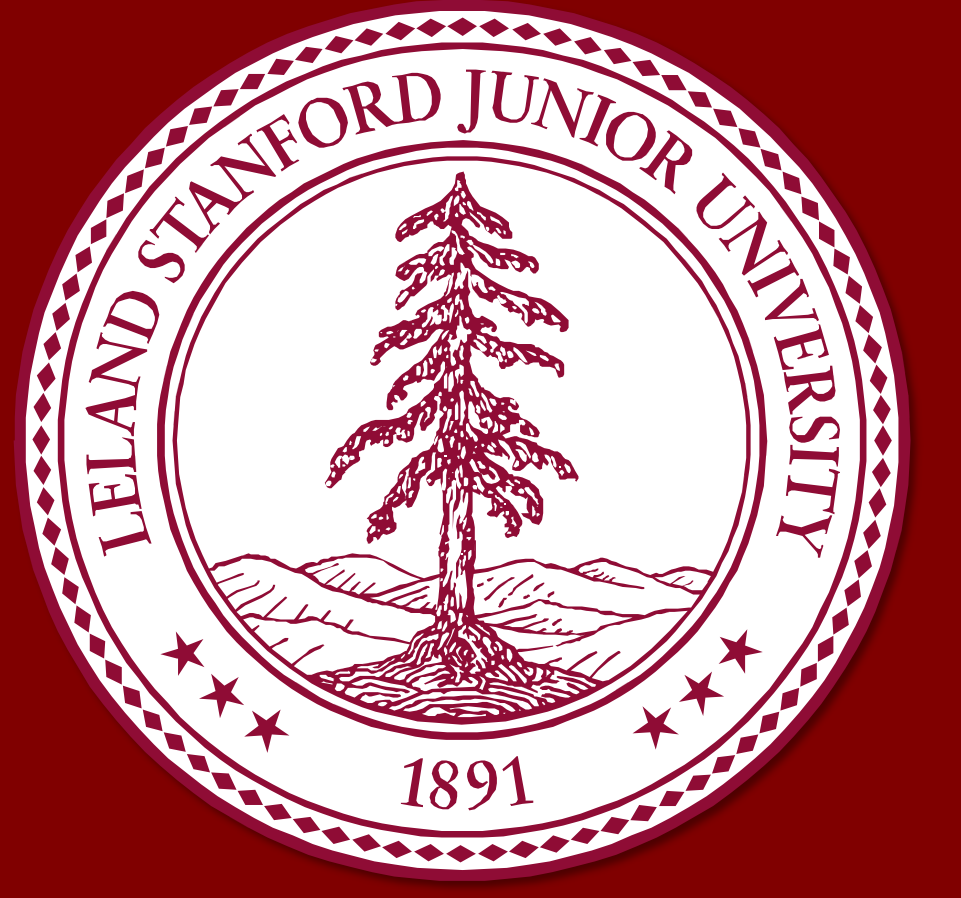




Impact of wait times for cardiac transplantation on outcomes after implantation of left ventricular assist devices

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Background

The optimal timing for orthotopic heart transplantation (OHT) after the implantation of left ventricular assist devices (LVAD) is unknown. In determining the optimal time for OHT after LVAD, the need for clinical stability and time to recover from major surgery is balanced by the risk of LVAD complications and the formation of adhesions and scarring. Some have argued that performing OHT early after LVAD placement poses an increased risk of morbidity and mortality to patients.

Methods

Data Source: The Nationwide Inpatient Sample (NIS), from the Healthcare Cost and Utilization Project, Agency for Healthcare Research and Quality, is the largest database of all-payer inpatient discharge information, sampling approximately 20% of all non-federal US hospitals and including approximately 9 million hospital admissions each year. It contains discharge data from over 5000 hospitals located across 45 states, of which approximately 1,200 hospitals are sampled each year to create a stratified sample of United States hospitals. Each NIS entry includes all diagnosis and procedure codes of activity during the patient's hospitalization at the time of discharge, as well as patient demographics, hospital characteristics, and short-term complications of the hospitalization.

