Anesthetic Management for Implantation of the Left Ventricular Assist Device

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Mechanical methods of supporting the circulation using compact blood pumps have been developed to better treat profound heart failure[1]. Pneumatically powered left ventricular assist devices (LVADs) are now in clinical use to provide temporary circulatory support for patients with profound but reversible heart failure after openheart surgery or acute myocardial infarction.

Though general anesthesia is required for this procedure, we have encountered no related literature in the anesthetic field. We describe our experiences in anesthetic management for the implantation of LVADs in twelve patients.

Report of Our Experiences

Clinical application of the LVAD system began at our institution in 1982[2]. Since then LVADs have been used in twelve patients with profound left ventricular failure which did not respond to catecholamine administration and intra-aortic balloon pumping. In our patients, left ventricular failure was determined by systolic arterial pressure lower than 80 mmHg, mean left atrial pressure greater than 20 mmHg and cardiac index of less than 2.0 l/min/m^2. A list of our twelve patients is shown in table 1.

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Preoperative diagnoses of the patients revealed coronary artery disease in seven patients, valvular heart disease in four and congenital anomalies of the heart in one. LVADs were indicated in eight patients because of the difficulty in weaning them from cardiopulmonary bypass after surgical repair was completed. Another three patients were returned to the operation room for LVAD implantation because of postoperative hemodynamic deterioration. In the one remaining patient, refractory cardiac failure due to acute myocardial infarction necessitated the surgical intervention. Ages of the twelve patients ranged from 3 to 73.

The preoperative condition of our patients showed that three were in ASA class 3, six were in class 4, and another three were in class 5. Ten of the twelve patients were emergency cases. Emergency operations were performed in the catheterization suite following cardiopulmonary resuscitation in two patients because cardiac arrest occurred during cardiac catheterization.

The anesthesia was induced and maintained with 10–70 (mean 35) μg/kg of fentanyl and pancuronium bromide, supplemented by diazepam (0.1–0.5 mg/kg) and/or nitrous oxide (less than 50%). In all patient for whom LVAD implantation was the primary procedure, circulatory support with an intra-aortic balloon pumping and catecholamine infusion had been instituted preoperatively. The pump was implanted

Table 1. List of the patients

Case	Age	Diagnosis	Procedure	ASA	Outcome
1	36	mitral stenosis/regurgitation tricuspid regurgitation	mitral valve replacement tricuspid anuloplasty	4E	weaned
2	62	coronary artery disease VSD	VSD closure	4E	weaned
3	52	aortic stenosis/regurgitation mitral stenosis/regurgitation	ACBG aortic valve replacement	5E	died on pump (DOT)
4	3	VSD	VSD closure	3	weaned
5	66	mitral stenosis	mitral valve replacement	3	died on pump
6	66	coronary artery disease	ACBG	5E	weaned
7	71	coronary artery disease VSD	VSD closure	4E	survived
8	60	coronary artery disease	ACBG	4E	weaned
9	26	aortic stenosis (supra-valvular)	aortoplasty	5E	died on pump (DOT)
10	69	coronary artery disease	LVAD implanted exclusively	3E	died on pump
11	73	coronary artery disease VSD	VSD closure	4E	survived
12	44	coronary artery disease left ventricular aneurysm	aneurysmectomy cryoabrasion	4E	died on pump

ACBG: aorto-coronary bypass graft, DOT: death on the table, LVAD: left ventricular assist device, VSD: ventricular septal defect

under cardiopulmonary bypass through the median sternotomy incision. In our LVAD system, the blood is drained from the left atrium and returned to the ascending aorta. Figure 1 shows the completion of the procedure.

Pumping from the device was started along with gradually reducing the flow of the cardiopulmonary bypass. When elevation of the central venous pressure (CVP) up to 15 mmHg by volume loading did not make sufficient return of the blood to the left atrium, we started right heart support with catecholamine infusion. In most of the cases dopamine and/or epinephrine were successfully administered. Occasional systemic hypotension was treated with norepinephrine infusion. Besides catecholamine infusion we also used intravenous nitroglycerin to decrease right ventricular afterload. In one patient, biventricular bypass was employed using another assist device between the right atrium and the pulmonary artery.

We used the CVP rather than the left atrial pressure (LAP) to assess preload when the drainage of the blood from the left atrium was fluctuating. Cardiopulmonary bypass discontinued when LVAD flow reached 2.0 $l/min/m^2$ and was stabilized. Then protamine sulfate was administered to reverse heparinization.

