Intraoperative transoesophageal echocardiography for implantation of a pulsatile left ventricular assist device

S. J. GEORGE, J. J. M. BLACK AND M. J. BOSCOE

Summary
We describe the insertion of a permanent implantable left ventricular assist device and intraoperative transoesophageal echocardiography in this instance. We also review the literature on the use of intraoperative transoesophageal echocardiography. (Br. J. Anaesth. 1995; 75: 794–797)

Key words
Monitoring, echocardiography. Equipment, left ventricular assist device.

The successful use of the HeartMate (ThermoCardioSystems Inc., (TCI) Woburn, MA, USA) left ventricular assist device as a bridge to cardiac transplantation has previously been described [1, 2]. Currently, up to 40 % of patients awaiting cardiac transplantation die before an organ is available. The device (fig. 1) is a temporary means of maintaining adequate cardiac output, by draining blood from the left ventricle and pumping it into the ascending aorta, allowing a further period for transplantation. We describe our use of transoesophageal monitoring (TOE) during the procedure and propose a routine for its use in the different stages of implantation (table 1).

Case report
A 44-yr-old man with a history of idiopathic dilated cardiomyopathy was scheduled for implantation of a TCI, HeartMate implantable left ventricular assist device. Two days before surgery he was admitted to the ITU after deterioration in his cardiac status, and required ventilation of the lungs and inotropic support. On the morning of surgery he was haemodynamically stable, receiving maximal inotropic support with adrenaline, dobutamine and enoximone, and had a central venous pressure of 11 mm Hg, pulmonary artery pressure 35 mm Hg and pulmonary capillary wedge pressure 26 mm Hg. Systolic pressure (100 mm Hg) was augmented by intra-aortic balloon counterpulsation at 1:1. Preoperative transthoracic echocardiography showed moderate mitral regurgitation and a dilated poorly functioning left ventricle with fractional shortening of 10 %. Additionally renal and hepatic impairment was present, with a preoperative creatinine concentration of 170 μmol litre⁻¹, aspartate aminotransferase 1687 iu litre⁻¹ and plasma bilirubin 107 μmol litre⁻¹.

Marked hypotension was associated with the instability of transfer from the intensive care unit. However, this gradually improved before induction of anaesthesia. After induction of anaesthesia in the operating room, a Hewlett-Packard 5-MHz Omniplane transoesophageal probe was introduced uneventfully. TOE assessment continued while the surgical procedure progressed. After sternotomy, hypotension was persistent and cardiopulmonary bypass (CPB) was begun rapidly. TOE showed a dilated poorly contracting left ventricle, as expected, and no thrombi were identified in any of the cardiac chambers. Right ventricular assessment was curtailed by haemodynamic instability and rapid institution of CPB.

The sternotomy wound was extended to below the umbilicus and a pocket was created for the device in the left upper quadrant of the abdominal wall beneath the rectus abdominis and the internal oblique muscles. The device was placed within the pocket and the inflow conduit was tunneled through the left anterior hemidiaphragm adjacent to the left ventricular apex. The heart was fibrillated electrically while perfused and a core of left ventricular apex was excised. The inflow conduit was placed well away from the intraventricular septum, directed towards the mitral orifice and secured to the left ventricular apex. A pre-clotted woven Dacron outflow conduit was sutured to the right aspect of the ascending aorta and secured to the outflow of the device (fig. 1). After thorough de-airing he was weaned from CPB with some difficulty because of poor right ventricular function; he was receiving a combination of adrenaline, enoximone and noradrenaline, with left ventricular assist device output of 2.5 litre min⁻¹. With the addition of nitric oxide at 30 ppm, left ventricular assist device output increased to 4.0 litre min⁻¹. He was then transferred to the intensive care unit. After an initial promising period, he developed progressive hepatic failure and subsequently multiple organ failure from which he died on the 13th postoperative day.