Study design and Cohorts: This was a retrospective cross-sectional study using the Nationwide Inpatient Sample (NIS) between 1988 and 2011. We identified all hospitalizations from 1988 to 2011 of patients 18 years of age or greater that underwent placement of a left ventricular assist device and for which the hospital day of each procedure was available. Procedures during the hospitalization in addition to LVAD placement, including orthotopic heart transplant, extracorporeal membrane oxygenation, intubation, hemodialysis, invasive hemodynamic monitoring, and surgical revision were identified by associated ICD9 codes. Additionally, hospital mortality and perioperative morbidity such as post-operative infections, cardiopulmonary complications, and hemorrhagic complications requiring endoscopy were identified.

ICD-9 Codes

Diagnosis/Procedure	ICD9 Code(s)
Left ventricular assist device	3766
Orthotopic heart transplant	3751, 375
Swan-Ganz catheterization	8964
Diabetes	25000-25099
Disorders of lipid metabolism	2720-2729
Hypertension	4010-4019
History of or current use of tobacco	V1582, 3051
BMI ≥ 30 kg/m ²	27800, 27801
Reoperation	3403, 3764, 3470, 341, 3749
Sepsis	99591, 99592
Acute respiratory failure	51881
Postoperative cardiac complication	9971, 4294
Acute renal failure	5845-5849
Postoperative bleeding	4513, 4523, 9904, 9905, 9907, 9909
Stroke	43481
Acute liver failure	570
Device failure	99609

Baseline demographics

Table 1. Baseline demographics of all LVAD patients, LVAD patients who underwent invasive hemodynamic monitoring, and LVAD patients who received orthotopic heart transplant (OHT)	LVAD (n = 2200)	Swan-Ganz+ (n = 403)	OHT+ (n = 164)
Mortality, n (%)	590 (26.5)	86 (19.9)	26 (15.9)
Length of stay, mean ± SD	40.5 ± 38.9	45.4 ± 38.2	82.8 ± 59.3
Age, mean ± SD	53.4 ± 13.7	53.4 ± 13.7	48.2 ± 13.5
Sex, n (%)			
Male	1659 (75.4)	81 (20.1)	134 (81.7)
Female	541 (24.6)	322 (79.9)	30 (18.3)
Race, n (%)			
White	1274 (57.9)	218 (54.1)	89 (54.3)
Black	352 (16.0)	80 (19.9)	22 (13.4)
Hispanic	142 (6.5)	33 (8.2)	17 (10.4)
Asian/Pacific Islander	51 (2.3)	13 (3.2)	7 (4.3)
Native American	5 (0.2)	0 (0.0)	0 (0.0)
Other† or unknown*	376 (17.1)	59 (14.6)	29 (17.7)
Median household income, n (%)			
\$1-24,999	475 (21.6)	98 (24.3)	28 (17.1)
\$25,000-34,999	491 (22.3)	89 (22.1)	37 (22.6)
\$35,000-44,999	552 (25.1)	90 (22.3)	43 (26.2)
\$45,000 or more	631 (28.7)	115 (28.5)	52 (31.7)
Unknown*	51 (2.3)	11 (2.7)	4 (2.4)
Comorbidities			
Diabetes	392 (17.8)	65 (16.1)	19 (11.6)
Hyperlipidemia	310 (14.1)	63 (15.6)	13 (7.9)
Hypertension	301 (13.7)	44 (10.9)	10 (6.1)
History of smoking	144 (6.5)	33 (8.2)	7 (4.3)
BMI ≥ 30 kg/m ²	96 (4.4)	17 (4.2)	0 (0.0)
Number of comorbid diagnosis, mean ± SD	12.7 ± 2.9	13.6 ± 2.5	12.3 ± 3.1
Year of hospitalization, n (%)			
1998	18 (0.8)	1 (0.2)	5 (3.0)
1999	41 (1.9)	10 (2.5)	7 (4.3)
2000	71 (3.2)	9 (2.2)	9 (5.5)
2001	108 (4.9)	14 (3.5)	25 (15.2)
2002	93 (4.2)	4 (1.0)	16 (9.8)
2003	99 (4.5)	13 (3.2)	9 (5.5)
2004	80 (3.6)	8 (2.0)	13 (7.9)
2005	79 (3.6)	14 (3.5)	18 (11.0)
2006	131 (6.0)	26 (6.5)	9 (5.5)
2007	119 (5.4)	19 (4.7)	12 (7.3)
2008	209 (9.5)	42 (10.4)	14 (8.5)
2009	253 (11.5)	55 (13.6)	12 (7.3)
2010	427 (19.4)	72 (17.9)	8 (4.9)
2011	472 (21.5)	116 (28.8)	7 (4.3)
Location of hospital, n (%)			
Rural	17 (0.8)	0 (0.0)	0 (0.0)
Urban	2181 (99.1)	402 (99.8)	164 (100.0)
Urban	2 (0.1)	1 (0.2)	0 (0.0)
Bedsize of hospital, n (%)			
Small	38 (1.7)	1 (0.2)	6 (3.7)
Medium	229 (10.4)	49 (12.2)	18 (11.0)
Large	1931 (87.8)	352 (87.3)	140 (85.4)
Unknown*	2 (0.1)	1 (0.2)	0 (0.0)
Teaching status of hospital, n (%)			
Nonteaching	165 (7.5)	33 (8.2)	5 (3.0)
Teaching	2033 (92.4)	369 (91.6)	159 (97.0)
Unknown*	2 (0.1)	1 (0.2)	0 (0.0)

