Can Intraoperative Transesophageal Echocardiography Predict Postoperative Aortic Insufficiency in Patients Receiving Implantable Left Ventricular Assist Devices?

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Objective: **Aortic insufficiency (AI) develops in 25% of patients after left ventricular assist device (LVAD) insertion. The objective of this study was to evaluate the occurrence of new-onset AI upon initiation of cardiopulmonary bypass (CPB) required for LVAD insertion and the potential ability of this new-onset AI to predict development of post-LVAD insertion AI.**

Design: **Forty-one patients undergoing LVAD insertion were studied. Intraoperative transesophageal echocardiography (TEE) evaluation was performed at baseline (post-induction, pre-sternotomy), 5 minutes after CPB initiation, and post-chest closure. Patients were followed up postoperatively for development of AI.**

Setting: **Single university hospital.**

Participants: **Patients undergoing elective LVAD insertion.**

Interventions: **None.**

Measurements and Main Results: **At baseline, 35 patients exhibited none—trace AI, 4 exhibited mild AI, 2 exhibited moderate AI, and none exhibited severe AI. After initiation of CPB, 34 patients exhibited no change in degree of AI yet 7 exhibited an increase in AI severity. However, all 7 patients exhibited no change in degree of AI at chest closure and one exhibited a decrease in AI severity. Four patients developed at least moderate AI during the postoperative period (range 3-8 months). However, only one of these patients exhibited an increase in AI severity after initiation of CPB for LVAD insertion. No significant changes in aortic root measurements were observed during the entire intraoperative period (within patients nor between patients with/without development of at least moderate postoperative AI).**

Conclusions: **One in 5 patients undergoing LVAD insertion will demonstrate an increase in AI severity at CPB initiation without changes in aortic root measurements. None of the information obtained from intraoperative TEE seemed to predict development of at least moderate postoperative AI.**

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KEY WORDS: left ventricular assist device, aortic insufficiency

LEFT VENTRICULAR ASSIST DEVICE (LVAD) implantation is now an accepted treatment for patients with end-stage heart failure, both as a bridge-to-transplant as well as an alternative to transplant.[1] As LVAD technology has evolved rapidly, use of continuous-flow pumps now predominates due to improved clinical outcomes, reduced complication rates, and improved durability when compared with first-generation pulsatile pumps.[2] Indeed, continuous-flow LVAD support improves functional capacity, quality of life, and survival in patients with New York Heart Association (NYHA) Class IIIB or IV heart failure.[2]

Unfortunately, as use of LVADs has increased, specific device-related morbidity has been discovered.[3,4] One of the most important morbidities associated with use of LVADs is postoperative development of aortic insufficiency (AI). Despite relatively normal aortic valve (AV) anatomy/function at time of LVAD insertion, AI develops in approximately 25% of patients at 1 year post-LVAD insertion.[5–15] Furthermore, development of AI in this scenario decreases survival.[12]

The mechanism of post-LVAD insertion AI is complex and poorly understood yet likely contributing factors include altered AV biomechanics from direct injection of blood into the ascending aorta, generating unnatural forces which jeopardize valve integrity.[4,16] Recent retrospective analyses[8,12–14] indicated that important risk factors for development of post-LVAD insertion AI may be increased aortic root size and/or failure of the AV to open normally after LVAD insertion.

Typically, initiation of cardiopulmonary bypass (CPB) is required for LVAD insertion. In many ways, initiation of CPB mimics an LVAD (direct nonpulsatile injection of blood into the ascending aorta). Perhaps altered AV biomechanics at initiation of CPB may predict altered AV biomechanics initiated by an LVAD. Previous clinical studies evaluating risk factors for post-LVAD insertion AI are limited by retrospective design and reliance on preoperative echocardiographic assessment (which may be months before surgery). No study has yet evaluated the ability of intraoperative transesophageal echocardiography (TEE) to assess the AV immediately before and after initiation of CPB to potentially clarify risk factors for development of post-LVAD insertion AI. The authors' hypothesis was that patients will develop new-onset AI upon initiation of CPB required for LVAD insertion and that this new-onset AI may predict development of post-LVAD insertion AI.

METHODS

After institutional review board approval and informed written consent, 41 patients undergoing elective LVAD insertion over 1 year (Feb 3, 2012 to Feb 28, 2013) were studied prospectively. Exclusion criteria were known AV pathology, previous AV surgery, mechanical ventilator support, and/or mechanical circulatory support. Intra-aortic balloon support was not an exclusion criterion.

After intravenous access and radial artery catheterization, general endotracheal anesthesia was induced. Intraoperative anesthetic technique was standardized and consisted of

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1053-0770/2601-0001$36.00/0

http://dx.doi.org/10.1053/j.jvca.2015.01.004

moderate amounts of intravenous midazolam/fentanyl/muscle relaxant/inhaled isoflurane consistent with tracheal extubation 2-4 hours after intensive care unit arrival. After anesthetic induction, all patients underwent central venous cannulation via the internal jugular vein or subclavian vein (MAC two-lumen central venous access set, 9-French, Arrow International, Inc., Reading, PA) and insertion of a continuous cardiac output pulmonary artery catheter (Swan-Ganz CCOmbo CCO/SvO_2/VIP, 8-French, Edwards Lifesciences, LLC, Irvine, CA).

