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Predictors of Hospital Length of Stay Following Implantation of a Left Ventricular Assist Device: An Analysis of the INTERMACS Registry

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Abstract

Introduction—Few studies have reported on hospital length of stay (LOS) after left ventricular assist device (LVAD) implantation. The purpose of this study was to determine pre-operative and peri-operative predictors of hospital LOS after LVAD implantation.

Methods and Materials—We analyzed adult primary continuous flow LVAD patients implanted between 6/23/06 and 12/31/10 at 105 institutions from the Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS). Retrospective analyses included measures of central tendency, frequencies, correlations, and step-wise multivariable regression modeling ($p < 0.05$). Independent variables included demographic characteristics, pre-implant clinical and behavioral variables, and concomitant surgery.

Results—Characteristics of the patients ($n=2,200$) included a mean age of 54.6 ± 12.6 years, with 79% male, 69% white, 57% INTERMACS profile 1 or 2, 37% diabetic, 21% with history of CABG, 7% with history of valve surgery and 37% with concomitant surgery. Median hospital LOS (implant to discharge) was 20 days. Significant predictors of an increased hospital LOS included: demographic characteristics (older age and non-white), pre-implant clinical variables (history of CABG or valve surgery, diabetes, ascites, INTERMACS profiles 1 and 2, low albumin, high BUN, and high right atrial pressure), and concomitant surgery, explaining 12% variance, $F=22.65$, $p<0.001$.

Conclusions—Demographic characteristics, pre-implant variables and concomitant surgery partially explained hospital LOS after continuous flow LVAD implant. These variables have implications regarding selection of patients for mechanical circulatory support.

Increased survival and decreased adverse events with second generation continuous flow left ventricular assist devices (LVADs) have led to a significant increase in their use for patients with advanced heart failure. The Interagency Registry for Mechanically Assisted Circulatory Support (INTERMACS) is a prospective registry that collects data on patients who receive

prior to discharge. Data were entered electronically into the INTERMACS database and analyzed by the data coordinating center, located at the University of Alabama, Birmingham, AL.

Statistical analyses

Data were analyzed using SAS, version 9.13 (SAS Institute, Carey, NC). Descriptive analyses included measures of central tendency $\pm$ standard deviation for continuous variables and frequencies for categorical variables. Median values were also calculated for hospital LOS. Percentile plots, referred to as cumulative distribution functions, were used to convey the distribution of continuous variables. Step-wise multiple regression modeling was used to identify pre-implant and peri-operative (concomitant surgery) variables that were related to hospital LOS. A log transformation of the dependent variable, LOS, was used as it had less skewness and a better bell shaped curve as compared to an untransformed LOS. Variables including demographic characteristics: (age, gender, race) pre-implant variables (etiology of heart failure, blood type, history of coronary artery bypass and/or valve surgery, inotrope use, New York Heart Association class, serum lab tests [sodium, albumin, bilirubin, BUN, creatinine, INR, pre-albumin, sodium, WBC], inotrope therapy, presence of an ICD, co-morbidities [diabetes, stroke, severely decreased RVEF, chronic obstructive pulmonary disease, ascites, alcohol abuse], hemodynamics, device implant strategy, INTERMACS patient profile [1–7]), and peri- implant variables (concomitant surgery) were entered into the regression analyses. Missing data for independent variables were imputed with mean values. Assumptions of multiple regression were met; there was negligible multicollinearity. For all analyses, level of significance was set at $p < 0.05$.

RESULTS

Description of the cohort

Pre-implant patient characteristics are listed in Table 1. Patients ($n=2200$) receiving a continuous flow LVAD who survived to discharge were 54.6 ± 12.6 years, 78% male, and 69% white. The majority of pre implant patients were in INTERMACS profiles 1–4 while the fewest number of patients were in INTERMACS profiles 5–7. Patients were implanted most frequently as a bridge to transplantation (41%) (Table 1). Inotrope therapy (80%), and presence of an implantable cardioverter defibrillator (82%) at the time of implant were common. More than 1/3 of patients had a concomitant cardiac surgical procedure at the time of implant.

