Original article

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Bilateral mini-thoracotomy off-pump Jarvik 2000 implantation in regional asymmetric paravertebral analgesia

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We describe the surgical technique and treatment of a 59-year-old male with cardiogenic shock, who underwent a minimally invasive off-pump ventricular assist device (VAD) implantation with the aid of paravertebral regional analgesia in bilateral mini-thoracotomies as first procedure described in the literature. He was extubated soon after the procedure, in the operating room, with the aim to reduce the right ventricle impairment. These issues are particularly true for patients suffering from pulmonary hypertension and disease, in whom the shortest time of postoperative intubation is fundamental to allow self-inotropic support and recovery of the right ventricle. We illustrate how a minimally invasive implant may improve the clinical outcomes of VAD patients shortening their return time to active life.

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Introduction

Left ventricular assist devices (LVADs) represent the treatment for end-stage heart failure that is unresponsive to optimal medical therapy, as a bridge to either transplant or destination therapy. The Jarvik 2000 Ventricular Assist System development began in 1987 and has been refined over the past 27 years. Different approaches have been described for insertion of Jarvik 2000 (Jarvik Heart, New York, New York, USA), including off-pump,[1] subcostal[2] or mini upper sternotomy insertion.[3] We report the technical aspects of implantation of the Jarvik 2000 through a right mini-thoracotomy in second intercostals space and left mini-thoracotomy without the aid of the cardiopulmonary bypass (CPB), in bilateral asymmetric paravertebral block analgesia (PVB) in association with mild general anesthesia. Avoiding full sternotomy and CPB can significantly reduce the invasiveness of LVAD implantation. Additionally, continuous paravertebral analgesia is a well tolerated technique in cardiac surgery via thoracotomy, which enables early extubation with optimal pain control.[4] We describe the case of a male affected by chronic heart failure secondary to ischemic cardiomyopathy, who received a LVAD Jarvik 2000 with a less invasive technique consisting of a minimal surgical approach, off-pump implantation and bilateral asymmetric continuous PVB analgesia.

Technique

Patient

We describe the case of a 59-year-old male, who is a heavy smoker (60–90 cigarettes/day), with postischemic dilated cardiomyopathy and history of multiple congestive heart failure episodes. He received high doses of diuretics with difficult hemodynamic management until LVAD implantation. Peak VO_2 was 8.2 ml/kg/min. A transthoracic echocardiogram showed an ejection fraction of 12%, with dilatation of the left ventricle (end-diastolic volume index 132 ml/mq) and moderate functional mitral and moderate tricuspid regurgitation. Moderate right ventricle dysfunction, with tricuspid annular plane systolic excursion of 12 mm, was described. He was referred for implantation of a Jarvik 2000 as destination therapy. Exclusion criteria for heart transplantation were high dependence on tobacco and psychological assessment of unsuitability to quit smoking. Preoperatively, a computer tomography scan of the head and of the thorax without contrast medium injection was performed to determine skull thickness in the parietal areas and the aorta position in the mediastinal space in relation to the edge of the sternum. Generally, relative dextraposition of the ascending aorta (at least 50% of the calliper beyond the right parasternal line in the right part of the thorax at the level of the pulmonary trunk bifurcation) and moderate profoundness of the aortic root (not >10 cm from skin to the aortic valve annulus) provide optimal surgical exposure for the right mini-thoracotomy.[5]

Device

The Jarvik 2000 LVAD is an axial-flow pump. From the pump, a 16-mm graft (Hemashield; Boston Scientific Corporation, Natick, Massachusetts, USA) conveys blood to the ascending or descending thoracic aorta. The

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internal power cable exits through either the right upper quadrant of the abdomen or a skull-mounted pedestal, where the external power cable is connected. The pump is controlled by an external controller connected to a battery pack and provides a maximum flow of 7 l/min.[6]

Perfusion

The ECMO pump, a MAQUET Rotaflow RF 32 with a hollow fiber Quadrox PLS membrane oxygenator (MAQUET Cardiopulmonary AG, Hirrlingen, Germany), was prepared as a stand-by in the operating room in case of necessity. All circuit components were heparin-coated (Bioline coating; MAQUET Cardiopulmonary AG, Hirrlingen, Germany). The left common femoral artery and vein were exposed in the operating field in case of necessity, but were not surgically isolated.

