Interhospital variability in health care–associated infections and payments after durable ventricular assist device implant among Medicare beneficiaries

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ABSTRACT

Objective: The objective of this study was to investigate variations across hospitals in infection rates and associated costs, the latter reflected in 90-day Medicare payments. Despite high rates and expenditures of health care–associated infections associated with durable ventricular assist device implantation, few studies have examined interhospital variation and associated costs.

Methods: Clinical data on 8688 patients who received primary durable ventricular assist devices from July 2008 to July 2017 from the Society of Thoracic Surgeons Interagency Registry for Mechanically Assisted Circulatory Support (Intermacs) hospitals ($n = 120$) were merged with postimplantation 90-day Medicare claims. Terciles of hospital-specific, risk-adjusted infection rates per 100 patient-months were estimated using InterMac and associated with Medicare payments (among 5440 Medicare beneficiaries). Primary outcomes included infections within 90 days of implantation and Medicare payments.

Results: There were 3982 infections identified among 27.8% (2417/8688) of patients developing an infection. The median (25th, 75th percentile) adjusted incidence of infections (per 100 patient-months) across hospitals was 14.3 (9.3, 19.5) and varied according to hospital (range, 0.0–35.6). Total Medicare payments from implantation to 90 days were 9.0% (absolute difference: \$13,652) greater in high versus low infection tercile hospitals ($P < .0001$). The period between implantation to discharge accounted for 73.1% of the difference in payments during the implantation to 90-day period across terciles.

Conclusions: Health care–associated infection rates post durable ventricular assist device implantation varied according to hospital and were associated with increased 90-day Medicare expenditures. Interventions targeting preventing infections could improve the value of durable ventricular assist device support from the societal and hospital perspectives. (*J Thorac Cardiovasc Surg* 2022;164:1561–8)

Annually more than 250,000 patients in the United States with advanced heart failure could potentially benefit from durable ventricular assist device (VAD) support as a bridge

to cardiac transplantation or as permanent support.¹ However, broader adoption of VAD therapy for permanent use is hindered by the burden of complications including health

Durable implantation payments were 9% (\$13,652) greater in high versus low infection terciles.

CENTRAL MESSAGE

Post durable implantation 90-day infection rates varied across hospitals (range, 0.0–35.6). Total 90-day payments were 9% (\$13,652) greater in high versus low infection tercile hospitals.

PERSPECTIVE

Interhospital variation in HAI rates and Medicare payments after durable VAD implantation were evaluated. Median adjusted 90-day HAI incidence varied according to hospital (range, 0.0–35.6). Total 90-day payments were 9.0% (\$13,652) greater in high versus low HAI tercile hospitals. HAI prevention could improve the value of durable VADs.

See Commentaries on pages 1569 and 1570.

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Donald S. Likosky received extramural support from the Agency for Healthcare Research and Quality (R01HS026003) and the National Heart, Lung, and Blood Institute (NHLBI, R01HL146619). Data for this study were provided, in part, by the Interagency Registry for Mechanically Assisted Circulatory Support (InterMac), previously funded, in part, by the NHLBI under contract HHSN268201100025C. This study was undertaken before the acquisition of InterMac by the Society of Thoracic Surgeons. Opinions expressed in this report do not represent those of Society of Thoracic Surgeons InterMac, the NHLBI, the Centers for Medicare and Medicaid

Services, the US Food and Drug Administration, the Agency for Healthcare Research and Quality, or the US Department of Health and Human Services.

Received for publication Nov 13, 2020; revisions received March 23, 2021; accepted for publication April 16, 2021; available ahead of print May 4, 2021.

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0022-5223

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<https://doi.org/10.1016/j.jtcvs.2021.04.074>

Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CI	= confidence interval
FDA	= US Food and Drug Administration
HAI	= health care–associated infection
Intermacs	= Interagency Registry for Mechanically Assisted Circulatory Support
SD	= standard deviation
STS	= The Society of Thoracic Surgeons
VAD	= ventricular assist device

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care–associated infections (HAIs),² which are common adverse events and a leading cause of death among this patient population.³ Although HAI rates have decreased over time,^{3,4} in part because of technological advancements, patients receiving VAD support continue to have substantial 90-day risk of HAIs (12.7 HAIs per 100 patient-months [device-related] and 38.5 HAIs per 100 patient-months [non-device-related]).^{5–8}

Although previous work has informed an understanding of risk factors associated with HAIs after VAD implantation,^{9,10} less is known about interhospital variability in HAI risk and its effect on spending beyond the initial implantation admission. Addressing these knowledge gaps would provide: (1) clinical and financial benchmarks for hospitals wishing to assess their HAI performance, and (2) targets for local quality improvement to reduce HAIs.