Overall Hospital LOS

Percentile plots were created to illustrate overall hospital LOS and differences in LOS by demographic, and pre- and peri- implant clinical variables for LVAD recipients discharged alive on device ($n=2200$). The median hospital LOS for LVAD recipients discharged alive ($n=2,200$) was 20 days (Figure 1). Ninety percent of patients were discharged by 45 days after implant. The vast majority of patients were discharged to home. (Table 2)

Differences in Hospital LOS by Demographic and Clinical Characteristics

Several patient characteristics were noted to be associated with an increased hospital LOS. There was a significant difference in LOS by age (Figure 2). Patients with a worse INTERMACS profile (e.g. profile 1) had a longer LOS than patients with a better INTERMACS profile (Figure 3). There were also significant differences in hospital LOS by presence versus absence of ascites, diabetes, ventilator use and concomitant surgery (Figure 4A – D).

Multivariate Analyses

Multiple regression analyses were conducted using hospital LOS as the dependent variable. Factors associated with longer hospital LOS were older age, history of CABG, history of valve surgery, diabetes, ascites, ventilator use, increased BUN, increased RA pressure, INTERMACS profiles 1 and 2, and concomitant surgery (Table 3). Factors associated with a decreased hospital LOS were white race and a normal serum albumin. These factors explained 12% variance in hospital LOS, $F=22.65$, $p=0.05$.

Risk Factor Model

A risk factor model was constructed using the variables that were significantly associated with hospital LOS. Cut-points were determined from median values of continuous variables (Table 4). Using these risk factors, the model demonstrated that patients with more risk factors were more likely to have a longer hospital LOS (Figure 5). Specifically, we identified a trend towards increased hospital LOS as the number of risk factors increased, which was significant when comparing those with < 4 risk factors to those with > 9 risk factors ($p<0.0001$).

DISCUSSION

The current healthcare climate, driven partially by concerns about rising healthcare costs, has warranted an examination of hospital LOS for patients receiving continuous flow LVADs. This study demonstrated that for patients enrolled in INTERMACS, median hospital LOS after implantation with a continuous flow LVAD was 20 days. This represents a significant decrease in hospital LOS as compared to the median LOS of 29 days with a pulsatile VAD, as reported in the Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure (REMATCH) trial.^{9,10} A number of factors may be responsible for this change. In addition to advances in VAD technology, more scrutiny of risk factors in patient selection and improvements in peri- and postoperative device management may have contributed to a decreased hospital LOS with second generation technology. For example, there has been a significant decrease in the selection of more critically ill (i.e., INTERMACS 1 and 2) patients to more stable patients who are more likely to tolerate VAD implantation during the peri- and postoperative periods.⁴

In this study, a number of pre- and peri-implant factors were found to be associated with hospital LOS. This study demonstrated that increased age was a risk factor for an increased hospital LOS. In a previous study, for patients who received pulsatile VADs, an age of 64–70 was a predictor of 90-day in-hospital mortality.¹¹ Recent findings from INTERMACS

have also demonstrated that older age was a risk factor for death in 4,366 primary MCS implant patients (early hazard ratio=1.54, $p<0.0001$) from age 70 to 80 years).⁴ Importantly, Kirklin et al reported a significant increase in mean age at time of implant from 52.48 years to 56.85 years ($p\text{-value}<0.0001$).⁴ Thus, despite age-associated risk factors of MCS specific to both resource use and outcomes, these devices are being increasingly used in older patients with advanced heart failure. Additionally, and perhaps not surprisingly, we found that previous cardiac operations, such as coronary artery bypass (CABG) and valve surgery, were associated with a longer hospital LOS in patients receiving primary continuous flow LVADs. These factors were also identified as risk factors for early death as per a previous INTERMACS report.⁴

While we reported that diabetes was also found to correlate with increased hospital LOS, it was not found to be a risk factor for early death after MCS implant in the most recent INTERMACS registry.⁴ However, Butler et al¹² showed a significant risk of death in diabetic patients versus non-diabetics in a population of patients receiving pulsatile left ventricular assist devices. Additionally, findings in the post-CABG population demonstrate a significant risk for post-operative mortality in diabetic patients.^{13–16} Furthermore, studies after CABG and heart transplantation support the benefit of tighter glycemic control.^{17,18, 19} Aggressive identification and management of hyperglycemia in the VAD population may contribute to a reduction in LOS after implant.

The positive associations of ascites and right atrial pressure with LOS are consistent with previous findings that demonstrate an association between right sided heart failure and poor outcomes.⁸ Recent INTERMACS registry data demonstrate that both higher right atrial pressures and the need for biventricular assistance are associated with death in patients receiving LVADs.⁴ Careful pre-operative selection along with timely right-sided MCS and medical therapy may be beneficial in addressing right-sided heart failure.

