

ORIGINAL RESEARCH

An Increasing Burden of Disease: Emergency Department Visits Among Patients With Ventricular Assist Devices From 2010 to 2017

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BACKGROUND: With a growing population of patients supported by ventricular assist devices (VADs) and the improvement in survival of this patient population, understanding the healthcare system burden is critical to improving outcomes. Thus, we sought to examine national estimates of VAD-related emergency department (ED) visits and characterize their demographic, clinical, and outcomes profile. Additionally, we tested the hypotheses that resource use increased and mortality improved over time.

METHODS AND RESULTS: This retrospective database analysis uses encounter-level data from the 2010 to 2017 Nationwide Emergency Department Sample. The primary outcome was mortality. From 2010 to 2017, >880 million ED visits were evaluated, with 44 042 VAD-related ED visits identified. The annual mean visits were 5505 (SD 4258), but increased 16-fold from 2010 to 2017 (824 versus 13 155). VAD-related ED visits frequently resulted in admission (72%) and/or death (3.0%). Median inflation-adjusted charges were \$25 679 (interquartile range, \$7450, \$63 119) per encounter. The most common primary diagnoses were cardiac (22%), and almost 30% of encounters were because of bleeding, stroke, or device complications. From 2010 to 2017, admission and mortality decreased from 82% to 71% and 3.4% to 2.4%, respectively (*P* for trends <0.001, both).

CONCLUSIONS: We present the first study using national-level data to characterize the growing ED resource use and financial burden of patients supported by VAD. During the past decade, admission and mortality rates decreased but remain substantial; in 2017 ≈1 in every 40 VAD ED encounters resulted in death, making it critical that clinical decision-making be optimized for patients with VAD to maximize good outcomes.

Key Words: emergency ■ mortality ■ ventricular assist device

Heat failure is a national epidemic with profound effects on morbidity, mortality, and resource utilization. Heart failure affects 5.7 million American adults, or 2.4% of the population, and with an aging population this prevalence is expected to increase to

8 million in the next decade.^{1,2} Despite efforts to prevent heart failure progression through rigorously studied and standardized medical therapy,^{3–6} between 5% and 10% of this population have end-stage disease refractory to optimal medical therapy.⁷ Outcomes

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CLINICAL PERSPECTIVE

What Is New?

- In this study we leverage 882 million emergency department visits in order to assess emergency department visits and associated inpatient admissions of patients with advanced heart failure with ventricular assist devices (VADs) over an 8-year period.
- Ambulatory patients with VADs who present to the emergency department are placing an increasingly large financial burden on the health-care system, and much of this burden appears to be related to the VAD or to VAD-associated complications.
- Mortality has improved in recent years, but in the current era, ≈ 1 in 40 encounters of VAD-supported patients who present to the emergency department result in death.

What Are the Clinical Implications?

- This study highlights the high-risk and high-resource use of ambulatory patients with VADs, which underscores the importance of implementing evidence-based care strategies that can improve healthcare resource use and mitigate their risk of death.

Nonstandard Abbreviations and Acronyms

NEDS Nationwide Emergency Department Sample

for these patients are bleak, with a life expectancy of <2 years.^{4,8}

In this context, and in the setting of a limited supply of available organs for transplantation,⁹ ventricular assist devices (VADs) have emerged as a critical therapy for patients with refractory end-stage heart failure.¹⁰ Recent years have seen a remarkable increase in the use of durable mechanical circulatory support devices as a lifesaving and life-sustaining therapy, with the most recent INTERMACS-STs (Interagency Registry for Mechanically Assisted Circulatory Support-Society of Thoracic Surgeons) report describing nearly 23 000 patients in 185 hospitals in the United States in whom US Food and Drug Administration–approved durable mechanical circulatory support devices were placed over the past 10 years.¹¹ With the increased use of durable VADs for end-stage heart disease, efforts to improve outcomes for these patients have emerged, with studies showing that improved survival is also associated with an increase in overall cost because

of frequent admissions, complications, and need for close long-term follow-up.^{12–15}

Although this patient population is growing, data regarding visits to the Emergency Department (ED) among patients with VADs are lacking, and there are none that offer a national population-based assessment or assess trends in outcomes and resource utilization over time. Thus, the purpose of this study is to describe nationwide estimates of VAD-related ED visits over an 8-year period with attention to their presenting complaints, medical complexity, volume of admissions, and the associated financial burden, and ultimately to test the hypothesis that ED visits in patients supported with VADs resulted in increased resource utilization and a coincident decrease in mortality over time.