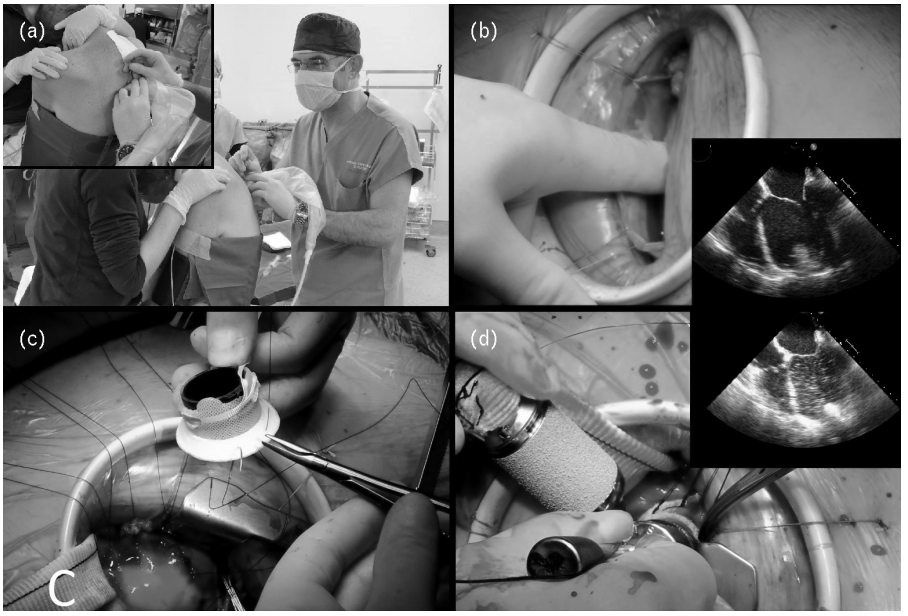
Anesthesia

In the operating room, after fully informed consent and light sedation, asymmetric bilateral PVB analgesia was performed. The left block was set by a catheter inserted 3 cm on the left side of the spinous process of T4 dorsalis vertebra, between fourth and fifth intertransverse process, and the right PVB was established by a catheter inserted 3 cm on the right of the spinous process of T2 dorsalis vertebra, between third and fourth intertransverse process. Identification of paravertebral space was done by the loss of resistance technique, with the aid of ultrasound guidance (Fig. 1a). A cumulative dose of 20 ml of 0.5% ropivacaine (100 mg) was given intraoperatively and 10 ml at mini-thoracotomies closure. The patient was positioned supine. Mild general anesthesia was induced with doses of sodium-thiopental (250 mg), fentanyl (200 μg) and rocuronium (50 mg). Endotracheal intubation was performed with a double-lumen tube, with the possibility to exclude the right or left lung when necessary. Anesthesia was maintained by propofol (3–5 mg/kg/h) and remifentanil infusions (0.05–0.1 μg/kg/min). Defibrillator pads were properly placed across the chest wall. Necessary arterial and venous lines were prepared and continuous monitoring of the patient was established. Central venous cathether and a transesophageal echocardiography probe were positioned for monitoring.

Implant procedure

After anesthesia was instituted and double-lumen endotracheal intubation performed, left-sided anterior minithoracotomy (5 cm) in fifth intercostal space was first performed and soft tissue and retractors were used for exposure. The left lung was excluded from the ventilation, providing a good exposure of the pericardium. By opening the pericardium, the heart apex was exposed. The insertion site of the Jarvik 2000 was marked on the left ventricle by echocardiographic assessment using a finger pushed on the apex for mimicking the inflow cannula (Fig. 1b). Heparin at this point was administered (5000 IU). The activated clotting time target was kept between 180 and 200 s. The sewing ring was sutured to

Fig. 1



(a) Asymmetric bilateral PVB analgesia was performed by a catheter inserted 3 cm on the left side of the spinous process of T4 dorsalis vertebra, between fourth and fifth intertransverse process, and by a catheter inserted 3 cm on the right of the spinous process of T2 dorsalis vertebra, between third and fourth intertransverse process. (b) The insertion site of the Jarvik 2000 was echocardiographically marked on the left ventricle. (c) The sewing ring was sutured to the myocardium using eight interrupted pledgeted, double-armed 3–0 polypropylene sutures. (d) Jarvik 2000 was off-pump inserted into the left ventricular cavity.