We also demonstrated the contribution of ventilator use within 24 hours of VAD implant to an increased hospital LOS. In another study of resource utilization, Lietz et al reported that the presence of a ventilator is associated with an increased risk for 90-day re-hospitalization in patients receiving pulsatile VAD support.¹¹ A BUN of greater than 37.0 mg/dl was found to be a predictor of increased hospital LOS in this study. In patients with heart failure, an elevated BUN is likely to correlate with poor perfusion and renal insufficiency. The recently published INTERMACS report also found that an increased BUN was associated with death in patients receiving MCS.⁴ Although a higher creatinine was also a risk factor for death in this same registry report, creatinine was not a predictor of a longer hospital LOS.

Concomitant cardiac surgery at the time of LVAD implantation was also found to be a risk factor for increased LOS. Recent INTERMACS data has demonstrated a 1.36 early hazard ratio ($p=0.01$) for concomitant surgery in patients receiving LVADs.⁴ Perhaps the most important variable affecting LOS was severity of cardiac failure preceding device implantation. In this study, median LOS was 25 days in patients who were INTERMACS 1 versus 15 days in INTERMACS 5–7 patients. Boyle et al demonstrated a significantly decreased LOS in INTERMACS 4–7 patients versus INTERMACS 1 and 2 patients.⁶ This is also consistent with INTERMACS data that demonstrate a significant risk of mortality in

more acutely ill patients undergoing LVAD implantation.⁴ Less than 20% of the patients in this study were INTERMACS 4–7. Thus, it will be important to examine LOS in future studies that contain more patients with less severe heart failure.

A decreased albumin was associated with longer LOS in this study. Lietz et al¹¹ demonstrated that an albumin of < 3.3 g/dL conferred an odds ratio of 3.8 ($p<0.001$) for 90-day in-hospital mortality in patients receiving pulsatile pumps for destination therapy. The presence of low albumin as a risk factor for outcomes has led to recommendations for evaluation of nutrition and development of a plan to improve nutrition prior to LVAD implantation.^{20, 21}

Importantly, we reported that more risk factors increased hospital LOS after MCS implantation. This finding is especially important when selecting patients with multiple risk factors for MCS implant.

Our study has important limitations. The exact time of pre-operative hemodynamic measurements were not recorded. Therefore, it is not known how close to LVAD implantation the hemodynamics were measured. Also, it is important to note that this study is based on a retrospective analysis of data from a registry. However, the large sample size and number of sites contributing data to this registry support generalizability of our findings.

Finally, our findings explained 12.5% variance in hospital LOS. It is therefore likely that other factors, including postoperative factors, explained additional variance in LOS. Additionally, there may be other factors which affect LOS, such as socioeconomic and psychosocial variables that were not analyzed in this study.

Conclusions

Hospital LOS is significantly lower in the current era of continuous flow LVADs. Both pre and peri-operative factors are associated with increased hospital LOS, and increasing numbers of risk factors are related to a longer hospital LOS. Understanding risk factors for hospital LOS after continuous flow LVAD implantation may contribute to enhanced patient selection and management prior to LVAD implantation.

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REFERENCES

1. Kirklin JK, Naftel DC, Stevenson LW, et al. INTERMACS database for durable devices for circulatory support: first annual report. The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation. 2008; 27:1065–1072.