METHODS

Data Source

The Nationwide Emergency Department Sample (NEDS) was utilized for this study. NEDS is the largest publicly available all-payer ED database in the United States, encompassing ≈ 30 million annual ED visits from 953 hospitals across 37 states. Because no patient-identifying information was used in the study, the University of Pennsylvania Institutional Review Board granted a waiver of submission for this study. The database is provided by the Healthcare Cost and Utilization Project and contains a stratified sample, which estimates 20% of ED visits from across the United States.^{16,17} It provides appropriate sample weights to obtain nationally representative estimates. NEDS data capture information on ED visits that result in admission, transfer, or discharge. The unit of analysis is the ED visit, not a patient (ie, a patient may therefore be represented by multiple ED visits in any given year or multiple years). An ED to ED transfer is recognized as a single encounter. Data regarding admissions linked to ED encounter were also included in this analysis.¹⁸ The data sets generated and analyzed for the current study were obtained, and can be similarly purchased, from the Healthcare Cost and Utilization Project.

Study Population

ED visits of patients 18 years or older with a diagnosis code for durable VAD (*International Classification of Diseases Clinical Modification, Ninth Revision* [ICD-9-CM] code V43.21, and *Tenth Revision* [ICD-10-CM] code Z95.811) were identified between 2010 and 2017. Patients with a procedure code for VAD implant during an associated admission who were not coded for history of prior VAD during their ED encounter were excluded from the cohort, as were patients supported with a total artificial heart. To identify diagnoses and procedures, ICD-9 codes were used for encounters

between January 2010 and September 2015, and *ICD-10* codes were used for encounters starting in October 2015 (Table S1).

Outcomes of Interest

In the current study, we examined the following outcomes of interest: (1) Volume of and causes for ED encounter; (2) Mortality (death in ED or during admission associated with ED visit); and (3) Total ED and hospital charges adjusted for inflation to 2017 US dollars using the consumer price index for medical care.

Covariates

The following patient characteristics for ED encounters were evaluated: age in years categorized based on United States Census Bureau practice (18–44, 45–64, and ≥65), sex, insurance status (government, private, other), patient residence (urban versus rural), time of visit (weekday versus weekend), and chronic medical conditions (dialysis dependence, liver cirrhosis, hypertension, diabetes mellitus, obesity, chronic obstructive pulmonary disease, and depression). Hospital characteristics included geographic region, using groupings from the United States Census Bureau (Northeast, Midwest, West, and South), and hospital location/teaching status (metropolitan/teaching, metropolitan/nonteaching or nonmetropolitan area). Primary diagnoses, a defined field in the NEDS database with a single possible value for each encounter, were collected for all encounters and then categorized as device complication, stroke, cardiac, infection, bleeding, thrombus, respiratory, gastrointestinal, kidney, neurological (nonstroke), psychiatric, trauma, vascular, and other (Table S1).

Statistical Analysis

All analyses accounted for NEDS's complex survey design utilizing appropriate survey weights. Descriptive statistics are reported as weighted frequencies and percentages for categorical variables, and continuous variables are reported as median and interquartile range (IQR). National estimates of ED visits overall, among patients with VADs and without VADs by year across 2010 to 2017, were calculated. We evaluated trends in admission, mortality, and overall charges using weighted linear regression. Charges for VAD-related ED visits and subsequent hospitalizations were compared with those for patients age 18 years or older who have previously received an orthotopic heart transplant (OHT), identified using *ICD-9-CM* (V42.1) and *ICD-10-CM* (Z94.1 and Z48.21) codes. All analyses were performed with SAS version 9.4 (SAS Institute, Cary,

NC), and a 2-sided $P < 0.05$ was considered statistically significant.

