Jarvik 2000: evolution of surgical implantation from conventional to minimally invasive technique

Vincenzo Tarzia[1], Edward Buratto[1,2], Carlo Dal Lin[1], Michele Gallo[1], Giacomo Bortolussi[1], Jonida Bejko[1], Tomaso Bottio[1], Gino Gerosa[1]

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

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 Jarvik 2000 is a continuous axial flow left ventricular assist device (LVAD) with an impeller type pump. It has a unique power delivery system, which is tunneled to a retro-auricular skull pedestal in order to minimize driveline infections (1).

Conventional implantation of the Jarvik 2000 is performed off-pump through a left postero-lateral thoracotomy, with the outflow conduit anastomosed to the descending aorta. An alternative technique is performed through a full sternotomy, on cardiopulmonary bypass, with the outflow graft anastomosed to the ascending aorta (1-3). In both cases, the pump is implanted at the left ventricular apex. We describe an evolution of the Jarvik 2000 implantation technique, using a less invasive approach to surgery and perfusion (4) (*Video 1*).

Case 1—Conventional implantation via postero-lateral thoracotomy

Clinical vignette

A 62-year-old man presented with primary dilated cardiomyopathy, severe left ventricular dysfunction, severe pulmonary hypertension, high pulmonary vascular resistance, and was graded as INTERMACS class 2. A Jarvik 2000 was implanted as a bridge to transplant.

Surgical technique

The mastoid was prepared with a curvilinear incision, the skin and subcutaneous tissues were retracted and the periosteum was removed. Holes were drilled using a template to ensure correct location. The three-pin power connector was tunneled from the left postero-lateral thoracotomy, via incisions at the superior margin of the scapula and at the base of the neck, to the retro-auricular incision using a drain tube. The pins of the power cable were inserted into the pedestal, which was then mounted to the skull with six screws.

The descending aorta was exposed and a side-biting clamp was applied. The outflow conduit was anastomosed to the descending aorta using continuous 4-0 polypropylene sutures. Transesophageal echocardiogram (TEE) was used in conjunction with digital pressure to carefully locate the left ventricular (LV) apex. The sewing ring was secured to the LV apex with pledgeted interrupted sutures. A cruciate incision was made at the LV apex with a scalpel. The coring knife was then passed through this incision to remove a core of myocardium. Following its removal, the pump was quickly inserted and secured. TEE was used to confirm correct alignment of the pump inflow with the mitral valve, to avoid suction on the interventricular septum, as well as assist with de-airing maneuvers.

Case 2—Conventional implantation via full sternotomy

Clinical vignette

A 66-year-old man presented with idiopathic dilated cardiomyopathy and obesity, chronic renal insufficiency post right total nephrectomy, chronic hepatitis C infection,

chronic atrial fibrillation and severe pulmonary hypertension. He suffered frequent episodes of decompensated heart failure requiring admission and presented in INTERMACS class 3. A Jarvik 2000 was implanted as destination therapy due to multiple medical comorbidities and advanced age.

Surgical technique

The skull-mounted pedestal was prepared as previously described, and the three-pin connector on this occasion was tunneled to the pedestal via an incision on the neck. Using a median sternotomy and femoro-femoral cardiopulmonary bypass (CPB), the LV apex was exposed and the Jarvik 2000 pump was implanted. The outflow graft was inserted into a 20 mm ringed Gore-Tex conduit in order to prevent kinking and compression. The ascending aorta was identified and a side-biting clamp was applied. The outflow graft was anastomosed to the ascending aorta with a continuous 4-0 polypropylene suture. A needle was inserted into the vascular graft and the pump was activated at low flow to ensure de-airing, which was confirmed with TEE. The aortic clamp was then removed and the pump was fully activated. CPB was gradually weaned and then discontinued.

Case 3—Minimally invasive implantation

Clinical vignette

A 67-year-old man with congestive heart failure secondary to idiopathic dilated cardiomyopathy, and a history of frequent exacerbations, presented in INTERMACS class 2. He was not considered for cardiac transplantation due to age and multiple comorbidities, and was referred for Jarvik 2000 implantation as destination therapy.

Surgical technique

The skull pedestal was prepared as previously described and femoro-femoral ECMO was instituted for circulatory support. A left anterior mini-thoracotomy was made in the 5th intercostal space, providing access to the LV apex.

The pump was inserted as previously stated. A mini-sternotomy in an inverted T fashion was performed to allow access to the ascending aorta, and a side-biting clamp was applied. The outflow conduit was again encased in a ringed Gore-Tex conduit and anastomosed to the aorta with continuous 4-0 polypropylene sutures. De-airing was once more performed as previously described, and the pump was set to full flow. The patient was then weaned from ECMO.

Comments

Clinical results

Currently, we routinely implant the Jarvik 2000 using the minimally invasive technique. However in patients who have undergone previous sternotomy, postero-lateral thoracotomy remains the preferred technique to avoid the technical difficulties associated with re-sternotomy due to adhesions. Our experience has demonstrated that the minimally invasive technique allows earlier discharge from ICU and from the ward (4,5).

Advantages

The Jarvik 2000 has traditionally been implanted on CPB or off-pump by either left postero-lateral thoracotomy or median sternotomy (1-3). The benefits of the minimally invasive technique lie in the use of ECMO, the ability to directly access sites of anastomosis, and smaller incisions, which allow for a more rapid functional recovery. We choose to use ECMO support, considering the risk of ventricular arrhythmias and hemodynamic instability during implantation of the intraventricular pump, which are often poorly tolerated in patients with severe heart failure. Other authors have inserted cannulae for CPB to be used in case of emergency, but performed the procedure off-pump (6). However, we feel that there is an additional benefit in the routine use of ECMO as it allows the heart to be less volume loaded; this facilitates manipulation of the LV, reducing bleeding. Furthermore, compared to CPB, a lower dose of heparin is used, which reduces the risk of hemorrhage, and there is a lesser degree of inflammation.

Performing a mini-sternotomy in addition to the mini-thoracotomy has the benefit of allowing direct access to the ascending aorta and to the pulmonary artery. Thus, if right ventricular mechanical support is necessary, by removing the membrane oxygenator, the ECMO can be converted to a right ventricular assist device as a temporary measure.

Caveats

Due to the smaller incision, access to the left ventricular apex may be impaired, making implantation of the pump's sewing ring more challenging. Furthermore, assessment for presence of LV clot, myocardial bands and incomplete removal of

myocardial core may be impeded. In addition, as the outflow graft is blindly passed through the pericardium, its entire length cannot be visualized to assess for kinking, twisting or compression. To overcome this difficulty, the graft is protected with a more rigid Gore-Tex sleeve and echocardiography is used to ensure that there is adequate flow.

Conclusions

Evolution of surgical technique, now allows the implantation of the Jarvik 2000 axial flow pump through a combination of mini-thoracotomy and mini-sternotomy in ECMO. This provides the advantages of smaller incisions, more direct access to anastomotic sites and continuous circulatory support throughout the procedure.

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