is based on information available at the time of research and cannot be expected to cover any developments arising from subsequent improvements to health technologies. This report is based on a limited literature search and is not a definitive statement on the safety, effectiveness or cost-effectiveness of the health technology covered.

The Commonwealth does not guarantee the accuracy, currency or completeness of the information in this report. This report is not intended to be used as medical advice and it is not intended to be used to diagnose, treat, cure or prevent any disease, nor should it be used for therapeutic purposes or as a substitute for a health professional's advice. The Commonwealth does not accept any liability for any injury, loss or damage incurred by use of or reliance on the information.

The production of this Horizon scanning prioritising summary was overseen by the Health Policy Advisory Committee on Technology (HealthPACT), a sub-committee of the Medical Services Advisory Committee (MSAC). HealthPACT comprises representatives from health departments in all states and territories, the Australia and New Zealand governments; MSAC and ASERNIP-S. The Australian Health Ministers’ Advisory Council (AHMAC) supports HealthPACT through funding.

This Horizon scanning prioritising summary was prepared by staff from the Australian safety and Efficacy Register of New Interventional Procedures – Surgical (ASERNIP-S).
Horizon Scanning Technology
Prioritising Summary

Name of Technology:
CardioWest Total Artificial Heart (TAH) (Syncardia Systems Inc., Tucson, Arizona)

Purpose and Target Group:
The CardioWest TAH was designed to completely replace a patient’s native ventricles and all four cardiac valves. It was developed to be used as a bridge to transplant device and aims to improve the survival rate of cardiac transplant-eligible candidates who are at risk of imminent death from biventricular failure (Syncardia 2005).

Stage of Development (in Australia): Not yet emerged in Australia

☐ Experimental
☐ Investigational
☐ Nearly established
☐ Established
☐ Established but changed indication or modification of technique
☐ Should be taken out of use

The CardioWest TAH is not listed or registered in the Australian Register of Therapeutic Goods (ARTG).

International Utilisation:

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>LEVEL OF USE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trials underway</td>
</tr>
<tr>
<td>United States</td>
<td>✓</td>
</tr>
<tr>
<td>Canada</td>
<td>✓</td>
</tr>
<tr>
<td>France</td>
<td>✓</td>
</tr>
<tr>
<td>Germany</td>
<td>✓</td>
</tr>
</tbody>
</table>

Impact Summary:

Background
In heart failure, damage to the heart weakens the cardiovascular system and limits the ability of the heart to pump blood to other organs of the body. One of the most common causes of heart failure is coronary artery disease where narrowed arteries are less able to deliver sufficient blood and oxygen to the heart. Symptoms include shortness of breath due to pulmonary oedema, fatigue, and swollen ankles due to fluid retention.
Although survival rates have improved significantly, nearly half the patients diagnosed with heart failure will die within five years (Goldstein et al. 1998).

Lifestyle modifications, a range of pharmacological treatments, and sometimes surgical treatments, are used to treat congestive heart failure, but eventually most patients will progress to end-stage disease. Ideally patients who also have end stage disease would undergo heart transplantation, but there is a severe shortage of, and increased demands for, donor hearts. While waiting for a heart, patients may need some form of mechanical circulatory device such as a ventricular assist device, which acts as a ‘bridge to transplantation’.

Early artificial hearts (such as the Jarvik TAH were associated with a high incidence of death and complications. CardioWest is the successor to the Jarvik-7 and was designed as a short-term bridge to transplantation rather than a long-term option.

The CardioWest TAH is a modified version of the Symbion Jarvik-7 TAH, and is a pneumatic device which attaches to the heart’s natural atria. The Jarvik-7 was renamed to CardioWest in 1993 following the modifications to its design. The ventricles of the CardioWest TAH are made of polyurethane, and blood is pumped simultaneously out of each ventricle by a disk shaped device which, powered by air pressure, forces blood from the inlet to the outlet valve of the ventricle (Texas Heart Institute 2005).

A major disadvantage of this artificial heart is the fact that the patient has to be constantly attached to a large console which pneumatically powers the device. This limits the patient’s mobility considerably while on the device. However, as the device is intended to be a temporary bridge until a donor heart becomes available the period of restricted activity is not prolonged.