RESULTS

Patient Population

Among an estimated 882 million national visits to the ED over an 8-year period among adults 18 years and older, there were 44 042 VAD-related ED visits. The majority of visits were among male patients (73.5%), with the 45- to 64-year age group the most frequently represented (44.7%). Clinically significant comorbidities were frequent among VAD-related ED encounters, with hypertension and diabetes mellitus being the most prevalent chronic medical conditions. Depression was seen in 11.8% of VAD patient visits compared with 4.7% of ED visits of non-VAD patients ($P < 0.0001$) (Table 1). Government insurance was the primary payer for most encounters (74.1%). Most patients lived in an urban area (86.6%) and presented to metropolitan teaching hospitals (86.0%) (Table 2).

Table 1. Clinical Characteristics of Study Population

Characteristic	ED Encounters of Adults Supported With VADS	ED Encounters of Adults Without VADS
	(N=44 042)	(N=882 879 802)
Sex		
Male	32 388 (73.54%)	377 202 663 (42.72%)
Female	11 654 (26.46%)	505 595 095 (57.27%)
Patient age		
18–44 y	6782 (15.40%)	427 478 488 (48.42%)
45–64 y	19 673 (44.67%)	254 684 632 (28.85%)
≥65 y	17 586 (39.93%)	200 716 682 (22.73%)
Median age (IQR)	60.72 (50.37, 68.85)	46.74 (30.89, 63.78)*
Chronic medical conditions		
Dialysis-dependent	966 (2.19%)	6 816 736 (0.77%)
Cirrhosis	325 (0.74%)	548 9764 (0.62%)
Hypertension	23 926 (54.33%)	222 579 831 (25.21%)
Diabetes mellitus	16 746 (38.02%)	113 958 736 (12.91%)
Obesity	5618 (12.76%)	30 215 236 (3.42%)
COPD	4777 (10.85%)	26 684 562 (3.02%)
Depression	5211 (11.83%)	41 153 403 (4.66%)
Number of Chronic Medical Conditions		
No chronic conditions	11 438 (25.97%)	577 401 984 (65.40%)
1 chronic condition	14 693 (33.36%)	193 254 651 (21.89%)
≥2 chronic conditions	17 910 (40.67%)	112 190 710 (12.71%)

COPD indicates chronic obstructive pulmonary disease; ED, emergency department; IQR, interquartile range; and VADs, ventricular assist devices.

*Available for 2017 data only.

Table 2. Demographics of Study Population

Characteristic	ED Encounters of Adults Supported With VADS	ED Encounters of Adults Without VADS
	(N=44 042)	(N=882 879 802)
Location of patient		
Urban	38 062 (86.62%)	714 989 763 (80.98%)
Rural	5880 (13.38%)	162 507 079 (18.41%)
Region		
Northeast	5336 (12.12%)	167 212 348 (18.94%)
Midwest	16 204 (36.79%)	203 298 363 (23.03%)
South	17 499 (39.73%)	351 701 648 (39.84%)
West	5003 (11.36%)	160 667 445 (18.20%)
Teaching status of hospital		
Metropolitan nonteaching	3427 (7.78%)	308 805 053 (34.98%)
Metropolitan teaching	37 869 (85.99%)	425 856 860 (48.23%)
Nonmetropolitan	2745 (6.23%)	148 217 889 (16.79%)
Primary payer		
Government	32 638 (74.11%)	445 110 398 (50.42%)
Private	9749 (22.14%)	247 804 244 (28.07%)
Other	661 (1.50%)	145 982 328 (16.53%)
Missing/unknown	992 (2.25%)	43 982 831 (4.98%)

ED indicates emergency department; and VADs, ventricular assist devices.

Cause of ED Visits

More than half of all encounters had 1 of 3 primary diagnoses (Table 3), in order of prevalence: cardiac (21.5%), bleeding (19.4%), and infection (12.5%). Most cardiac complaints were either arrhythmia (7.6%) or heart failure (9.6%), and more than half of bleeding events were gastrointestinal in origin. Sepsis or bacteremia comprised more than one fourth of infections. Notably, nearly 1 in 10 encounters were because of stroke (5.7%) or a device complication (4.2%).

