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Anesthesia for Ventricular Assist Device Placement in Pediatric Patients: Experience From a Single Center

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ABSTRACT

Background. The use of a ventricular assist device (VAD) as a bridge to heart transplantation in the pediatric population has evolved over the past decades This article presents our institution's clinical experience in the anesthetic management of pediatric patients with end-stage heart failure who underwent implantation of a VAD between June 2009 and August 2012.

Methods. Between February 2011 and August 2012, implantation of a VAD was performed in 10 children of mean age 8.6 years. This retrospective review analyzed their perioperative anesthetic care.

Results. All patients had end-stage heart failure due to dilated cardiomyopathy. We used invasive arterial and central venous pressure monitoring and intraoperative transesophageal echocardiography in conjunction with intravenous administration of either ketamine (1 mg/kg) and midazolam (n = 3) or thiopental (3–5 mg/kg; n = 7). The mean intraoperative fentanyl dose was 434 ± 264.27 μg. Anesthesia was maintained with sevoflurane. Dopamine, dobutamine, and epinephrine were infused in 8, 10, and 5 patients, respectively. Inhaled nitric oxide was administered to all patients. The amounts of perioperative blood, fresh frozen plasma, and thrombocyte suspension transfusions were be 2.3 ± 0.82 (range, 1–4), 1.6 ± 0.69 (range, 1–3), and 2.4 ± 1.42 (range, 0–4) units, respectively. On average, patients were extubated 23 hours after arrival in the intensive care unit and exited there on day 6. Six patients were successfully bridged to heart transplantation, 2 died during the follow-up, and 2 patients remain on VAD support.

Conclusion. VAD is increasingly being used as a bridge to heart transplantation in the pediatric population. Anesthesiologists must be vigilant about the pathophysiology of heart failure, the operative procedure, and the implanted device.

CARDIAC transplantation, the definitive therapy for pediatric patients with congenital or acquired end-stage heart failure, is limited by the number of available donors.[1] The use of a ventricular assist device (VAD) as a bridge to heart transplantation in the pediatric population has evolved over past decades.[2] These devices act as mechanical pumps assisting the damaged ventricle and helping restore normal perfusion and end-organ function. The systems for mechanical support in children include intra-aortic balloon pumps, extracorporeal membrane oxygenators (ECMO), centrifugal pumps, and pulsatile or axial flow VADs.[3–7] It is always a challenge for anesthesiologists to manage pediatric patients with cardiomyopathy, an important cause of heart failure and a major indication for heart transplantation in children. This article presents our institution's clinical experience in the anesthetic management of pediatric patients with end-stage heart failure who underwent implantation of a VAD between June 2009 and August 2012.

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0041-1345/–see front matter
http://dx.doi.org/10.1016/j.transproceed.2013.02.068

METHODS

Between June 2009 and August 2012, we performed implantations of a VAD in 10 children (8 males, 2 females) of mean age of 8.6 years who were diagnosed with end-stage heart failure. Nine patients were implanted with the Berlin Heart Excor Pediatrics (Berlin Heart AG, Berlin, Germany) and 1 with the Heartware Ventricular Assist System (HeartWare, Inc., Miramar, Fla, United States). Our retrospective review analyzed perioperative anesthetic care. The preoperative patient data extracted from the patient folders included demographic features, congestive heart failure etiology, Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) grade, and the last left ventricular ejection fraction on preoperative two-dimensional echocardiography. Intraoperative and postoperative patient data extracted from anesthesia and intensive care unit (ICU) records, respectively, included the following: intravenous (iv) access, including peripheral and central lines; anesthetic drugs such as induction drug and dose; volatile anesthetic; intraoperative fentanyl dose; and muscle relaxants. The intraoperative record also included duration of cardiopulmonary bypass (CPB), blood transfusions, and vasoactive medications upon exiting the operating room. Postoperative data extracted from the ICU record included blood product transfusions, as well as times to extubation and to ICU discharge.

Statistics

Continuous data are presented as mean values ± standard deviations; discrete variables are presented as percentages and total numbers.