In-hospital mortality of LVAD patients (1998-2011)

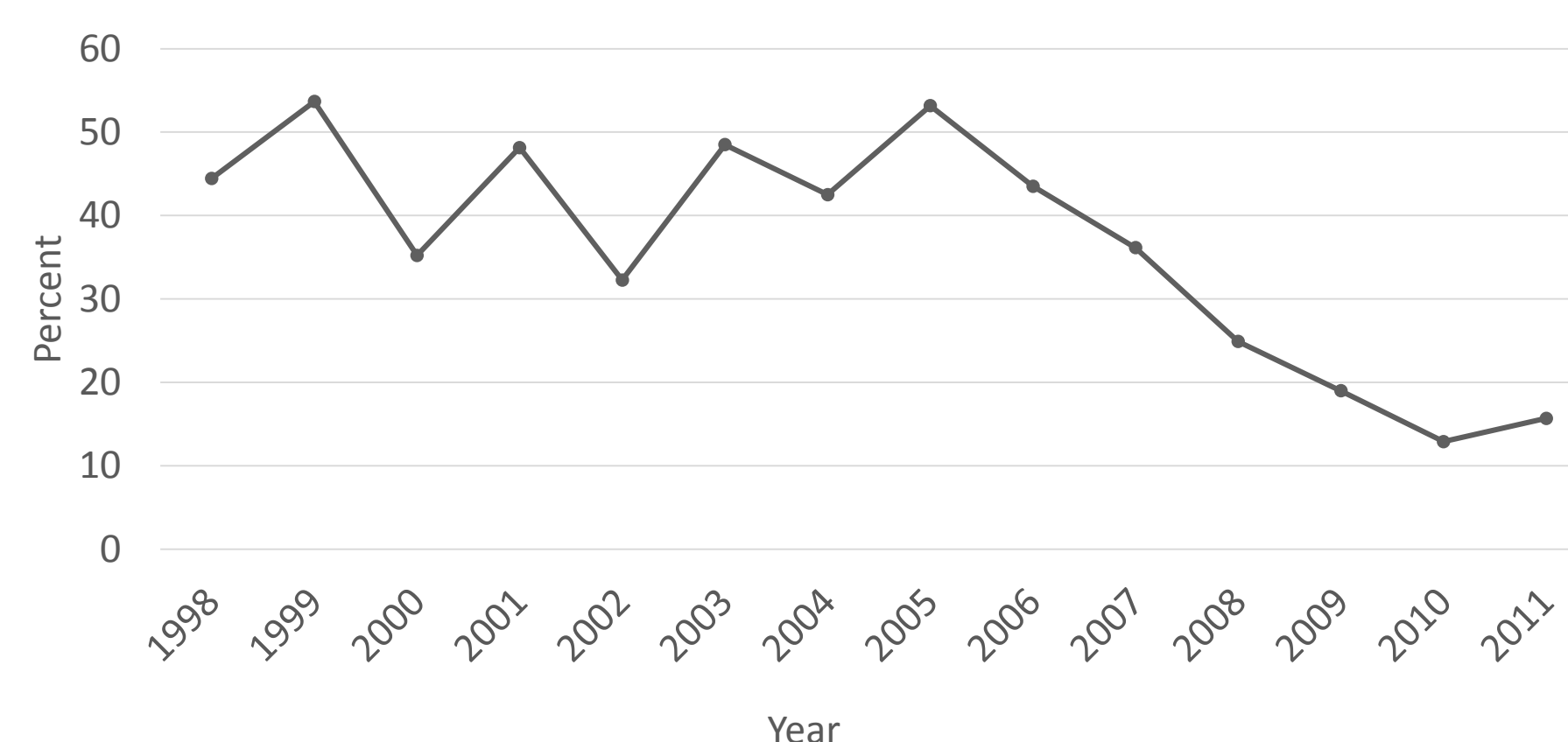


Figure 1. Trends in in-hospital mortality among LVAD patients from 1998 to 2011 Percent mortality for each year was calculated as number of deaths by total number of LVAD patients. Overall in-hospital mortality remained stable between 1998 and 2006 ($r^2 = 0.1403$, trend p -value = 0.9042) and linearly decreased between 2007 and 2011 ($r^2 = 0.7648$, trend p value = 0.033)