In October 2004, the FDA approved the CardioWest TAH for use as a bridge to transplantation device in the United States. It is important to note that the CardioWest TAH was developed to be used in a select group of transplant eligible patients who are facing imminent death due to bi-ventricular failure.

**Clinical Need and Burden of Disease**

An estimated 300,000 Australians are afflicted with chronic heart failure with approximately 30,000 new cases diagnosed every year (AIHW 2003). In 2003-2004, the number of patients (data collected from public hospitals) suffering from congestive heart failure or left ventricular failure was 29,346 and 10,957 respectively (AIHW 2005). Of this group, 1.5% would represent patients afflicted with acute heart failure and hence are possible candidates for extracorporeal membrane oxygenation or to have a left ventricular assist device (LVAD) implanted (Stevenson & Kormos 2001). A small proportion of this group would be patients facing imminent biventricular failure and are potential recipients of CardioWest.
Sixty five Australians were awaiting heart transplant as of 31 December 2003, six (9%) died while on the waiting list in 2003 (ANZOD 2004).

**Estimated Speed, Geographic and Practitioner Use, Patterns of Diffusion in the Health System**

The Cardiowest TAH is currently being used in the United States, France, Canada and Germany. SynCardia projects that the approximate 100 patients/year in the United States facing irreversible failure of both ventricles who are candidates for cardiac transplant could benefit significantly from the use of the CardioWest TAH (IntelliHealth 2004).

**Existing Comparators**

As previously stated, the CardioWest TAH was approved for use as a ‘bridge to transplantation’; the following devices may be used for the same purpose:

a) Ventricular assist device (LVADs and BVADs)
   - HeartMate Left Ventricular Assist Systems (Thoratec Corp., Pleasanton, California)
   - Novacor Left Ventricular Assist Device (Baxter Healthcare, Oakland, California)
   - Thoratec Ventricular Assist Device (Thoratec Corp., Pleasanton, California)

b) TAHs
   - AbioCor (AbioMed Inc., Danvers, Massachusetts) – intended as a long term option compared to CardioWest.

**Estimated Cost Impact**

The CardioWest TAH costs approximately USD$70,000 to USD$80,000 (Arizona Daily Star 2004), and this does not include surgical/hospital expenses. The Medicare Benefits Schedule does not list any reimbursement fees for heart transplants or any artificial heart implants. For the insertion of a left or right ventricular assist device (Item number 38615), Medicare reimbursement was $1299.90 while the reimbursement for a right and left ventricular assist device (Item number 38618) was $1620.30. According to the Health Insurance Commission, there have been 14 claims to Medicare for insertion of a left or right ventricular assist device (Item number 38615) and 12 claims for the insertion of a right and left ventricular assist device (Item number 38618) from June 2003 to June 2004 (Medicare Australia 2005).
Efficacy and Safety Issues

List of Studies Found

Total number of studies    5

Comparative studies    2

Case series studies    3 (16 papers)

The three studies included in this summary are highlighted in bold in the reference list.

Safety and efficacy data from two comparative studies and one case series have been selected for inclusion in this summary; these studied were included on the basis of patient numbers and years of experience with the use of the device. All Copeland studies were sponsored by SynCardia Inc. and patient overlap is probable between Copeland et al. (2004) and Copeland et al. (2001).

Survival to transplantation

Copeland et al. (2004) compared 81 heart failure patients who received the CardioWest TAH with 35 patients who did not receive any ventricular assist devices prior to cardiac transplantation (historical controls). Survival to transplantation was significantly higher in the CardioWest TAH patients (79%) compared to the control group (46%) (p<0.001). In addition to this, CardioWest recipients achieved an overall survival rate of 70% one year after the transplant, a significant improvement compared to the 31% survival attained of the control group (p<0.001). The treatment was considered successful (defined by the investigators as having the following characteristics 30 days post-transplant: alive, New York Heart Association Class I or II, ambulatory, non-ventilator dependent and not undergoing dialysis) in 69% of CardioWest recipients while controls achieved a 37% success rate (p=0.002).

A retrospective study (Copeland et al. 2001) compared the safety and efficacy of the CardioWest TAH (n=42), the Novacor left ventricular assist system (n=23), and the Thoratec ventricular assist system (n=26). The study revealed that survival to transplantation was 75% for CardioWest, 57% for Novacor and 38% for Thoratec ($X^2$ analysis indicates significant association between device type and survival to explant, p=0.012; CardioWest vs Thoratec; $z$ test, p=0.003) (Copeland et al. 2001). Survival rates from device implantation to discharge (after cardiac transplant) was 59% for CardioWest, 56% for Novacor and 33% for Thoratec ($X^2$ analysis, p=0.72; CardioWest vs Thoratec, p=0.035).