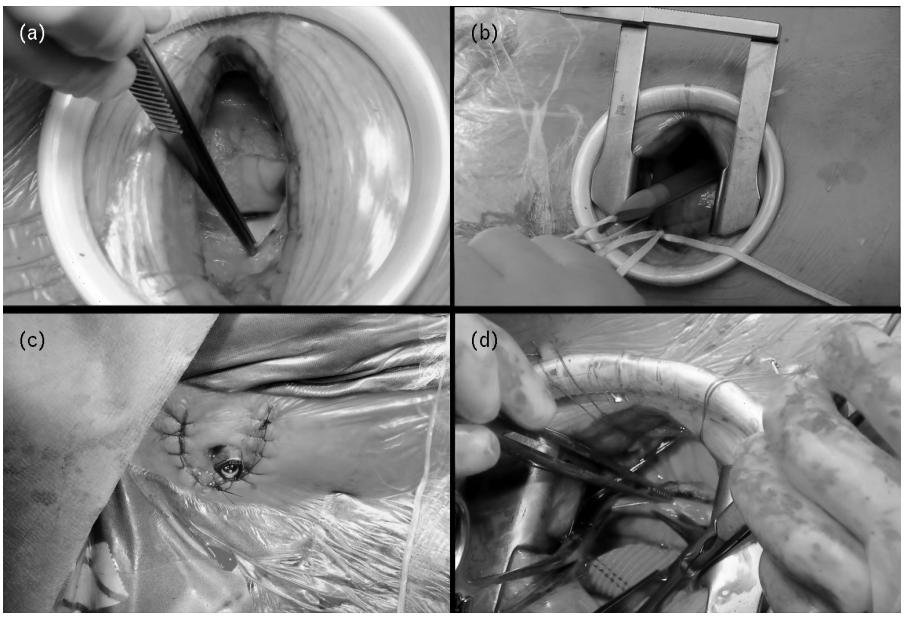
the myocardium using eight interrupted pledgeted, double-armed 3–0 polypropylene sutures (Fig. 1c). The sutures were tied to secure the sewing ring. The coring knife was inserted through a cruciate incision. A myocardial core and muscular debris were removed. As the coring knife was removed, the Jarvik 2000 simultaneously was off-pump inserted into the left ventricular cavity (Fig. 1d). The device was rotated to avoid rubbing of the power-connection or outflow-elbow against the rib-cage or diaphragm. The right housing position of the cannula was echocardiographically monitored and then secured to the ring by tightening the connecting strings. Immediate venting of the air bubbles detected in the left ventricle by transesophageal echocardiography was performed by releasing the clamp on the outflow vascular prosthesis, holding it high over the heart level, so that the blood pumping out from the ventricle flowed out through the graft.

The procedure continued through an incision in the second intercostal space (Fig. 2a). The medial angle of incision should correspond just prior to the projection of the right internal mammary artery, which is 1.1–1.5 cm lateral to the sternal edge, whereas the lateral angle is continued in the intercostal space considering the incision entity of almost 5–7 cm. Upon the opening of the pleural cavity, the right lung is gently pushed down with a moist gauze. The right lung was this time excluded from the ventilation. The anterolateral mediastinal fat tissue and thymic remnants are divided and coagulated for better hemostasis. The right mammary artery was resected to better expose and reduce the risk of post-operative bleeding. The pericardium is opened antero-laterally and pericardial sutures are tacked to the skin edges, enhancing the exposure of the ascending aorta (Fig. 2a). The soft tissue protector and rib retractor were used to open the working field. At this point, the outflow tract and the power cable were tunneled through the left mini-thoracotomy underneath the pericardium following the profile, using a blunt-tip instrument, and stretched to the right thoracotomy (Fig. 2b).