It was hypothesized that substantial interhospital variability in HAI rates exist after durable VAD implantation and that HAIs are associated with increased morbidity and expenditure. To address these hypotheses, interhospital variability in HAI rates for durable VAD implantation from July 2008 to July 2017 across The Society of Thoracic Surgeons (STS) Interagency Registry for Mechanically Assisted Circulatory Support (Intermacs) participants was studied. The relationship between HAI rates and total as well as component Medicare expenditures was also examined within a subset of patients.

METHODS

This study involved secondary analyses of 2 data sources: (1) Medicare claims (data use agreement 2019-54083 between the University of Michigan and the Research Data Assistance Center), and (2) Intermacs data (provided by the Data Coordinating Center at the University of Alabama to the University of Michigan through permission from the National Heart, Lung,

and Blood Institute). Details for hospital and patient linkages between these data sets have been reported.¹¹

The study sample ([Online Data Supplement](#)) included patients who underwent primary, durable VAD implantation with a US Food and Drug Administration (FDA)-approved device between July 2008 and July 2017. Medicare suppression rules were enforced and represented in data tables with a symbol when there were fewer than 11 observations.¹² Further exclusion criteria for payment data analyses are described in the [Online Data Supplement](#).

Research use of these data was approved by Michigan Medicine's institutional review board (HUM00155687). Written informed consent for registrant participation in Intermacs was required until protocol v4.0 (February 27, 2014).

Clinical Outcomes

The primary outcome was a postoperative HAI reported to Intermacs using the registry's definition for infection adverse event¹³ ([Online Data Supplement](#)). Rates of HAIs were estimated through 90 days after implantation, because the risk of HAIs is greatest within this time frame.¹⁴

Calculation of Medicare Payments

Payments (inpatient, physician, other services) between 180 days before the index admission and post index utilization up to 90 days after the VAD implantation, conditional on patient survival, were analyzed ([Online Data Supplement](#)). Payments were price-standardized (adjusted for geographical differences in Medicare reimbursement rates)¹⁵ and inflation-adjusted to 2017 dollars.¹⁶

Patient Characteristics

Intermacs and Medicare claims data were used to describe patient and clinical characteristics. Intermacs data¹³ ([Online Data Supplement](#)) were used to evaluate preoperative factors commonly used for risk adjustment.^{17–19}

Data files were additionally used for the following purposes: (1) The American Hospital Association annual file was used to identify the implanting hospital's location, number of beds, and transplant status; (2) diagnosis codes within Medicare Part A claims were used to sum the total number of the Elixhauser comorbidity index comorbidities^{20,21}; and (3) a hospital's overall VAD procedural volume was calculated on the basis of procedures identified in Medicare claims and the STS Intermacs.¹¹

Statistical Analysis

Recurrent event analysis was used to examine HAI events. For each hospital, the crude incidence rate of HAI was estimated as the ratio of the number of HAI events over the total patient follow-up time. The indirect standardization method was used to estimate the risk-adjusted HAI incidence rate for each hospital. Specifically, the risk-adjusted rate was calculated as the overall incidence rate in the entire study population multiplied by the ratio of the observed number of HAIs over the expected number of HAIs for the patient mix at a certain hospital, if the hospital is performing as an average hospital. Candidate important risk factors ([Online Data Supplement](#)) were informed by their postulated clinical relevance by VAD experts and their previously identified effect on death.^{17–19}

The expected number of HAIs was calculated on the basis of a 2-step strategy ([Online Data Supplement](#)). This strategy used the same approach leveraged for standardized hospitalization ratios.²²

Hospitals were categorized into terciles on the basis of performance (ie, incident rates of HAIs). Terciles were computed for unadjusted and risk-adjusted HAI rates. For each HAI tercile, patient characteristics, payments, and HAI outcomes (ie, mean and standard deviation [SD] and percentage, as appropriate) were evaluated and the cumulative mean number of HAIs were estimated.