Timing of OHT after LVAD implantation

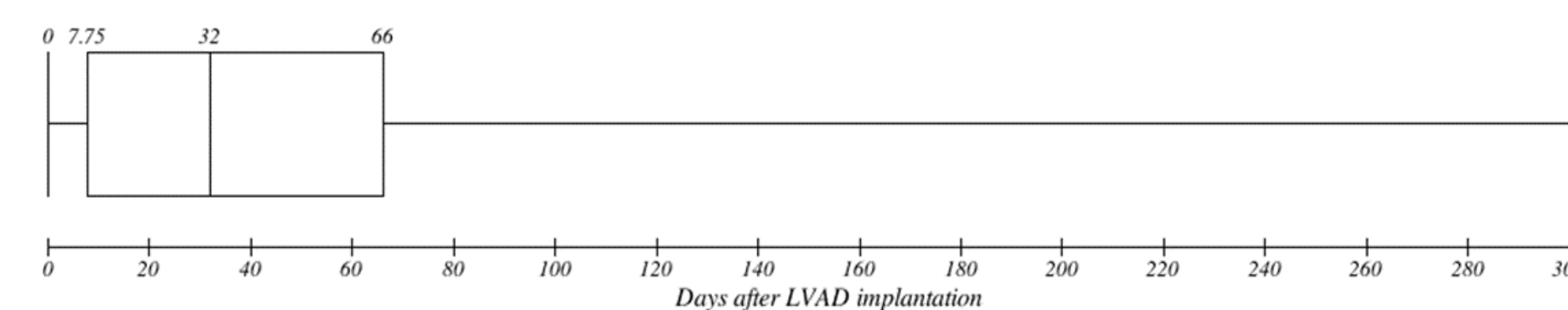


Figure 2: Box-and-whisker plot of wait time for OHT after LVAD implantation. Of the 2200 patients who underwent LVAD implantation, 164 (7.5%) patients also underwent orthotopic heart transplant during the same hospitalization (Table 1). OHT occurred a median of 32 days (IQR 7.75 to 66 days) after LVAD implantation