The case series study by Leprince et al. (2003) revealed significant improvements with regards to survival to transplantation over time. Survival rates increased from 43% (1986-1992, n=63, 32 patients received the old Jarvik-7 which is no longer manufactured) to 55% (1993-1997, n=36) and finally 74% (1998-2001, n=36) in heart failure patients whose main
aetiology was cardiomyopathy (98/127). This success was not duplicated in non-cardiomyopathic patients where 23% survived to transplantation prior to 1997 (n=19). However, marked improvements in this group of patients were achieved from 1998-2001 (n=10), where the patient survival to transplantation increased to 50%, this success however is partly attributed to better patient selection. Median duration of support with the CardioWest was 20 days before 1997 and escalated to 2 months after that due to shortage of donor hearts (Leprince et al. 2003).

Haddad et al. (2004) reported improvements in post-implantation survival over time similar to Leprince et al. (2003), with hospital survival rates improving from 61% (11/18 patients) for patients treated between 1986-1994 to 85% (11/13 patients) between 1994-2003. Haddad et al. (2004) attributed this improvement to changes in patient management (immediate sternal closure, early extubation, delayed transplantation, early rehabilitation and measurement of preformed reactive antibodies) as experience with the use of the device increased. As with Leprince et al. (2003), the duration of device support increased over time (1986-1994, 8[13.7] SD days cf. 1994-2003, 17[10.7] SD days), demonstrating the decline/shortage of donor hearts as more individuals are diagnosed with heart failure.

Arabia et al. (1997) reported a 70% (55/79 patients) survival rate for CardioWest recipients to transplantation (with 3 patients still awaiting transplantation at the time of writing). Of these, 50 patients (91%) survived the transplantation and were discharged. Mean duration of device support was 34 days (range 0-186 days).

**Cardiac Output**

Copeland et al. (2004) and Leprince et al. (2003) recorded patient’s cardiac output post-implantation as a separate measure of CardioWest’s effectiveness. Results revealed that haemodynamic status improved immediately after device implantation (Copeland et al. 2004, Leprince et al. 2003). Copeland et al. (2004) recorded sustained increases in cardiac index from a baseline of 1.9 to 3.2 litres/min/m² of body-surface-area, while Leprince et al. (2003) recorded similar findings with an increase from 1.9 [0.4] to 3 [0.5] litres /min/m². Other parameters such as mean arterial blood pressure, central venous pressure, mean systolic arterial pressure and organ perfusion pressure recorded considerable improvements as well (Copeland et al. 2004, Leprince et al. 2003).

**Infections and multiorgan failure**

Infection is a significant problem with implanted cardiac devices, Copeland et al. (2004) reported infection rates of 77% (73/95 patients, 125 events) from study entry to 30 days post-transplant (62% of infections occurred 28 days after device implantation), while Haddad et al. (2004) reported 39% (7/18, Group A) and 31% (4/13, Group B) infection.
rates during device support. Infection contributed to death in 9% (7/81) of patients in Copeland et al. (2004) and was the cause of death in one patient (1%). Leprince et al. (2003) stated that 18% (23/127) of patients died due to sepsis (mainly pulmonary infection) while the main cause of death was multiorgan failure (MOF), being responsible for 67% of deaths (Leprince et al. 2003). Similarly in Copeland et al. (2001), 50% of all deaths were due to MOF. Copeland et al. (2004) reported eight deaths (10%, 8/81 patients) in the CardioWest group due to MOF (seven died before transplant, one after transplant) while Arabia et al. (1997) reported that that MOF was responsible for 84% (15/21 patient deaths) of deaths during device support.