Data missingness was evaluated. In these instances, missing data were handled according to a pre-specified plan ([Online Data Supplement](#)).

Analyses were performed using SAS version 9.4 (SAS Institute, Inc, Cary, NC) and two-sided statistical tests ($\alpha = 0.05$). A link to the final analytical code is available in the [Online Data Supplement](#).

RESULTS

Study Population

Characteristics that significantly differed across unadjusted HAI terciles are shown in [Table 1](#). A more thorough list is provided in the [Online Data Supplement](#).

The study included 8688 unique patients (120 hospitals) who received a durable VAD implantation and whose procedure was present in the Medicare claims and Intermacs datasets. Medicare beneficiaries represent on average 47.6% of a hospital's total Intermacs implantations. Additional details concerning hospital characteristics according to tercile of unadjusted ([Online Data Supplement](#)) and adjusted ([Online Data Supplement](#)) hospital HAI rates are available.

There were 3982 HAIs, with 27.8% of patients developing at least 1 HAI within 90 days of VAD implantation. Patients with an HAI had a mean of 1.6 (1.1) HAIs. The overall adjusted HAI incidence rate was 17.0 per 100 patient-months (95% confidence interval [CI], 16.5-17.6), although varied according to tercile. Adjusted rates of HAIs decreased from 24.3 in 2008 to 16.2 in 2017 (P trend < .001).

Relative to the low tercile, patients in high tercile hospitals more often presented in Intermacs profile 1 or 2 (51.2% vs 41.1%) although were less likely to receive their VAD for destination therapy (52.2% vs 61.5%). Although in many instances statistically significant differences (nominal P values < .05) were present, patients were qualitatively similar across tercile with regard to age, hemodynamic status, and key laboratory results. High versus low tercile hospitals had longer lengths of stay from implantation to discharge (27.4 [SD, 26.0] vs 23.6 [SD, 27.5]), had higher risk of reoperation for bleeding within 48 hours of implantation (8.1% vs 5.4%), and were more likely to develop renal dysfunction ([Online Data Supplement](#)) within 90 days after implantation (12.7% vs 5.4%) and respiratory failure within 90 days after implantation (22.0% vs 8.5%). The final Cox model coefficients and 95% CIs are shown in the [Online Data Supplement](#).

Overall survival through 90 days after implantation was 88.1% (95% CI, 87.4%-88.7%), although varied according to adjusted HAI tercile: low, 88.9% (95% CI, 87.5%-90.1%); middle, 88.8% (95% CI, 87.6%-89.9%); and high, 87.0% (95% CI, 85.8%-88.0%; $P = .03$; [Online Data Supplement](#)). The association between patient-level characteristics and outcomes across device- and non-device-related HAIs are presented in the [Online Data Supplement](#).

Variability existed in the crude 90-day HAI rate across hospitals ([Figure 1](#)). The median (25th, 75th percentile) adjusted hospital HAI rate was 14.3 (9.3, 19.5) per 100

patient-months. The mean cumulative frequency of HAIs was 0.42 (95% CI, 0.41-0.44; [Figure 2](#)). Risk-adjusted rates increased across terciles: low, 0.15 (95% CI, 0.14-0.17), middle, 0.35 (95% CI, 0.33-0.38), and high, 0.64 (95% CI, 0.61-0.67).

Bacterial HAIs were the most common infection across unadjusted ([Table 2](#), [Online Data Supplement](#)) and risk-adjusted ([Online Data Supplement](#)) terciles. Rates of non-device-related HAIs were higher than device-related HAIs (15.6 vs 1.4), with both being more common in high versus low tercile hospitals: non-device-related, 24.3 versus 5.1; device-related, 1.9 versus 0.74. Pulmonary infections were the most common HAI across each tercile.

Total mean Medicare payments were \$256,600 (SD, \$93,120) and \$12,497 higher at high versus low tercile hospitals ($P < .001$; [Online Data Supplement](#)). Average payments during the 180 days before admission were \$34,910 (SD, \$30,269), from admission to implantation \$63,432 (SD, \$40,992), and from implantation to 90 days post implantation \$158,258 (SD, \$77,131). Most of the difference across terciles in total payments was attributed to the implantation to 90-day period ([Online Data Supplement](#)).