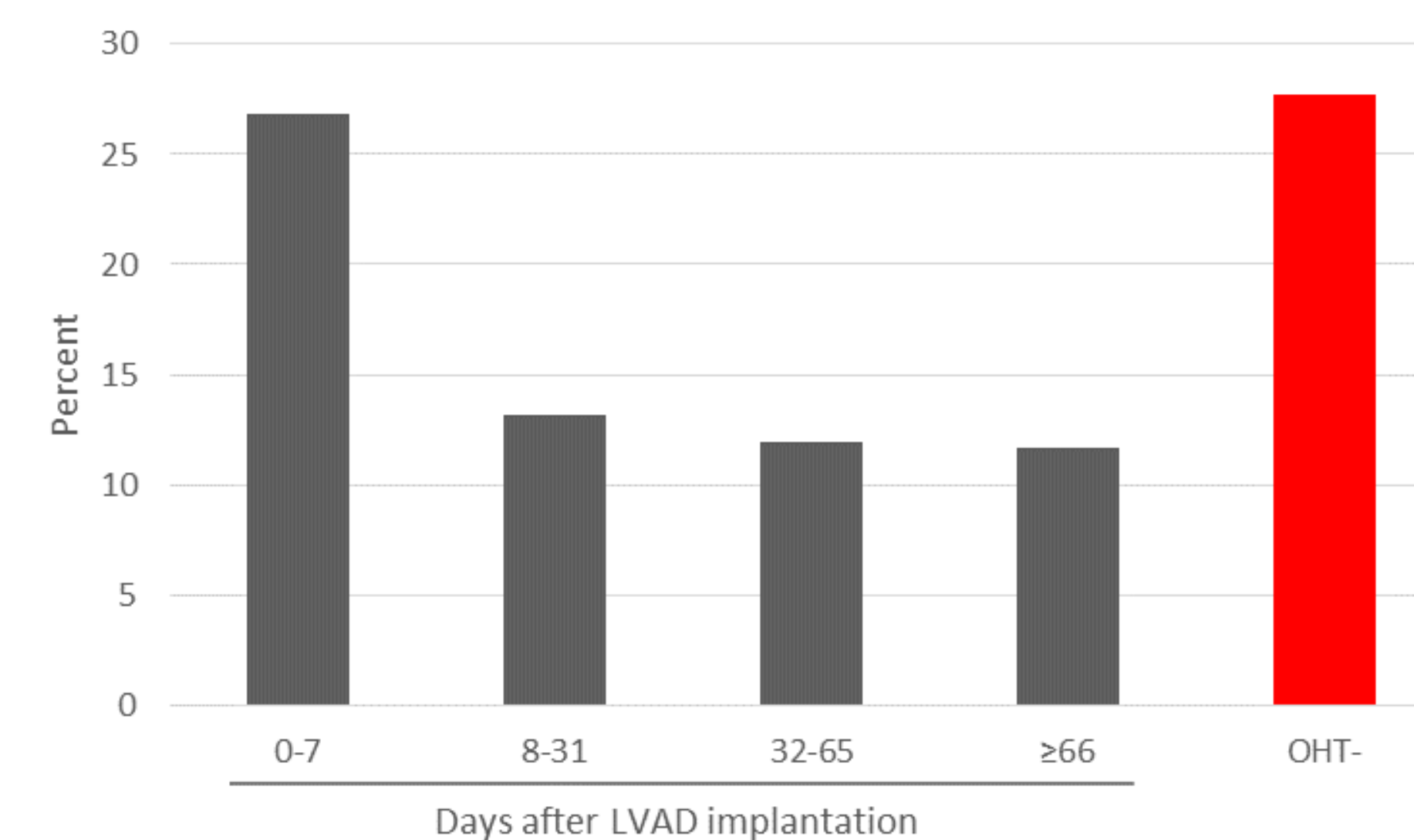


Figure 3. Comparison of percent mortality in hospitalized patients by wait time for OHT after LVAD implantation and no OHT after LVAD implantation. Of the 164 patients who underwent OHT, increased in-hospital mortality was identified in patients who underwent transplantation within 7 days of LVAD implantation compared to patients who underwent transplant after 8 days (26.8% vs. 12.2%, $p = 0.0483$). There was no statistically significant difference in patient demographics with regards to age, sex, race, household income, or number of comorbid diagnoses. Compared to patients who underwent LVAD implantation but did not undergo OHT, patients who underwent late OHT after LVAD had decreased mortality (12.2% vs. 27.0% $p < 0.001$). Patients who underwent early transplant after LVAD did not show a similar mortality benefit (26.8% vs. 27.0%, $p = 0.946$).

In-hospital complications of OHT after LVAD

Complications in hospitalized patients with or without same-admission Orthotopic Heart Transplant (OHT) after Left Ventricular Assist Device (LVAD)

	OHT+ (n = 164)	OHT- (n = 2036)	Total (n = 2200)
Acute renal failure	88 (53.7)	963 (47.3)	1051 (47.8)
Reoperation	115 (70.1)	803 (39.4)	918 (41.7)
Postoperative bleeding	29 (17.7)	570 (28.0)	599 (27.2)
Acute respiratory failure	45 (27.4)	518 (25.4)	563 (25.6)
Sepsis	19 (11.6)	233 (11.4)	252 (11.5)
Postoperative cardiac complication	20 (12.2)	226 (11.1)	246 (11.2)
Acute liver failure	12 (7.3)	223 (11.0)	235 (10.7)
Device failure	4 (2.4)	62 (3.0)	66 (3.0)
Stroke	2 (1.2)	53 (2.6)	55 (2.5)

