Masters of Cardiothoracic Surgery

Transitioning to total artificial heart for patients supported with short term mechanical circulatory devices

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Clinical vignette

The patient is a 58-year-old male with a history of ischemic cardiomyopathy who already underwent a coronary artery bypass surgery for myocardial infarction. He has developed progressive symptoms of decompensated heart failure over the last two years, with multiple recent readmissions. Cardiopulmonary exercise testing demonstrated a low maximal oxygen consumption (i.e., VO_2m =10.3 mL/kg min). Hemodynamic evaluation showed low cardiac output with pulmonary hypertension and elevated filling pressure. Echocardiography showed global hypokinesis and biventricular failure with a LVEF =15%. The patient was listed for heart transplantation. Despite inotropes, his condition continued to decline, requiring support with extra-corporeal membrane oxygenation (ECMO) and an intra-aortic balloon pump (IABP). Although listed as high priority for heart transplant, transplantation was not performed, thus, taking in consideration the high risk of mortality, a SynCardia 70 cc total artificial heart (TAH) was implanted as a bridge to heart transplantation.

Surgical techniques

Installation and preparation of the device

The patient was placed in the supine position with femoral and right jugular access made accessible in the operative field in the case veno-venous ECMO (V-V ECMO) was needed. Transesophageal echocardiogram (TEE) was prepared for use.

Before the surgery, the device was prepared by sealing the Dacron grafts, both aortic and pulmonary, with CoSeal Surgical Sealant (Baxter, Illinois, USA), then both the device and the grafts was soaked in Rifampin.

Exposition

After a routine median sternotomy, the heart and the main vessels were exposed in the same manner as for heart transplantation. We then medially divided the left diaphragm and dissected underneath the posterior rectus fascia creating a left upper abdominal peritoneal pocket. Next two 2 cm incisions, 5 cm apart, were made below the left costal margin through the rectus fascia and two intermuscular tunnels created for the pneumatic drivelines. These are maintained using two 1-inch Penrose drains.

Cannulation and initiation of cardiopulmonary bypass (CPB)

After heparin is administered, ECMO lines can be connected directly to the CPB circuit, and another venous cannula can be added in the jugular vein or in the superior vena cava (SVC). It is also worth noting that the SVC and inferior vena cava (IVC) are preferable to be preserved for subsequent transplantation; however, classical bi-caval—or through the right atrium—along with aortic cannulation are still available and possible options for cannulation as presented in the video. At this stage, the surgical field can be flooded with carbon dioxide to minimize air embolization.

Operation

After aortic cross clamping and administration of

cardioplegia, ventriculectomy was performed. We divided the aortic root and the main pulmonary artery just above the valvular commissures and then began excision of the right ventricle along the acute margin, 1–2 cm distal and parallel to atrioventricular groove. The incision is continued anteriorly into the right ventricular outflow tract. We then divided the intracardiac portion of any defibrillator or pacing wires and tract them in the SVC. Incision of the interventricular septum was made to open the left ventricle, similarly, extending the left ventricular incision laterally and parallel to the atrioventricular groove into the left ventricular outflow tract. We then divided and removed the remains of the interventricular septum.

Inspection was made of the right atrium through the tricuspid valve, specifically looking for the patent foramen ovale. If found, it can be closed using 3-0 Prolene sutures to prevent interatrial shunting. Similarly, we oversew the orifice of the coronary sinus with 3-0 Prolene.

Following this, we excised the tricuspid valve leaflets leaving cuffs several millimeters long to the annulus; in similar fashion, we excised the mitral valve leaflets, again leaving several millimeters to the annulus. Left and right ventricular cuffs are trimmed away to leave about 1 cm of ventricular muscle attached to the atrioventricular valves. The cuffs were oversewn with 2-0 Prolene suture for hemostasis and to reduce the orifice size to match the total artificial heart (TAH) atrial quick connects.

The left and right quick atrial connections were trimmed to 0.5–1 cm, then both were inverted in their respective left and right ventricular cuffs to make the anastomoses of the quick atrial connectors to mitral and tricuspid easier by using a continuous 3-0 Prolene suture. Reinforcement of the anastomosis was made with additional 2-0 Prolene. It is worth noting that the corners of the interventricular septum are common areas for leak, highlighting why they should also be reinforced. Now, the aortic graft quick connect is trimmed to about 2 cm and the pulmonary graft quick connect trimmed several cm longer to allow room for the aortic graft to pass below. Distal sutures of the pulmonary then aortic grafts are performed using a 4-0 Prolene in a continuous end-to-end suture.

To facilitate pump explantation and reduce blood loss at transplantation, two large sheets of Gore-Tex (W.L. Gore & Associates, Delaware, USA) were sutured to the atrioventricular groove. Next, suction and irrigation were made to the left and right atrium to ensure there was no residual embolic debris. Both ventricles were then connected to their respective orifices with careful assessment of the exact position of the ventricles, avoiding any twisting of the graft. After venting the aorta and the pulmonary outflow, the aortic cross clamp was removed and lungs ventilated. Pumping can be initiated at a very slow rate for de-airing, then accelerated gradually to increase the heart rate, while the patient is weaned from CPB.

Completion

Following weaning from CPB, decannulation and Protamine administration were performed, then a careful hemostasis was accomplished. It is worth mentioning that sometimes the pump is comprised of the IVC or left pulmonary veins and it is advisable to place a heavy suture around the artificial right ventricle and secure it with left costal margin. Next, a Gore-Tex membrane is placed around the anterior surface of both ventricles before chest closure in standard fashion.

Comments

Transitioning to TAH for patients who are supported with short-term mechanical circulatory devices is challenging (1,2). First, the INTERMACS level of these patients implies high-risk surgery. In addition, bleeding management is one of the key points which requires optimized hemostatic conditions (3). Furthermore, pulmonary edema can also occur under ECMO support, which may lead to hypoxemic complications at the initiation of TAH and this may also require V-V ECMO for temporary respiratory support (4). Hence, where femoral venous cannulae are used; we rinse them with saline solution to keep them available after protamine. For such patients, using jugulo-femoral drainage during CPB could be interesting to facilitate VV-ECMO and to preserve superior and inferior vena cava for future transplantation (5).

Acknowledgments

None.

Footnote

Conflicts of Interest: Pascal Leprince and Guillaume Lebreton are proctor for SynCardia. The other authors have no conflicts of interest to declare.

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