The pedestal was then secured to the parietal bone behind and slightly above the right ear. A C-shaped incision was made around the right ear, and a full-thickness flap was raised down to the periostium. The periostium was elevated beneath the skin flap, and a template was used to define the position of the bone screws. Any skull irregularity was burred off to give a flat surface. The choice of positioning the pedestal on the right side was detected by major facility of tunneling the power cable from the second right intercostal space than tunneling it from the fifth intercostals mini-thoracotomy access. The three-pin connector was tunneled from the right mini-thoracotomy, through the neck, to the behind-the-ear connector position, and then inserted in the titanium pedestal (Fig. 2c).

To convey the three-pin connector and power cable to the skull-pedestal site, the incisions were made first 1 cm

Fig. 2



(a) The pericardium is opened anterolaterally and pericardial sutures are tacked to the skin edges, enhancing the exposure of the ascending aorta. (b) The outflow tract and the power cable were tunneled through the left mini-thoracotomy by using a blunt-tip instrument. (c) The pedestal is secured to the parietal bone behind and slightly above the right ear. (d) The prosthesis is cut and anastomosed to the aorta by using a continuous 4–0 polypropylene suture.

under the clavicle bone, and the other on the neck, almost 2 cm under the basis of the ear. The tunneling was achieved by inserting the three-pin connector within the end of an intercostal drain. The drain was withdrawn out of the chest and through the neck to the scalp. The three-pin connector was then inserted through the titanium pedestal. This was then implanted firmly onto the external table by using 7-mm or 8-mm bone screws. The postauricular skin flap was repositioned with the percutaneous pedestal through the punched-out defect. The scalp and skin incisions were then closed securely. The external power cable was attached to the skull pedestal, and with the Jarvik 2000 heart inside the ventricle, the power was switched on to test the circuit and remove eventual air bubbles.

Measurement of the right length and position of the outflow graft was established, monitored by echocardiography in order that no encumbrances on the right ventricle were detected. A side-biting clamp was placed on the ascending aorta. The prosthesis was cut and anastomosed to the aorta using a continuous 4–0 polypropylene suture and then reinforced with bioglue surgical adhesive (Fig. 2d). Air removal was accomplished using a needle inserted into the outflow graft and activating the pump at low speed. Once no air bubbles were detected in the left ventricle by transesophageal echocardiography, the side-biting clamp was released and the Jarvik 2000 was fully activated. Two drainage tubes and a catheter for continuous flushing with saline and antibiotic solution for each access were positioned.

Immediately after skin suturing, the mild general anesthesia with remifentanil and propofol infusion was suspended. The patient was rapidly weaned from the mechanical ventilation. An optimal postoperative pain control was observed. Four times he was asked whether he was in pain, and he always answered negatively. The extubation was possible in a short time in the operating room, to guarantee self-inotropic support and afterload reduction to the right ventricle (Fig. 3a and b).

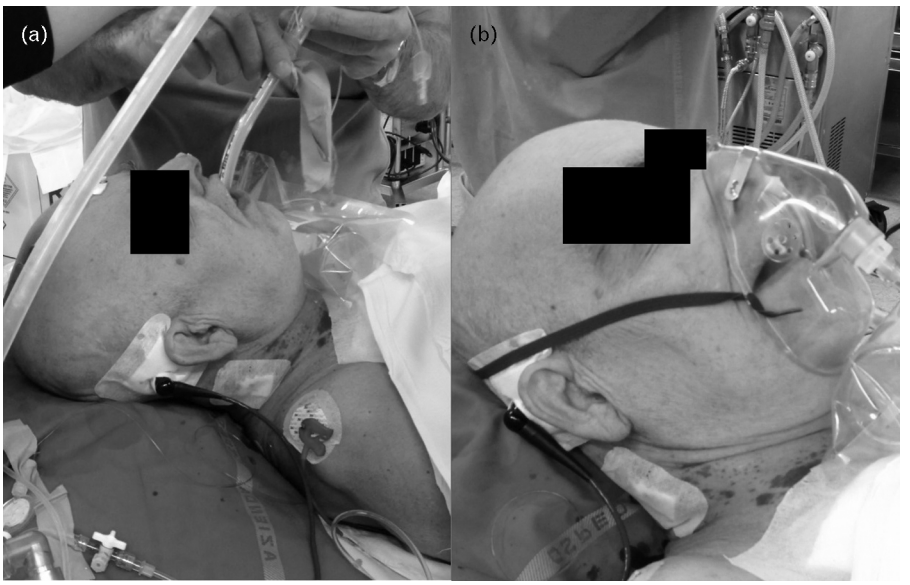
The patient was transferred to the ICU in stable hemodynamic conditions, with low infusion of inotropic drugs. Postoperative pain control was assured by continuous infusions of 0.2% paravertebral ropivacaine at 5 ml/h speed, 3 μg/h in elastomeric device of sufentanil, and paracetamol boluses (1 g/6 h). The Visual Analog Scale was used to assess the quality of analgesia and data were collected at 1, 6, 24 and 48 h and reported to be between 2 and 3. PVB catheter was maintained for 48 h and removed when the patient was discharged from the ICU. There were no complications related to the PVB, both intraoperatively and postoperatively.