S. J. GEORGE, MRCP (UK), FRCA, J. J. M. BLACK, FRCS, M. J. BOSCOE, FRCA, Harefield Hospital, Hill End Road, Harefield, UB9 7JH. Accepted for publication: July 14, 1995. Correspondence to S.J.G.
Table 1  Proposed routine for the use of transoesophageal echocardiographic monitoring in the different stages of implantation of a left ventricular assist device

| After induction and before CPB                                                                 | Presence of atrial septal defect and patent foramen ovale  |
| Right ventricular function                                                                    | Tricuspid and aortic valve competence                      |
| Detection of thrombi in the cardiac chambers and ascending aorta                              |                                                             |
| Before weaning from CPB                                                                        | Position—visual inspection of left ventricular inflow cannula |
|                                                                                               | Air emboli—exclude air entrapment and entrainment         |
|                                                                                               | Right and left ventricular volume adjustments—adjustment of the device flows to maintain adequate right ventricular filling |
| After bypass                                                                                    | Right ventricular function—assessment of right ventricular function and filling, response to pharmacological agents and need for assist device |
|                                                                                               | Air embolism—continuous assessment of four-chamber view/aortic outflow to detect air introduction into the device caused by generated subatmospheric pressure |
|                                                                                               | Doppler— independent confirmation of device flows and cardiac output |

Figure 1  Schematic diagram illustrating the position of the left ventricular assist device.

Discussion

Some aspects of the use of TOE monitoring to aid the insertion and subsequent weaning from CPB have been discussed in previous reports of the use of ventricular assist devices and the HeartMate [3–5]. We aim to consolidate previous reports and propose a routine (table 1) for TOE in this situation to maximize its benefits.

After induction and before CPB, TOE can assess the presence of thrombi, an atrial septal defect, patent foramen ovale, right ventricular function, tricuspid and aortic valve competence and ascending aortic plaques. TOE has demonstrated superior sensitivity in the identification of intracardiac thrombi compared with transthoracic echocardiography [6]. Suitable candidates for implantation of the device have a higher risk of cardiac thrombi because of many factors, including cardiac chamber dilatation, atrial fibrillation and low cardiac output. Intraoperative assessment would enable removal of a significant thrombus or other appropriate measure.

Similarly, identification of aortic incompetence may allow correction. Aortic incompetence compromises the function of the device as forward flow from the device into the ascending aorta would result in regurgitant flow back into the left ventricle. The presence of an atrial septal defect would allow a shunt, especially as a subatmospheric pressure is applied by the device to the left ventricle. Intraoperative identification would allow operative closure.

Right ventricular function is critical to the success of the implantation as it is only the left ventricle that is assisted. A pre-bypass baseline would allow a reasonable goal for postoperative support with fluid management, inotropic support and reduction of pulmonary vascular resistance. Unfortunately, there was inadequate time for pre-bypass assessment of right ventricular function, although we were able to confirm aortic competence and lack of thrombi.

Before weaning from CPB, TOE may play a central role in confirming optimal placement of the inflow cannula, that is [5], away from the interventricular septum, directed towards the mitral valve and ensure that the position allows the left ventricle to empty completely. Air emboli may be distinguished echocardiographically either as microemboli (small echodense circles that are highly mobile) or macroemboli (large intensely echodense areas with acoustic shadowing beyond). TOE may help to identify air entrapment in three situations thus allowing effective de-airing and reducing the probability of air emboli.

In open heart procedures air may be retained in those areas that can provide a roof over an air pocket [7]. Additionally, air may be retained within the device. Third, and as a late feature, air may be entrained sometimes catastrophically because of subatmospheric pressure generated through the device. When the device tries to fill against an empty and collapsed left ventricle, a subatmospheric pressure of up to 5 mm Hg can be generated. This may allow entry of air through sites (venting needle holes, the interstices of the graft and suture lines) that are otherwise airtight. In our patient, we detected this as a sudden backwash of microemboli in the left ventricle (fig. 2) and we immediately clamped the outflow graft to prevent systemic air embolization. Alternatively, it may be possible to monitor continuously the aorta distal to insertion of the outflow cannula to detect air embolization.

In a multicentre study, Frazier and colleagues [1] demonstrated the uniformly poor outcome in those requiring right ventricular assist devices. With TOE, right ventricular function can be monitored continuously [8] as CPB is weaned. Progressive right ventricular dilatation with diminishing device flows suggested right ventricular failure and we were able to assess the need for right ventricular assist, vary fluid management and introduce nitric oxide.

After bypass, TOE enabled us to confirm aortic valve competence with the device in situ, and satisfactory emptying of the left ventricle was confirmed by the aortic valve remaining closed. In addition, knowing the internal diameter of the outflow cannula, and with continuous wave Doppler
from within the outflow cannula [9], we were able to confirm the device cardiac output with an independent measure in vivo (fig. 3).

In summary, we have described our use of transoesophageal echocardiography in the implantation of the TCI HeartMate device. We recommend that its use is invaluable and propose a routine for examination to maximize its benefits.

References

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