2. Kirklin JK, Naftel DC, Kormos RL, et al. Second INTERMACS annual report: more than 1,000 primary left ventricular assist device implants. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2010; 29:1–10.
3. Kirklin JK, Naftel DC, Kormos RL, et al. Third INTERMACS Annual Report: the evolution of destination therapy in the United States. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2011; 30:115–123.
4. Kirklin JK, Naftel DC, Kormos RL, et al. The Fourth INTERMACS Annual Report: 4,000 implants and counting. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2012; 31:117–126.
5. Slaughter MS, Bostic R, Tong K, Russo M, Rogers JG. Temporal changes in hospital costs for left ventricular assist device implantation. *J Card Surg*. 2011; 26:535–541. [PubMed: 21848578]
6. Boyle AJ, Ascheim DD, Russo MJ, et al. Clinical outcomes for continuous-flow left ventricular assist device patients stratified by pre-operative INTERMACS classification. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2011; 30:402–407.
7. Ketchum ES, Moorman AJ, Fishbein DP, et al. Predictive value of the Seattle Heart Failure Model in patients undergoing left ventricular assist device placement. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2010; 29:1021–1025.
8. Kormos RL, Teuteberg JJ, Pagani FD, et al. Right ventricular failure in patients with the Heart Mate II continuous-flow left ventricular assist device: incidence, risk factors, and effect on outcomes. *J Thorac Cardiovasc Surg*. 2010; 139:1316–1324. [PubMed: 20132950]
9. Miller LW, Nelson KE, Bostic RR, Tong K, Slaughter MS, Long JW. Hospital costs for left ventricular assist devices for destination therapy: lower costs for implantation in the post-REMATCH era. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2006; 25:778–784.
10. Rose EA, Gelijns AC, Moskowitz AJ, et al. Long-term use of a left ventricular assist device for end-stage heart failure. *The New England journal of medicine*. 2001; 345:1435–1443. [PubMed: 11794191]
11. Lietz K, Long JW, Kfoury AG, et al. Outcomes of left ventricular assist device implantation as destination therapy in the post-REMATCH era: implications for patient selection. *Circulation*. 2007; 116:497–505. [PubMed: 17638928]
12. Butler J, Howser R, Portner PM, Pierson RN 3rd. Diabetes and outcomes after left ventricular assist device placement. *Journal of cardiac failure*. 2005; 11:510–515. [PubMed: 16198246]
13. Lazar HL, McDonnell M, Chipkin SR, et al. The Society of Thoracic Surgeons practice guideline series: Blood glucose management during adult cardiac surgery. *The Annals of thoracic surgery*. 2009; 87:663–669. [PubMed: 19161815]
14. Carson JL, Scholz PM, Chen AY, Peterson ED, Gold J, Schneider SH. Diabetes mellitus increases short-term mortality and morbidity in patients undergoing coronary artery bypass graft surgery. *Journal of the American College of Cardiology*. 2002; 40:418–423. [PubMed: 12142105]
15. Cohen Y, Raz I, Merin G, Mozes B. Comparison of factors associated with 30-day mortality after coronary artery bypass grafting in patients with versus without diabetes mellitus. *Israeli Coronary Artery Bypass (ISCAB) Study Consortium. The American journal of cardiology*. 1998; 81:7–11. [PubMed: 9462597]
16. Szabo Z, Hakanson E, Svedjeholm R. Early postoperative outcome and medium-term survival in 540 diabetic and 2239 nondiabetic patients undergoing coronary artery bypass grafting. *The Annals of thoracic surgery*. 2002; 74:712–719. [PubMed: 12238829]
17. Lazar HL, Chipkin SR, Fitzgerald CA, Bao Y, Cabral H, Apstein CS. Tight glycemic control in diabetic coronary artery bypass graft patients improves perioperative outcomes and decreases recurrent ischemic events. *Circulation*. 2004; 109:1497–1502. [PubMed: 15006999]
18. van den Berghe G, Wouters P, Weekers F, et al. Intensive insulin therapy in critically ill patients. *The New England journal of medicine*. 2001; 345:1359–1367. [PubMed: 11794168]

19. Garcia C, Wallia A, Gupta S, et al. Intensive glycemic control after heart transplantation is safe and effective for diabetic and non-diabetic patients. *Clinical transplantation*. 2013; 27:444–454. [PubMed: 23574363]
20. Slaughter MS, Pagani FD, Rogers JG, et al. Clinical management of continuous-flow left ventricular assist devices in advanced heart failure. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2010; 29:S1–S39.
21. Feldman D, Pamboukian SV, Teuteberg JJ, et al. The 2013 International Society for Heart and Lung Transplantation Guidelines for mechanical circulatory support: executive summary. *The Journal of heart and lung transplantation : the official publication of the International Society for Heart Transplantation*. 2013; 32:157–187.

Figure 1.
Percentile plot of LOS

Figure 2.
Association of age and LOS

Figure 3.
LOS by INTERMACS profile

Figure 4.

