Preoperative patient optimization for mechanical circulatory support

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Introduction

Two patients are presented for consideration of left ventricular assist device (LVAD) placement for mechanical circulatory support. Pertinent right heart catheterization and laboratory data are presented in *Table 1*.

(I) A 56-year-old man with ischemic cardiomyopathy with a left ventricular ejection fraction of 20%. He has had five admissions in the last six months for intravenous loop diuretics, despite dietary and medication compliance and optimization of his outpatient medical regimen. Body mass index (BMI) is 18;

(II) A 42-year-old woman presents from home with lethargy after months of "feeling sick". On admission, blood pressure is 72/58 mmHg, heart rate is 118 beats/minutes, and oxygen saturation is 84% on room air. She is intubated and transferred to the cardiac intensive care unit, where transthoracic echocardiogram shows a dilated left ventricle with an ejection fraction of 15% and global hypokinesis of both ventricles.

Both of these patients raise unique questions of how the team can best optimize their risk prior to LVAD placement in order to avoid foreseeable postoperative pitfalls. There are three common postoperative complications in LVAD patients and established pre-operative predictors and preventative strategies for each.

Prior to discussing those complications, it is important to review the contraindications for LVAD placement (*Table 2*) (1). While these may change as technology advances, currently, the presence of any of these contraindications should obviate LVAD placement. It is also important to recognize that some contraindications are reversible and short term mechanical support can occasionally be considered in these patients.

Safeguards and pitfalls

Postoperative pitfall 1: right ventricular (RV) failure

In the early post-operative period, several mechanisms may contribute to RV failure, including a sudden increase in cardiac output, increased RV preload from increased venous return, and increased RV wall strain and afterload due to septal shift, and pulmonary vasoreactivity after cardiopulmonary bypass. RV failure leads to liver and renal failure, underfilling of the LV and pump causing arrhythmias or shock, and a higher peri-operative mortality (1). *Table 3* lists independent clinical, laboratory, hemodynamic, and echocardiographic predictors of RV failure.

Prospective data is limited regarding pre-operative interventions (aside from diligent patient selection) that effectively reduce the risk of RV failure. Anecdotal evidence and experience has suggested that pre-operative diuresis, use of intra-aortic balloon pump, and inotropic support to optimize RV preload and hemodynamics can reduce the risk of RV failure in high risk patients (1).

Postoperative pitfall 2: bleeding

In patients undergoing placement of continuous flow devices, the most common postoperative adverse event in the first 30 days is nonsurgical bleeding (2). The reported incidence of nonsurgical bleeding ranges from 15-53% in the literature (2,3), with studies of newer centrifugal flow devices reporting lower bleeding rates (13-15%) (4). The most common sources of bleeding are mediastinal and thoracic (high early risk, but diminishing over time), epistaxis, intracranial, and gastrointestinal (GI) tract (more prominent later after implantation, with an average time to first GI bleed of 460 days) (2,5). The risk of GI bleeding is higher with continuous-flow than with pulsatile-flow

Table 1 Laboratory and hemodynamic data for patient 1 and patient 2

Parameters	Patient 1	Patient 2
Blood urea nitrogen (mg/dL)	21	54
Creatinine (mg/dL)	1.1	2.3
Total protein (g/dL)	4.2	7.4
Albumin (g/dL)	1.8	3.8
Bilirubin (mg/dL)	0.5	3.2
Aspartate aminotransferase (AST) (U/L)	22	96
Prothrombin time (seconds)	10.1	21.2
White blood cell count (per mm^3)	3,300	12,100
Absolute lymphocyte count (per mm^3)	600	4,500
Hemoglobin (g/dL)	9.6	13.4
Platelet count (per mm^3)	175,000	430,000
Central venous pressure (mmHg)	7	18
Pulmonary artery pressure (mmHg)	35/12	55/25
Pulmonary capillary wedge pressure (mmHg)	11	23
Systemic vascular resistance (mmHg)	1,150	2,700
Right ventricular stroke work index (mmHg)	650 (8.8)	240 (3.3)
Cardiac index (L/min/m^2)	2.2	1.5

Table 2 Contraindications for permanent left ventricular assist device implantation

Irreversible contraindication to heart transplant if destination therapy is not the aim
Non-systolic heart failure
Co-existing illness with life expectancy <2 years
Terminal severe comorbidity
Renal disease (creatinine >2.5 mg/dL)
Liver disease (spontaneous INR >2.5, bilirubin >5, cirrhosis)
Lung disease (severe obstructive or restrictive disease requiring home oxygen)
Unresolved severe stroke
Severe neuromuscular disorder
Advanced or metastatic cancer
Active uncontrolled systemic infection
Active severe bleeding
Chronic platelet count <$50,000\times10^9$ per liter
Heparin-induced thrombocytopenia
Intolerance to the anticoagulation regimen specific to the device
Right heart failure not secondary to left heart failure
Moderate or severe aortic valve insufficiency that will not be repaired
Mechanical aortic valve that will not be converted to a bioprosthesis
Left ventricular thrombus that will not be removed
Anatomic considerations (severe hypertrophic cardiomyopathy, large VSD, complex congenital disease)
Body surface area ≤1.2-1.5 m^2 or other dimensional limitations
Inability to grasp risks and benefits and provide informed consent
Psychosocial limitations—e.g., inability to comply with medical regimen or maintain LVAD operations

LVAD, left ventricular assist device.

devices, and also higher than would be expected from the anticoagulation required for the continuous-flow devices (which is not required in the pulsatile-flow devices) (6). Proposed mechanisms include the loss of high-molecular-weight von Willebrand factor induced by increased shear stress in axial-flow devices (which is known to occur in the first 30 days after implantation), angiodysplasia formation, and impaired platelet aggregation (5,6).