Table 4. Acute renal failure, reoperation, postoperative bleeding, and acute respiratory failure are among the most frequent in-hospital complications in LVAD patients with or without OHT. Reoperation is more frequent in LVAD patients receiving OHT than in LVAD patients without OHT. Repeat LVAD surgeries suggest significant surgical complications, with significant excess mortality in patients who received two LVADs (56.7%) and three LVADs (100.0%).

Conclusions

- Number of LVAD implantations have significantly increased from 1998 to 2011
- Percent in-hospital mortality of LVAD patients significantly decreased from 2007 to 2011
- In-hospital mortality is decreased for patients who undergo OHT greater than 8 days after LVAD implantation compared to both patients who do not receive OHT (12.2% vs 27.0%) and patients who undergo OHT within 1 week of LVAD implantation (12.2% vs 26.8%)
- Acute renal failure, reoperation, postoperative bleeding, and acute respiratory failure are among the most frequent in-hospital complications in LVAD patients with or without OHT. Reoperation is more frequent in LVAD patients receiving OHT than in LVAD patients without OHT.
- Patients with invasive hemodynamic monitoring have increased in-hospital survival (80.1% vs 71.9%) despite longer hospitalizations and longer time to LVAD implantation during the hospitalization (data not shown)

Future Directions

Our analysis of LVAD implantation, hemodynamic monitoring, and OHT can help inform decisions on the appropriate use and timing of these procedures. With significant variation in institutional best practices, use of national registries and databases can help clarify differences in outcomes based on various practice features. For outcomes of rare procedures or complicated clinical scenarios, such retrospective cohort studies are the only way to identify trends in practice.

Citations

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Disclosures

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