Payments between implantation to 90 days post implantation varied \$13,652 between high (\$166,170 [SD, \$83,855]) and low terciles (\$152,518 [SD, \$69,716]). Most (83.7%) of the difference across high and low terciles for payments from implantation to 90 days was attributed to inpatient services (43.3% and 40.4% attributed to diagnostic-related group and outlier payments, respectively; [Online Data Supplement](#)). The period between implantation to discharge accounted for 73.1% of the difference in payments during the implantation to 90-day period across terciles. Further stratification of payments across HAI subtypes is provided in the [Online Data Supplement](#).

There was a significant correlation ($r = 0.24$) between a hospital's HAI rate and its average payments for the period from implantation to 90 days ($F = 7.06$; $P = .01$; [Online Data Supplement](#)). However, after adjusting for baseline variables, this association was still positive but not significant ($P = .61$).

DISCUSSION

This large, population-based study advances the literature concerning postimplantation HAIs. Specifically, significant interhospital variability was observed in: (1) the rate of HAIs and (2) payments for the period from 90 days after durable VAD implantation.

To our knowledge, this study is the first to report significant hospital variation in the rate and effect of HAIs after durable VAD implantation. Previous work in the setting of isolated coronary artery bypass grafting (CABG) surgery has documented large-scale differences in observed HAI rates.^{23,24} Shih and colleagues reported an 18.2% absolute difference in observed HAIs in contrast to a 2.8% predicted difference across hospitals performing CABG surgery in

TABLE 1. Patient characteristics according to tercile of unadjusted 90-day HAI rate after durable VAD implantation

	First (low)	Second (middle)	Third (high)	P value
HAI incidence rate (95% CI) per 100 person-month	5.8 (5.2-6.5)	13.9 (13.1-14.8)	26.2 (25.2-27.3)	
Patient n	2101	2976	3611	
Demographic characteristics				
Age, y	66.2 (57.4-71.0)	65.2 (55.8-70.0)	65.2 (56.2-69.3)	<.0001
Female sex	406 (19.4)	627 (21.1)	678 (18.8)	.05
Race				<.0001
White	1594 (75.9)	2059 (69.2)	2439 (67.5)	
African-American	388 (18.5)	712 (23.9)	857 (23.7)	
Other	119 (5.7)	205 (6.9)	315 (8.7)	
Hispanic	125 (6.0)	130 (4.4)	253 (7.1)	<.0001
Indication				
Device strategy*				<.0001
Group 1	583 (27.8)	972 (32.7)	1389 (38.5)	
Group 2	225 (10.7)	373 (12.5)	338 (9.4)	
Group 3	1293 (61.5)	1631 (54.8)	1884 (52.2)	
Device				<.0001
HeartMate II LVAS	1897 (90.3)	2504 (84.1)	2913 (80.7)	
HeartWare HVAD	†	†	639 (17.7)	
Other	†	†	59 (1.6)	
Patient characteristics				
Intermacs profile				<.0001
Profile 1	185 (8.8)	332 (11.2)	482 (13.4)	
Profile 2	678 (32.3)	1095 (36.8)	1365 (37.8)	
Profile 3	827 (39.4)	999 (33.6)	1067 (29.6)	
Profile 4-7	411 (19.6)	550 (18.5)	697 (19.3)	
New York Heart Association Class				<.0001
I-II	19 (0.9)	22 (0.7)	19 (0.5)	
III	423 (20.1)	503 (16.9)	524 (14.5)	
IV	1587 (75.5)	2245 (75.4)	2868 (79.4)	
Missing	72 (3.4)	206 (6.9)	200 (5.5)	
History of cardiac operation	825 (39.3)	1122 (37.7)	1508 (41.8)	<.01
Hemodynamics				
Systolic blood pressure, mm Hg	106.0 (97.0-117.0)	106.0 (96.0-117.0)	104.0 (95.0-115.0)	<.0001
Diastolic blood pressure, mm Hg	64.0 (57.0-71.0)	65.0 (57.0-72.0)	63.0 (56.0-71.0)	<.0001
Central venous pressure, mm Hg	11.0 (7.0-16.0)	12.0 (7.0-17.0)	11.0 (7.0-16.0)	<.01
Pulmonary artery systolic pressure, mm Hg	48.0 (39.0-58.0)	51.0 (41.0-62.0)	51.0 (41.0-61.0)	<.0001
Pulmonary artery diastolic pressure, mm Hg	23.0 (18.0-29.0)	25.0 (19.0-31.0)	25.0 (19.0-30.0)	<.0001
Pulmonary capillary wedge pressure, mm Hg	24.0 (18.0-30.0)	24.0 (19.0-30.0)	24.0 (18.0-30.0)	.04
Laboratory studies				
Serum creatinine, mg/dL	1.3 (1.1-1.7)	1.3 (1.0-1.7)	1.4 (1.1-1.8)	<.0001
Blood urea nitrogen, mg/dL	27.0 (19.0-38.0)	26.0 (18.0-37.0)	27.0 (19.0-40.0)	<.0001
Hemoglobin, g/dL	11.3 (10.0-12.8)	11.2 (9.9-12.6)	11.2 (9.8-12.6)	.01
Albumin, g/dL	3.4 (3.0-3.8)	3.4 (3.0-3.8)	3.5 (3.1-3.9)	<.0001
Alanine aminotransferase, U/L	26.0 (17.0-41.0)	28.0 (18.0-45.0)	26.0 (18.0-45.0)	<.01
Aspartate aminotransferase, U/L	27.0 (20.0-39.0)	29.0 (22.0-42.0)	28.0 (21.0-42.0)	<.0001
International normalized ratio	1.2 (1.1-1.3)	1.2 (1.1-1.4)	1.2 (1.1-1.4)	<.0001
Procedural details				
LVAD with subsequent RVAD within 90 d after implantation, n (%)	16 (0.8)	33 (1.1)	70 (1.9)	<.001
Interventions at index hospitalization				
Intravenous inotropes	1760 (84.1)	2422 (81.7)	2797 (77.7)	<.0001
Intra-aortic balloon pump within 48 h	352 (16.8)	644 (21.6)	888 (24.6)	<.0001
Extracorporeal membrane oxygenation within 48 h	20 (1.0)	52 (1.8)	70 (1.9)	.02
Modifier temporary circulatory support	266 (16.7)	630 (27.2)	753 (27.1)	<.0001