- A. Association of ascites and LOS
- B. Association of diabetes and LOS
- C. Association of ventilator use and LOS
- D. Association of concomitant surgery and LOS

Figure 5.
Number of risk factors versus mean LOS

Table 1

Characteristics of pre implant adult primary continuous flow LVAD implants for BTT, BTC, or DT baseline characteristics for categorical variables (n=2200)

Pre-Implant Characteristics	
<i><u>Demographic and behavioral characteristics</u></i>	
Age at implant (mean years±SD)	54.6±12.6
Male (%)	78.4
Race (% white)	68.5
Married at time of implant (%)	64.6
> high school education (%)	52.0
Currently smoking (%)	12.3
Current alcohol abuse (%)	15.8
Current drug abuse (%)	2.5
<i><u>Clinical characteristics</u></i>	
Primary cardiac diagnosis (%)	
Ischemic cardiomyopathy	45.4
Dilated cardiomyopathy	50.1
Other	3.9
History of CABG (%)	20.5
History of valve surgery (%)	6.4
Co-morbidities (%)	
Diabetes	37.4
CVA	7.4
RVEF severe	25.6
Pre COPD	14.6
Ascites	7.2
NYHA class IV (%)	77.7
Intra aortic balloon pump (%)	32.5
Ventilator (%)	7.1
ECMO (%)	1.6
Dialysis (32.5%)	32.5
INTERMACS profile at implant (%)	
1	12.6
2	43.8
3	24.0
4	13.4
5	3.0
6	2.1
7	1.1
Device strategy (%)	

Pre-Implant Characteristics	
Bridge to transplant – listed	41.1
Bridge to transplant – likely to be listed	29.3
Bridge to transplant – moderately likely to be listed	9.6
Bridge to transplant – unlikely to be listed	2.6
Destination therapy	2.6
Inotrope therapy (%)	80.4
Implantable cardioverter defibrillator (%)	82.1
Temporary circulatory support (%)	14.5
Concomitant surgery (%)	37.0
<i>Laboratory studies</i> mean±SD	
Albumin (g/dL)	3.4±.6
Total bilirubin (mg/dL)	1.4±1.3
BUN (mg/dL)	29.7±18.2
Creatinine (mg/dL)	1.43±.8
INR	1.3±.5
Pre-albumin (mg/dL)	18.5±7.4
SGOT/AST (u/L)	76.1±364.4
SGPT/ALT (u/L)	85.9±309.5
Sodium (mmol/L)	134.5±4.8
WBC (K/uL)	8.5±3.9
<i>Hemodynamics</i> mean±SD	
RA pressure (mmHg)	12.3±6.9
Pulmonary artery systolic pressure (mmHg)	50.8±14.8
Pulmonary artery diastolic pressure (mmHg)	25.8±8.7

CABG=coronary artery bypass grafting, CVA = cerebrovascular accident, RVEF=right ventricular ejection fraction, COPD=chronic obstructive pulmonary disease, ECMO=extracorporeal membrane oxygenation, BUN=blood urea nitrogen, INR=international normalized ratio, SGOT=serum glutamic oxaloacetic transaminase, SGPT=serum glutamic pyruvate transaminase, WBC=white blood cell count, RA=right atrial.

Table 2

Distribution of Discharge Mode of Patients

intermaes		
DISCHARGE TO	Frequency	Percent
Home	1776	80.73
Nursing Home/Assisted Care	21	0.95
Hospice	5	0.23
Another Hospital	26	1.18
Rehabilitation Facility	335	15.23
Unknown	37	1.68
Total	2200	100.00

Table 3

Pre-Implant Factors Associated with Increased Length of Stay*

Factors associated with hospital LOS after LVAD		
Factors with a “increased” length of stay		
Factor	Estimate	P-Value
Age (yrs)	0.00099	0.0019
History of CABG	3.56577	0.0003
History of Valve Surgery	3.62397	0.0178
Diabetes	1.57668	0.0467
Ascites	0.10821	0.0159
Ventilator	3.16864	0.0427
BUN (mg/dL)	0.08497	<0.0001
RA Pressure (mmHg)	0.17239	0.0183
Patient Profile 1	6.11823	<0.0001
Patient Profile 2	4.31201	<0.0001
Concomitant Surgery	2.63594	0.0008
Factors with a “decreased” length of stay		
Factor	Estimate	P-Value
White	−2.68358	0.0013
Albumin (g/dL)	−3.06995	<0.0001

* Coefficients with negative value are associated with a decreased length of stay

Table 4

Risk Factors for an Increased Hospital LOS (days)	
• Age > 64 yrs	• Ventilator
• History of CABG	• BUN > 37.0 (mg/dL)
• History of Valve Surgery	• RAP > 16 (mmHg)
• Diabetes	• Patient Profile Level 1
• Ascites	• Patient Profile Level 2
• Concomitant Surgery	
Risk Factors for a Decreased Hospital LOS (days)	
• White Race	
• Albumin > 3.0 (g/dL)	