Seven of the twelve patients were successfully weaned from LVADs. However, five of the seven died from infection or multiple organ failure during their stay in the intensive care unit. The remaining two of the seven were discharged from the hospital.

Discussion

Pneumatically powered LVADs have developed to provide circulatory support in patients with profound left heart failure which was refractory to pharmacologic therapy and intra-aortic balloon pumping[1]. LVADs perform pumping function, reducing cardiac work, improving coronary blood flow until the heart recovers from its injury. According to a recent report[3], implantation

was performed in more than 250 patients with a long-term survival rate of over 20%.

During the induction and pre-bypass period, anesthetic management for implantation of LVADs is similar to that for open-heart surgery for seriously ill patients. However, one must consider physiologic changes after the implantation since a large portion of cardiac output in the systemic circulation depends on the LVAD. Neither drug mediated cardiac depression nor arrythmia exists in mechanical pumps. On the other hand, one can not expect inotropic effects of catecholamines on the left heart performance. Therefore left heart output is mostly determined by preload in an LVAD system. Peripheral actions of anesthetics and other agents might be exaggeratedly appeared in patients on LVADs. Emphasis must be placed on adjustment of pre and afterload in the systemic circulation.

Right heart function is reported to be very important for the proper performance of LVADs[4]. Sufficient preload is necesary if one is to expect acceptable performance from LVADs. However, pulmonary blood flow, which is preload of the pump, decreases when right ventricular failure occurs. Right heart function may be impaired by concomitant left heart decompensation and/or myocardial ischemia. Prolonged duration of cardiopulmonary bypass is also a possible cause of depressed right heart performance. A left heart bypass may unmask pre-existing right heart failure[5]. Furthermore, decompression of the left ventricle by the left heart bypass could possibly cause right heart dysfunction[6].

In these circumstances, catecholamine infusion is essential to enhance right ventricular contractility. We successfully used dopamine and/or epinephrine infusion. Others reported that isoproterenol was the most effective with its vasodilating action on pulmonary arteries[7].

Besides catecholamine infusion, vasodilators are effective for both systemic vasoconstriction and elevated pulmonary artery pressure. However, excessive use of vasodilating agents can cause systemic hypotension, reducing blood flow to vital organs. An appropriate dose of such agents should be administered to maintain the systemic resistance within normal range.

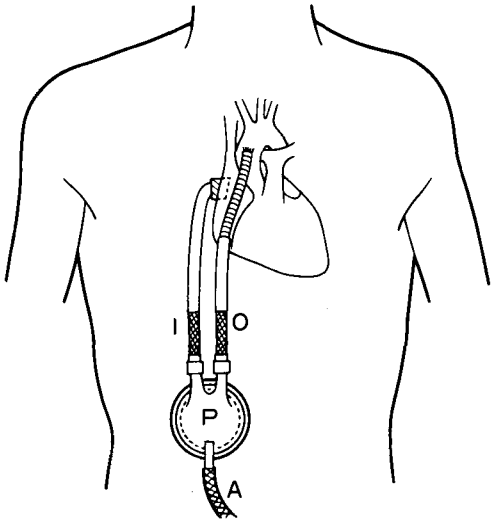

Fig. 1. Diagram of implanted left ventricular assist device (LVAD). The blood is drained from the left atrium and returned to the ascending aorta. I, inlet conduit; O, outlet conduit; P, pneumatic pump; A, air line.

One of the serious complications associated with LVAD implantation was continued bleeding. In fact, two of our twelve patients returned to the operation room for reexploration because of diffuse postoperative bleeding. Platelet transfusion was reported to be helpful in achieving hemostasis[5].

Monitoring during this procedure was basically the same as other open-heart surgery. In general, LAP is used for monitoring preload. In patients on LVADs, LAP is not only an indicator of preload but also essential to control the pump flow[2]. However, surgical manipulation of the heart may affect the drainage of the blood to the pump, and LAP may fluctuate. As a result, LAP may not be the best indicator of preload. It is better to perform volume loading according to CVP in these conditions.

Application of the LVADs may be a promising modality for patients with refractory heart failure. Progress in this field, however, remains a challenge for cardiac anesthesiologists. Meticulous management including adjustment of pre and afterload, and administration of catecholamines and vasodilators for right heart support is essential in the anesthetic management for implantation of LVADs.

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