(Continued)

TABLE 1. Continued

	First (low)	Second (middle)	Third (high)	P value
Dialysis or continuous venovenous ultrafiltration within 48 h	19 (0.9)	52 (1.8)	86 (2.4)	<.001
Diuretic type (bumetamide)	324 (16.6)	331 (11.8)	531 (15.9)	<.0001
Outcomes				
Length of stay, implantation to discharge, d	18.0 (13.0-26.0)	18.0 (14.0-27.0)	21.0 (15.0-32.0)	<.0001
Acute care duration, d	7.0 (5.0-12.0)	7.0 (5.0-13.0)	7.0 (5.0-14.0)	.9986
Intermediate/step-down care duration, d	9.0 (6.0-13.0)	9.0 (6.0-14.0)	11.0 (7.0-17.0)	<.0001
Discharge location†				<.0001
Home	1296 (61.7)	1849 (62.1)	2035 (56.4)	
Nursing home/assisted care	29 (1.4)	63 (2.1)	68 (1.9)	
Rehabilitation facility	504 (24.0)	728 (24.5)	980 (27.1)	
Other (Hospice, another hospital, other facility, unknown)	14 (0.7)	36 (1.2)	45 (1.3)	
Missing	258 (12.3)	300 (10.1)	483 (13.4)	
Reoperation for bleeding within 48 h of implantation	66 (5.4)	92 (5.1)	182 (8.1)	<.001
Renal dysfunction within 90 d after implantation	114 (5.4)	272 (9.1)	460 (12.7)	<.0001
Respiratory failure within 90 d after implantation	178 (8.5)	474 (15.9)	794 (22.0)	<.0001
Stroke within 90 d after implantation	122 (5.8)	189 (6.4)	268 (7.4)	.04
Death within 90 d after implantation	230 (11.0)	320 (10.8)	477 (13.2)	<.01