Again, careful patient selection is crucial to mitigating postoperative nonsurgical bleeding. The Model for End-Stage Liver Disease (MELD) score has been found to identify LVAD candidates at high risk for perioperative bleeding (7). This score incorporates bilirubin, creatinine, and prothrombin time, factors which should be included in any pre-operative screen in patients considered for LVAD placement. Hematocrit, platelet count and aggregation studies, and partial thromboplastin time should also be checked. In addition, improving nutrition (particularly vitamin K supplementation), and to the extent possible, hepatic function can reduce the risk of peri-operative bleeding (7). Preoperatively, one should try to aggressively diurese to decongest the liver, which anecdotally appears to decrease the risk of bleeding. Post-operatively, considering holding all anticoagulation for a few days is reasonable and does not appear to increase the risk of pump thrombus. Care should also be taken in the post-operative period to tightly control anticoagulation levels and educate patients about the dietary and monitoring requirements of systemic anticoagulation therapy (8).

Table 3 Independent predictors of RV failure after LVAD implantation

Clinical
Female gender
Nonischemic etiology
Previous cardiac surgery
Laboratory
Bilirubin ≥2.0 mg/dL
Creatinine ≥1.9 mg/dL
AST ≥80 U/L
Hemodynamic
High CVP
High transpulmonary gradient
High SVR
Systolic blood pressure ≤96 mmHg
RVSWI <250
CI <2.2 L/min/m^2
Vasopressor requirement
Echocardiographic
Severe tricuspid regurgitation
RV short/long axis >0.6
Tricuspid annular plane systolic excursion <7.5 mm
Severe RV dysfunction

RV, right ventricular; LVAD, left ventricular assist device; AST, aspartate aminotransferase; RVSWI, right ventricular stroke work index; CVP, central venous pressure; SVR, systemic vascular resistance; CI, cardiac index.

Postoperative pitfall 3: infection

Post-implantation sepsis and device-related infections remain inherent risks in patients undergoing LVAD implantation. Depending on the population, between 19% and 48% of patients suffer a device-related infectious complication (2,9). In one trial, sepsis accounted for more than twice the number of deaths than device failure (41% *vs.* 17%) (10). Risk factors for developing infection can be divided into device-related factors (larger device size, driveline caliber), operative factors (longer surgical times, increased bleeding, failure to provide operative antibiotics), and patient-related factors (9). While numerous studies have failed to identify age, gender, race, and even the presence of diabetes as patient-related risk factors for infection, there is substantial data suggesting that malnutrition is associated with increased risk (9,11).

Heart failure patients are at risk for malnutrition through multiple mechanisms—anorexia, early satiety, delayed gastric emptying, and a chronic inflammatory state all contribute to cardiac cachexia (12). Serologic markers of nutritional status (low serum albumin, total protein, and absolute lymphocyte count) are associated with adverse clinical outcomes, including post-implantation sepsis (11).

What remains less clear is our ability to diminish a malnourished patient's risk with enteral or parenteral nutritional supplementation. Several studies have documented reduced mortality in patients with higher pre-implantation BMI—the so-called "obesity paradox"—with patients with a BMI <20 accruing the highest risk (12). Thus, it is reasonable to consider nutrition supplementation in patients with high risk serologic markers of malnutrition and a low BMI, prior to LVAD implantation. This must be done with care, considering the inherent risks of the supplementation strategy itself. For example, with the above-noted mechanisms leading to difficult alimentation in heart failure patients, a parenteral strategy is tempting. However, studies have shown an increased risk for device infection (particularly fungal infection) in patients with an LVAD receiving total parenteral nutrition (9).

Conclusions

Our two patients provide distinct challenges in assessing their peri-operative risk prior to LVAD implantation. Patient 1 appears to be at low risk for RV failure and bleeding [normal CVP and RVSWI, adequate renal function, low aspartate aminotransferase (AST), low MELD score] but is likely malnourished based on his low albumin, total protein, absolute lymphocyte count, and BMI. It would be reasonable to involve a nutrition specialist to consider supplementation strategies for this patient prior to implantation. Patient 2 is at high risk for both RV failure and bleeding. In this patient, hemodynamic optimization strategies (diuresis, inotropic support, afterload reduction, consideration of intra-aortic balloon pump placement) may mitigate her risk for both post-operative complications.

To this point, studies of patients prior to mechanical circulatory support have been largely observational or retrospective, and serve to provide a profile of patients at high risk. More prospective studies are required to define strategies to effectively optimize the moderate or high-risk patient prior to mechanical circulatory support.

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