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Postoperative Support With the Centrifugal Pump Ventricular Assist Device (VAD)

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Centrifugal pump left ventricular assist device is a useful adjunct in pediatric cardiac surgery, as a bridge to recovery, or in some cases, to transplantation. This form of circulatory support may not have the universal applicability of extracorporeal membrane oxygenation, but it is equally or more effective in properly selected patients. The technology for centrifugal pump support is now quite standardized, and the advantages well documented. In this chapter we discuss the problems of indications, case selection, technical aspects of the circuit, and general clinical management. Results since 1989 are also presented.
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Centrifugal pump ventricular assist device (VAD) was first used at the Royal Children's Hospital in Melbourne, Australia in 1989, and continues to occupy an important place in the armamentarium of the pediatric cardiothoracic surgeon.[1] An example follows: An 11-year-old girl with a history of multiple syncopal episodes experienced a prolonged episode after exercise and a sudden change in posture. She was resuscitated by a team of paramedics who noted that she had monomorphic ventricular tachycardia on her electrocardiographic monitor. Subsequently, she was cardioverted to sinus tachycardia, intubated, and ventilated for severe pulmonary edema.

On arrival at University of California-San Francisco Children's Hospital, her 2-dimensional transthoracic echocardiogram showed depressed left ventricular contractility but no coronary anomaly. Her 12-lead electrocardiogram showed Q waves in V_1 and V_2, suggestive of anterior wall myocardial infarction, supported by elevations in troponin and creatine kinase levels.

The patient was taken to be catheterized, but developed new ST changes on induction of anesthesia, with further worsening in her left ventricular contractility. Just after catheter insertion her pulmonary artery pressure was 71/41 mm Hg, and her left ventricular pressure 77/37 mm Hg. She had increasing pulmonary edema, hypotension, and obvious low cardiac output. Aortic root angiography showed a normal right coronary artery. An injection in the left sinus did not produce a coronary artery image, but when the left coronary was engaged a normal distal vessel was seen. At this point a transesophageal echocardiographic study was performed which demonstrated that the left coronary arose from what should have been a non-coronary sinus (Fig 1).

The patient was immediately taken to surgery, where it was noted that the left coronary did indeed arise from the non-coronary sinus, with a proximal intramural segment. There was a slit-shaped orifice with an acute angle of exit, and an effective left coronary artery stenosis due to the above features. The operation performed to deal with this lesion was a combination of techniques developed at the University of California-San Francisco (Fig 2),[2,3] including pericardial patch ostioplasty (extended onto the body of the coronary artery) and translocation of the main pulmonary artery to the left pulmonary artery, to open the space between the great vessels and relieve any possible compression. Myocardial ischemic time was 30 minutes, but low cardiac output, systemic hypotension, and left atrial and pulmonary hypertension supervened after separation from cardiopulmonary bypass (CPB), and pump support was resumed. A