Continuous variables are given as median (IQR) and categorical variables as n (%), except where otherwise noted. P values are calculated using the Kruskal-Wallis test (continuous variables) and Pearson χ^2 test (categorical variables). The HeartMate II LVAS is from Abbott Laboratories (Abbott Park, Ill). The HeartWare HVAD is from Medtronic (Dublin, Ireland). HAI, Health care–associated infection; VAD, ventricular assist device; CI, confidence interval; LVAS, left ventricular assist system; Intermacs, Intermacs Registry for Mechanically Assisted Circulatory Support; LVAD, left ventricular assist device; RVAD, right ventricular assist device. *For device strategy, group 1 includes bridge to transplant (listed) + bridge to transplant (likely) + bridge to recovery; group 2 includes bridge to transplant (moderately likely) + bridge to transplant (unlikely) + rescue therapy + other; and group 3 includes destination therapy. †Data cells with <11 beneficiaries have been replaced with a “†” symbol in accordance with the Centers for Medicare and Medicaid Services suppression policy. ‡Among patients discharged alive.

Michigan.²⁴ However, an analysis of 998 hospitals suggested that only 2% of hospital variation in CABG HAIs is accounted for using traditional risk factors.²⁵ In this present analysis of VAD devices, adjusted 90-day HAI rates varied 35.6% in absolute terms across hospitals.

Further, this study is the first to our knowledge to link interhospital HAI variability to Medicare payments, thereby leveraging the strengths inherent in the claims and clinical registry databases. Findings from this study reinforce the importance (from a value standpoint) of identifying and disseminating optimal HAI preventive practices at high performing institutions because: (1) patients at high versus low

HAI hospitals were more likely to have higher payments between the implantation to 90-day period, and (2) the implantation to discharge period accounted for most of the difference in 90-day payments across terciles.

These findings have important implications for reducing VAD-associated HAIs. Previous studies have established the effect of targeted interventions to reduce HAIs in other cardiac surgical settings. Likosky, using a collaborative learning intervention (ie, quarterly data feedback reporting, site visits, and centralized quality improvement support), reported significant reductions in post-CABG pneumonia relative to hospitals receiving quarterly STS feedback reports.²⁶ However, CABG-specific HAI prevention strategies might not apply given: (2) VAD represents a large cardiovascular implantable electrical device, (2) unique surgical features (eg, percutaneous lead), and (3) frequent hemodynamic instability at implantation. The STS is well positioned to advance VAD-specific HAI benchmarking and evaluate HAI-preventive practices at low- and high-performance outlier hospitals, an initiative currently under way through a grant from the Agency for Healthcare Research and Quality.²⁷

Several limitations exist in this descriptive study. First, this Intermacs cohort does not include all durable VADs implanted in the United States.¹¹ However, Intermacs does include nearly all FDA-approved implanted devices. Second, the dataset used for this study lacks important specificity regarding infections

FIGURE 1. Crude 90-day hospital health care–associated infection rate (per 100 patient-months) after durable ventricular assist device implantation. Distribution of crude 90-day hospital infection rates.

FIGURE 2. Mean crude and risk-adjusted cumulative frequency of 90-day hospital health care–associated infection rate after durable ventricular assist device implantation. Overall (*left panel*), crude (*center panel*), and risk-adjusted (*right panel*) cumulative frequency of 90-day hospital infection rates, along with 95% confidence intervals. The *center* and *right* panels are stratified according to tercile of hospital infection rates.

TABLE 2. Ninety-day HAI rates according to tercile of crude 90-day HAI rate after durable VAD implantation

	Overall (n = 8688)	Tercile of unadjusted HAI rate (per 100 patient-months)*			P value†
		First (low; n = 2101)	Second (middle; n = 2976)	Third (high; n = 3611)	
Infection type					
Bacterial	14.2	4.8	11.9	21.8	<.0001
Fungal	1.2	0.3	0.7	2.1	<.0001
Protozoan	0.03	0.02	0.1	0.03	.58
Viral	0.3	0.1	0.3	0.4	<.001
Unknown	1.3	0.7	1.1	1.9	<.0001
Device or non-device-related infections					
Non-device-related only	15.6	5.1	12.6	24.3	<.0001
Device-related only	1.4	0.7	1.3	1.9	<.0001
Overall	17.0	5.8	13.9	26.2	<.0001
Location of infection					
Pulmonary	4.6	1.3	3.6	7.4	<.0001
Urine	3.4	1.2	2.8	5.3	<.0001
Blood cultures, positive	2.7	0.8	2.1	4.3	<.0001
Other	1.9	0.6	1.4	3.0	<.0001
Gastrointestinal	1.2	0.5	1.0	1.8	<.0001
Pump-related: drive line or percutaneous lead	1.0	0.5	1.0	1.4	<.0001
Mediastinum	0.6	0.3	0.6	0.7	<.001
Line sepsis	0.4	0.2	0.4	0.6	<.001
Unknown	0.5	0.2	0.4	0.7	<.0001
Peripheral wound	0.4	0.1	0.3	0.6	<.0001
Pump-related: pump pocket	0.3	0.2	0.3	0.4	.27
Pump-related: exit cannula	0.04	0.04	0.01	0.1	.12
Pump-related: pump interior	0.03	0.0	0.01	0.1	.03