Surgical/CPB technique was standardized. After sternotomy and exposure of the heart, intravenous heparin (300 units/kg) was administered and CPB initiated. Target activating clotting time was greater than 420 seconds. Standard ascending aortic cannulation and venous cannulation (1 cannula if simple LVAD, 2 if additional valve surgery) were used. Both participating cardiac surgeons used a "long" aortic cannula (tip in distal aortic arch/descending aorta verified via TEE). Target CPB flow was greater than 2.4 L/min/m^2 and target mean arterial blood pressure was greater than 60 mmHg. Normothermia was used if simple LVAD, mild hypothermia (34°C) if additional valve surgery. Separation from CPB (after TEE verification of cardiac de-airing) entailed decreasing CPB flow while increasing LVAD revolutions per minute. Clinical CPB separation goals via TEE were a decompressed left ventricle, a midline ventricular septum, and reasonable right ventricular function (with appropriate inotropic/pulmonary vasodilator support). Protamine was administered in amounts that normalized the activating clotting time.

All patients underwent a comprehensive TEE examination[17] after induction of anesthesia. AV assessment[18] was performed at 3 intraoperative time points: Baseline (postinduction, presternotomy), 5 minutes after CPB initiation, and post-chest closure. At each time point, the midesophageal aortic valve long-axis view (120°-140°) was obtained and 4 AV diameters assessed: Aortic annulus diameter (AoAnD), sinus of Valsalva diameter (SOVD), sinotubular junction diameter (STJD), and ascending aorta diameter (AsAoD).[18] Also, at each time point, AI was graded (none—trace, mild, moderate, and severe) via color-flow Doppler (Nyquist limit 50-60 cm/sec) and objectively determined/defined via standardized criteria (jet diameter/left ventricular outflow tract diameter, vena contracta, etc) and the jet (if present) characterized (central, eccentric).[18] The AV was evaluated for opening (none, intermittent, and every heartbeat) at the time of chest closure. The authors chose to evaluate AV opening at this time because "optimal" LVAD settings (revolutions per minute, etc) have been determined by the cardiac surgeon and functional for at least an hour.

AV assessment via TEE or transthoracic echocardiography usually was performed during the postoperative period before hospital discharge and intermittently thereafter. Follow-up echocardiograms (when performed) were evaluated for AoAnD, SOVD, STJD, and AsAoD grading/characterization of AI (if present) as previously described.

Statistical Analysis

Microsoft Excel software was used for all statistical analysis. Results are presented as the mean (including standard deviation and/or range) or absolute number of patients. Within-group differences (aortic root measurements) and between-group differences (aortic root measurements in patients with/without AI) were analyzed via a type-2, two-tailed t-test.

RESULTS

Preoperative demographic characteristics are presented in Table 1. Of the 41 patients, 17 represented destination therapy, 17 were bridge-to-transplant, 1 was bridge-to-decision, and 6 were unknown. All surgeries were performed by 1 of 2 experienced cardiac surgeons and anesthesia was delivered by 1 of 7 experienced cardiac anesthesiologists who performed the intraoperative TEE examinations (all diplomates/certified via the National Board of Echocardiography; Perioperative Transesophageal Echocardiography). Nineteen patients exhibited preoperative atrial fibrillation, 1 required hemodialysis, and 4 were profoundly obese (body mass index >40 kg/m^2). Thirty-two patients had some sort of defibrillator/pacemaker in situ and 6 were on intra-aortic balloon support. Thirteen patients had undergone previous cardiac surgery (8 coronary revascularization, 2 coronary revascularization + mitral valve surgery, 2 mitral valve surgery, and 1 mitral/tricuspid valve surgery).

Thirty-four patients had the HeartMate II (Thoratec Corporation, Pleasanton, CA) inserted, and 7 patients received the HeartWare (HeartWare Inc., Framingham, MA). Eleven patients had simple LVAD insertion (no additional cardiac surgery). Of the 30 patients having additional cardiac surgery, 23 underwent tricuspid valve repair, 14 underwent mitral valve repair, 5 underwent AV repair/closure, 5 underwent patent foramen ovale closure, 3 underwent coronary revascularization, and 2 required right ventricular assist device insertion.

Five patients died during the immediate postoperative period (in-hospital death). Of the 36 patients discharged, the

Table 1. Preoperative Demographic Characteristics

Characteristic	Mean or Absolute Number of Patients	Range
Age (years)	58.0	(25-84)
Gender (male:female)	35:6	
Height (cm)	174.8	(157-189)
Weight (kg)	90.7	(57-187)
Body surface area (kg/m^2)	2.08	(1.63-3.13)
Creatinine (mg/dL)	1.6	(0.6-4.9)
Previous cardiac surgery	13	
Oral medications		
Beta-blocker	16	
Angiotensin-converting enzyme inhibitor	18	
Angiotensin-receptor blocker	4	
Nitrate	11	
Diuretic	30	
Antiarrhythmic	22	
Oral hypoglycemic	3	
Insulin	16	
Intravenous medications		
Milrinone	15	
Dobutamine	4	
Dopamine	2	
Nitroprusside	5	
Bumex	1	
Heparin	7	

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