**Device malfunctions or complications**

Copeland et al. (2004) reported a perforation in one of the four layers of the CardioWest left ventricular diaphragm, resulting in one patient death 124 days post-implantation. Prior to that, Copeland et al. (2001) reported one death at 145 days post-implantation, also due to diaphragm rupture. A case device dysfunction was reported by Leprince et al. (2003), but was not fatal. The dysfunction was caused by a right ventricle diaphragm rupture that led to partial occlusion of inflow and outflow valves (Leprince et al. 2003). Leprince et al. (2003) postulates that the rupture was caused by the sterilisation process which involves high temperatures. CardioWest is now sterilised by SynCardia Systems Inc. prior to delivery, the risk of rupture may be decreased. Central venous catheter entrapment of the prosthetic tricuspid valve in the right ventricle occurred in two patients, causing the device to shutdown and hence resulting in death (Copeland et al. 2001).

Copeland et al. (2004) experienced complications with fitting the device in 6% (5/81) of patients; this was rectified in three patients by repeat surgery. Poor fitting of the device contributed to the deaths of two patients (2%, 2/81) (Copeland et al. 2004) while Leprince et al. (2003) stated that two device repositions were required due to filling curve impairment in the first post-operative day; the procedure was completed without complications.

Arabia et al. (1997) reported one device malfunction where the CardioWest drive lines were transiently kinked (but did not result in death) and three (4%) fit complications.

**Neurological events**

Copeland et al. (2004) reported 26 neurological events in the CardioWest TAH group; 11 stroke events, four transient ischemic attacks (TIAs), five anoxic encephalopathies, one metabolic encephalopathy, four seizures and one syncope. The linearised rate of stroke was 0.05 event per month. No deaths were cause by neurologic complications in this study (Copeland et al. 2004). Haddad et al. (2004) reported one TIA in patients treated from 1986-1994 and three TIAs in patients treated from 1995-2003. Leprince et al. (2003) reported two
TIAs in two patients (2/127); linearised neurologic accident rate was 0.2 event per patient-year (0.016 event per patient-month). Copeland et al. (2001) reported a lower stroke incidence for CardioWest patients (8%) compared to Novacor (21%) and Thoratec (12%). With regards to TIAs, 8% of CardioWest patients experienced TIAs, Novacor’s TIA rate was 21% while Thoratec was 4% (Copeland et al. 2001). Overall, neurological events appear to be fewer in CardioWest recipients. Nineteen neurological events occurred in 10 patients (13%) in Arabia et al. (1997)

**Ethical Issues**
CardioWest was designed to be a bridge to transplantation, so while transplantation may be delayed ultimately patients will need to be transplanted to survive. Hence, this technology is not a viable alternative for patients who do not wish to undergo transplantation.

**Cultural or Religious Considerations**
See above under ethical issues.

**Other Issues**
No issues were identified from the retrieved material.

**Conclusion:**
Some evidence exists supporting the efficacy of the CardioWest TAH in improving cardiac function and hence survival in patients awaiting cardiac transplant. Only a small number of patients in Australia (~7 patients yearly based on population estimates) would be eligible for this treatment. Based on the evidence available and the number of patients likely to benefit from this device, it is recommended that the following be conducted:

- [ ] Horizon Scanning Report
- [ ] Full Health Technology Assessment
- [x] Monitor
- [ ] Archive

**References:**


Copeland JG, III, Smith RG, Arabia FA, Nolan PE, Mehta VK, McCarthy MS, Chisholm KA. Comparison of the CardioWest total artificial heart, the Novacor left ventricular assist system and the Thoratec ventricular assist system in bridge to transplantation. *Ann Thorac Surg* 2001; 71(3 Suppl): S92-S97.


**Sources of Further Information:**

Arizona Daily Star – UMC’s artificial heart 1st to gain FDA’s OK. Last updated 2005.  


Texas Heart Institute-Jarvik-7 Total Artificial Heart. Last updated 2005.  
Search Criteria:
A search of MEDLINE, PubMed and Cochrane Library, Current Controlled Trials metaRegister, UK National Research Register, International Network for Agencies for Health Technology Assessments, relevant online journals and the Internet was conducted in April 2005.

Search terms used were: ‘CardioWest’, ‘Syncardia’, ‘Jarvik’, ‘bridge to cardiac transplantation’, and ‘artificial heart’.

This Horizon Scanning Prioritising Summary was prepared by Mr. Irving Lee from the NET-S Project, ASERNIP-S for the Health Policy Advisory Committee on Technology (Health PACT), on behalf of the Medical Services Advisory Committee (MSAC) and the Australian Health Ministers’ Advisory Council (AHMAC).