HAI, Health care–associated infection; VAD, ventricular assist device. *Patients could have >1 infection. †P value calculated using the Wald test.

FIGURE 3. Study design, results, and implications. Adjusted incidence of infections varied by hospital, and total Medicare payments from implant to 90-days were 9.0% greater in high- versus low-infection tercile hospitals. Infection prevention could improve the value of durable ventricular assist devices.

(eg, specific infectious organisms, infection prevention practices) and might under-report the true number of HAIs; however, Intermacs-submitting hospitals leveraged trained data coordinators who used strict definitions to guide HAI determination and the database undergoes routine audits. Importantly, HAI rates reported in this study are very similar to other published HAI rates documented from recent randomized clinical trials of durable VADs.⁵⁻⁸ Third, pre- and postprocedure inpatient payment estimates assume a constant daily payment rate that might not be reflective of all patients’ experiences; nonetheless, price standardization methods account for differences attributed to local and regional practice differences. Fourth, unmeasured confounding might persist. To mitigate its effect, commonly cited patient-level factors and hospital variation were accounted for through hierarchical modeling. Although these data reflect experiences through July 2017, this cohort represents to our knowledge the largest, most contemporaneous VAD experience evaluating HAIs among Medicare beneficiaries. Comparable survival at 90-days and major HAI rates between this report and The Multicenter Study of MagLev Technology in Patients Undergoing Mechanical Circulatory Support Therapy With HeartMate 3 (MOMENTUM 3) experience⁸ support the generalizability of our findings.

Post VAD implantation HAIs are common and vary in rate across hospitals. Patients cared for at hospitals with higher HAI rates had greater associated index admission resource utilization, postoperative morbidity, and expenditures. The current findings suggest that a portion of

these HAIs might be preventable because of the 36.5% absolute difference in adjusted hospital HAI rates (Figure 3). Ongoing research on detailed hospital- and unit-level practices could provide further insight into determinants of HAI variation.²⁷ Large-scale improvements in the quality, safety, and expenditures associated with VAD care might be realized through the evaluation and subsequent dissemination of HAI prevention best practices.

Conflict of Interest Statement

Francis D. Pagani is a member of the scientific advisory board of FineHeart, Inc, member of the Data Safety Monitoring Board for Carmat, Inc, member of the Data Safety Monitoring Board for the National Heart, Blood, and Lung Institute PumpKIN clinical trial, and Chair of The STS Intermacs Task Force. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

The authors thank Daniel Gottlieb, Keith Aaronson, Lourdes Cabrera, Qixing Liang, Michael Thompson, and Xiaoting Wu for their contributions; Susan Meyers for assistance with data queries; and the Michigan Congestive Heart Failure Investigators: Donald S. Likosky, PhD, Francis D. Pagani, MD, PhD, Ashraf Shaaban Abdel Aziz Abou El Ela, MB, BCH, Paul C. Tang, MD, PhD, Michael P. Thompson, PhD, Keith Aaronson, MD, MS, Supriya Shore, MBBS, Thomas Cascino, MD, MSc, Katherine B. Saliccioli, MD, Min Zhang, PhD, Jeffrey S. McCullough,

PhD, Michelle Hou, MS, Allison M. Janda, MD, Michael R. Mathis, MD, Tessa M. F. Watt, MD, MSc, Michael J. Pienta, MD, MS, Alexander Brescia, MD, MSc, Austin Airhart, Daniel Liesman, and Khalil Nassar.

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Key Words: ventricular assist device, infection, expenditure