The patient was transferred to a ward section on the second postoperative day. In 2 weeks, he became autonomous for his daily activities and VAD management and was discharged from the hospital to the rehabilitation center. No blood unit was transfused during hospitalization.

Comments

Application of mechanical VAD in severe heart failure, opened for discussion decades ago, is now well established for temporary support such as a bridge to transplantation, or for long support as a bridge to decision.[7,8] The typical LVAD candidate is extremely ill and may not

Fig. 3



(a and b) The patient is rapidly weaned from the mechanical ventilation and extubated.

be able to tolerate even the slightest operative insult. Therefore, device implantation through smaller, less traumatic incisions is a desirable goal. For the patients who are transplant candidates, preserving the sternum intact is an important advantage, allowing safer transplant surgery. Additionally, the median sternotomy decreases lung volumes by up to 60% and reduces thoracic motion by up to 70%; 4 months postoperatively, significant decreases in vital capacity, forced expiratory volume in 1 s, peak expiratory flow rate, functional residual capacity and total lung capacity are still present, accounting for a restrictive respiratory pattern as compared with preoperative values. In contrast, with a less invasive approach, patients have greater sternal stability and less thoracic wall motion during inspiration.[9–11] Consequently, also the early postoperative extubation, allowing a rapid transit from a pressure positive mechanical ventilation toward a physiologic pressure negative spontaneous breathing, favors a pulmonary pressure drop and a right ventricle downloading, which is frequently compromised in these patients. In fact, no incidence of postoperative right ventricular assist device support was observed in a small series of patients treated with this technique (six patients already operated on). Furthermore, the inotropic support time in this small group was significantly shorter than in all the other 56 LVAD patients implanted in our unit, confirming the more prompt hemodynamic recovery of patients treated with the PVB and minimally invasive approach.

Minimally invasive cardiac surgery via mini-thoracotomy was devised to reduce morbidity because of its potentially less inflammatory response, reduced transfusion requirements and minimal scarring, reduced recovery times and the consequent cost.

Although this technique is associated with a smaller incision, the pain from thoracotomy persists. The management of postthoracotomy pain is very challenging and may diminish the advantage of this surgery.[12] Regional analgesic techniques have shown excellent analgesia in mini invasive cardiac surgery via thoracotomy, and PVB is a well accepted technique for pain relief. Continuous infusion of local anesthetic provides effective analgesia, restores respiratory mechanics and prevents early reduction of pulmonary functions. Moreover, there is no risk of epidural hematoma in the event of conversion to total heparinization.[13]

Additionally, avoidance of CPB should greatly improve early outcomes, preventing the deterioration in pulmonary gas exchange normally seen after cardiac surgery. Because only half the usual dose of heparin is given in off-pump cases, and because most CPB-related damage happens within the first few minutes, avoiding even a short period of CPB may reduce the postoperative bleeding that typically results from the patient's altered coagulative-state.[14]

In conclusion, our case of LVAD implantation with a minimally invasive technique, as the first case described in the literature, off-pump, throughout bi-minithoracotomies, and with the aid of paravertebral analgesia associated with mild general anesthesia, lends credence to the notion that a minimally invasive surgical technique associated with regional analgesia is a well tolerated and reproducible technique, even for this kind of surgery, and it enables early extubation with optimal pain control.

The authors state that this manuscript has not been published previously and is not currently being assessed for publication by any journal other than the *Journal of Cardiovascular Medicine*.

Each author has contributed substantially to the research, preparation and production of the article and approves of its submission to the journal.

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