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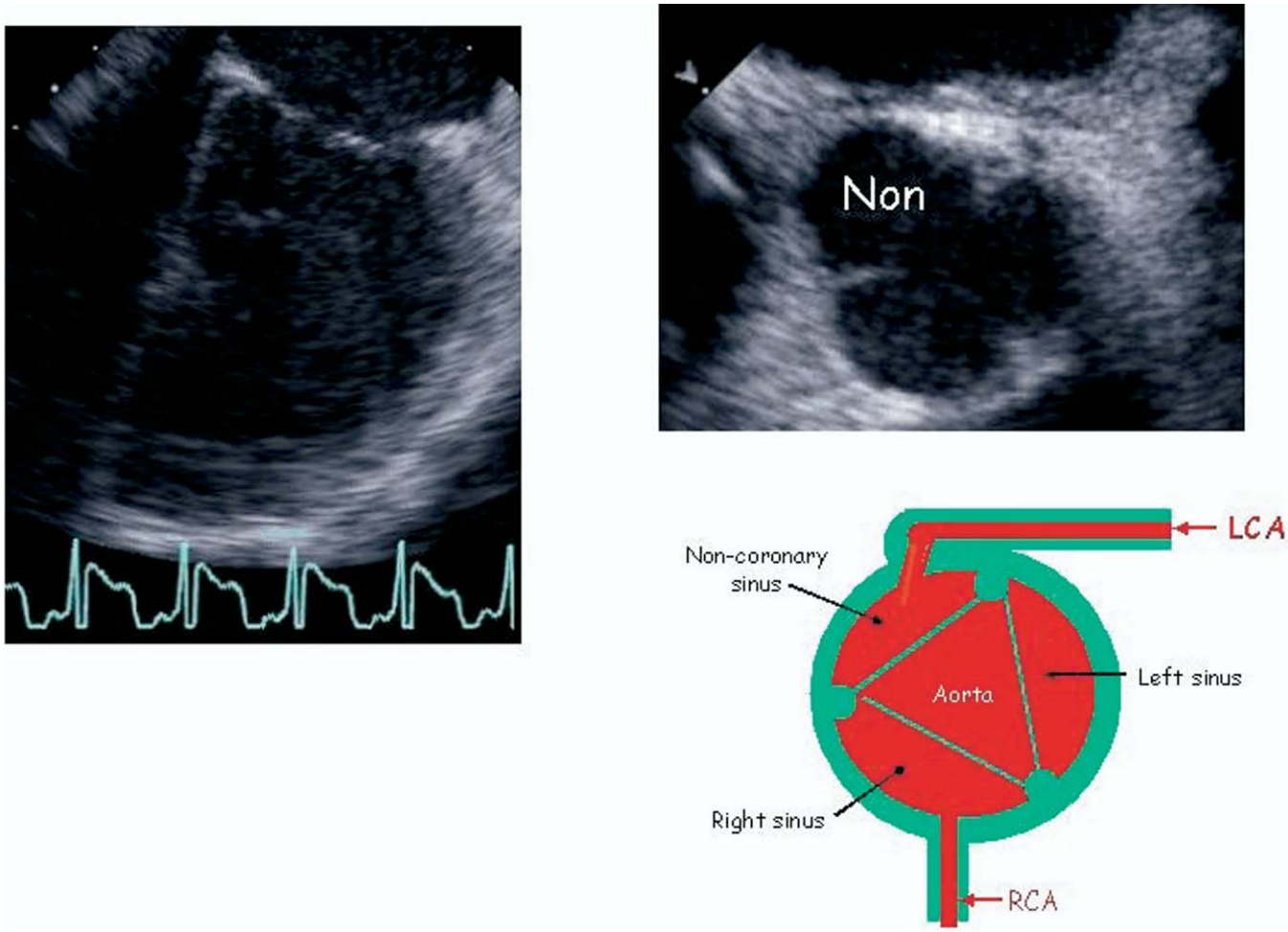

Figure 1 Transesophageal echocardiogram revealing an anomalous left coronary arising from what should have been a non-coronary sinus.

transesophageal echo study showed excellent flow in the reconstructed left coronary artery, but severe left ventricular contractile dysfunction.

This patient, with a structurally normal heart and acute left ventricular dysfunction, could not be weaned from CPB. The treatment options for such a patient are shown in Figure 3. Extracorporeal membrane oxygenation (ECMO) has been the mainstay of therapy in most units, either with a centrifugal or roller pump. However, a patient with potentially reversible univentricular dysfunction, in the absence of other severe problems, is very likely to be supportable in a simpler way, using a centrifugal pump left VAD, which was favored in this case.[4] Implantable assist devices would constitute another option, but the expense and perhaps the level of complexity of this type of treatment would probably outweigh any benefits over centrifugal pump support in the short term. The main factor that would lead many groups to use ECMO rather than VAD is skepticism regarding the ability of the right heart to cope with the cardiac output, with additional concerns concerning oxygenation and CO_2 clearance, both of which require a certain level of pulmonary parenchymal function and ventilation. These concerns are valid, but are overstated at times. We have used a simple algorithm to reach an intraoperative decision, and we now have confidence in our ability to predict and to provide successful short-term support without an oxygenator (Fig 4). With the patient at 150 mL/kg flow on standard arteriovenous CPB, a cannula is added to the left atrium. The patient is ventilated normally and the right atrial cannulas are removed. Inotropes are reduced to the level required to support right heart function, and a 2-dimensional echocardiographic assessment is made to look for right atrial and/or right ventricular dilation or other failure signs. If right atrial and pulmonary artery pressures remain in a physiologic range, gas exchange across the oxygenator is stopped, usually with the addition of inhaled nitrous oxide to the ventilator circuit. If blood gases and ventilatory mechanics remain in an acceptable range, then the CPB circuit can be changed for a centrifugal pump VAD circuit. If the patient fails this assessment, then one can use ECMO with a centrifugal pump circuit and hollow fiber oxygenator.

Our patient was supported with a Bio-Medicus BP80 centrifugal pump (Bio-Medicus, Eden Prairie, MN) using a heparin-bonded circuit with initial flows of 3 L/min. Cannulation was via the ascending aorta and right upper pulmonary vein to left atrium. Intraoperatively, heparin was reversed completely with protamine with a plan to resume anticoagulation