RESULTS

All patients had the diagnosis of end-stage heart failure due to dilated cardiomyopathy. Seven patients (70%) were INTERMACS grade 1 and 3 patients (30%) were INTERMACS grade 2 at the time of left ventricular assist device (LVAD) implantation. Patient demographic and preoperative data are summarized in Table 1. Review of the intraoperative anesthesia records showed an institutional protocol: operating room monitoring of electrocardiogram, pulse oximetry, and invasive blood pressure (Horizon XL, Mennen Medical Inc., Southampton, USA). On admission to the operating room, 20/22G radial arterial catheters and either 18G (n = 3), 20G (n = 5), or 22G (n = 2) peripheral venous cannulas had already been placed into patients. After anesthetic induction, a triple-lumen central venous catheter (Certofix Duo, B. Braun Melsungen A.G.) was placed in the internal jugular central vein with an additional 7F introducer sheath in 7/10 patients. Direct arterial blood pressure, central venous pressure, central and rectal body temperatures, and urine output were continuously monitored during the intraoperative period in addition to intraoperative transesophageal echocardiography (TEE).

Table 1. Preoperative Patient Characteristics

No. of patients	10
Age (y, range)	8.6 ± 5.05
Body weight (kg)	30.62 ± 19.44
Gender (M/F)	8/2
INTERMACS grade	
Grade 1	n = 7 (70%)
Grade 2	n = 3 (30%)
Left ventricular ejection fraction (%)	32.8 ± 9.07
Right ventricular ejection fraction (%)	36.8 ± 3.99
Preoperative 2 inotropes	10 (100%)
Preoperative 3 inotropes (added adrenaline)	7 (70%)
Preoperative mechanical ventilation	3 (30%)
Dialysis requiring renal failure	2 (20%)
Elevated bilirubin and hepatic enzymes	6 (60%)

Abbreviations: M, male; F, female.

Anesthesia was induced via the iv route in all patients, using ketamine (1 mg/kg) and midazolam (0.05 mg/kg; n = 3) or thiopental (3–5 mg/kg; n = 7). Neuromuscular relaxation was provided using 1 mg/kg rocuronium. The intubated patients were mechanically ventilated targeting an end-tidal CO_2 partial pressure of 32–40 mm Hg (Ventilator 710; Siemens, Solana, Sweden). Anesthesia was maintained with end-tidal 2%–4% sevoflurane in a 50% oxygen–50% air mixture. Fentanyl was the intraoperative analgesic for all patients (mean dose, 434 ± 264.27 μg; range, 150–750). A propofol infusion was used to supplement anesthesia in the majority of patients (n = 8; 80%).

Following a median sternotomy to cannulate the ascending aorta and both vena cavae, all operations were performed with CPB under moderate hypothermia. The 8-year-old child who was implanted with the Heartware Ventricular Assist System (HeartWare, Inc.) was placed on CPB and an atrial septal defect closed via a right atriotomy before device implantation. The inflow cannula of the HeartWare pump was placed into the left ventricular apex. The outflow graft was anastomosed to the ascending aorta under partial clamping. Review of the intraoperative records yielded a mean duration of CPB to be 105.71 ± 11.70 minutes. Intraoperative fluid replacement was established using crystalloids or colloids according to the hemodynamic data. The total perioperatively transfused amounts of blood, fresh frozen plasma, and thrombocyte suspension were 2.3 ± 0.82 (range, 1–4), 1.6 ± 0.69 (range, 1–3), and 2.4 ± 1.42 (range, 0–4) units, respectively. Dopamine, dobutamine, and epinephrine infused after weaning from CPB were continued upon exiting the operation room in 8, 10, and 5 patients, respectively. Inhaled nitric oxide was administered during and after weaning from CPB in all patients.

All patients were transferred to the cardiac intensive care unit and mechanically ventilated after the operation. Review of the ICU records indicated that inhaled nitric oxide, milrinon, and inotropic and vasopressor agents were used to support the right ventricle during the early postoperative period. The mean time to extubation was 23.90 ± 23.87 hours (range, 10–90). Inhaled iloprost treatment was started after extubation. Unfractionated heparin infusion was started at 18–24 hours with monitoring by activated partial thromboplastin time (aPTT) levels every 6 hours targeting 2.5–3.0 international normalized ratio. In addition to heparin, dipridamole was administered as antiadhesive therapy from the third day. Over the following days, acetylsalicylic acid (ASA) and warfarin Na were also added to the