Admissions, Mortality, and Financial Burden

Twenty-nine thousand ninety-one (66.1%) of encounters resulted in hospital admission while an additional 2808 (6.4%) led to transfer to another hospital. The median length of stay was 4.6 days for admitted patients. More than 3% of encounters resulted in death, either in the ED or during the associated admission, compared with 0.63% in the non-VAD population (P for all <0.0001). One in 150 visits led to a device exchange and 1 in 320 resulted in a heart transplant. There were 12.1% of visits that resulted in blood transfusion and 6.3% in endoscopy. Cardiac catheterizations were performed during 4.0% of encounters (Table 4).

Table 3. Primary Diagnoses of ED Encounters

Characteristic	ED Encounters of Adults Supported With VADS
	(N=44 042)
Primary diagnoses	
Device complication	1840 (4.18%)
Stroke (ischemic or hemorrhagic)	2525 (5.73%)
Bleeding: any	8560 (19.44%)
GI	4906 (11.14%)
Epistaxis/respiratory	1394 (3.16%)
Infection: any	5519 (12.53%)
Sepsis/bacteremia	1585 (3.60%)
Cardiac: any	9469 (21.50%)
Arrhythmia	3338 (7.58%)
Heart failure	4240 (9.63%)
Thromboembolic (venous)	149 (0.34%)
Respiratory	1525 (3.46%)
Other GI	2439 (5.54%)
Renal	1097 (2.49%)
Other neurologic	1624 (3.69%)
Psychiatric	426 (0.97%)
Trauma	1866 (4.24%)
Vascular	245 (0.56%)
Other	6652 (15.10%)
Arthritis/joint	832 (1.89%)
Chest pain	2001 (4.54%)
Dermatologic	160 (0.36%)
Diabetes mellitus	500 (1.14%)
GU/GYN	437 (0.99%)
Oncologic	235 (0.53%)

ED indicates emergency department; GI, gastrointestinal; GU, genitourinary; GYN, gynecologic; and VADs, ventricular assist devices.

In 2017, total charges amounted to \$786 681 096. Overall, the median charge per visit was \$25 679 (IQR 7449.87, 63 119); for the subset of encounters resulting in admission, the median charges were \$39 975 (IQR 19 953, 83 273). Charge was highest in visits presenting with device complications \$63 048 (IQR 23 343, 153 625), compared with stroke \$42 496 (IQR 18 535, 89 788), bleeding \$34 108 (IQR 10 313, 71 057), infection \$40 744 (IQR 17 356, 90 998), and cardiac \$26 021 (IQR 10 855, 60 101) (Figure 1).

In order to contextualize the financial burden of VAD-related ED encounters, charges were compared with ED encounters of patients after OHT ($n=140 698$). The median charge per OHT visit (\$12 913 [IQR 3774, 35 351]) and for the subset of OHT encounters that resulted in admission ($n=77 199$; \$29 158 [IQR 14 636, 57 006]) were lower when compared with VAD encounters (P for both <0.0001), and in 2017

Table 4. Outcomes of VAD-Related ED Visits, NEDS 2010 to 2017

	ED Encounters of Adults Supported With VAD	ED Encounters of Adults Without VADs
	(N=44 042)	(N=882 879 802)
Hospital admission	29 091 (66.05%)	148 143 332 (16.78%)
Transfer	2808 (6.38%)	25 738 352 (2.92%)
Admit/transfer	31 900 (72.43%)	173 881 685 (19.69%)
Mortality		
Overall	1336 (3.03%)	5 523 529 (0.63%)
Emergency department	114 (0.26%)	1 494 268 (0.17%)
Hospital	1221 (2.77%)	4 029 261 (0.46%)
Inpatient length of stay	4.55 (2.07, 9.06)	2.90 (1.53, 5.36)*
Inpatient and ED charges (\$, median, Q1, Q3)	25 679 (7449.87, 63 119)	3485.2 (1483.28, 10 201)*
Inpatient and ED charges among admitted patients (\$, median, Q1, Q3)	39 975 (19 953, 83 273)	26 547 (13 289, 51 917)*
Inpatient and ED charges (\$, median, Q1, Q3)—device complication	63 048 (23 343, 153 625)	
Inpatient and ED charges (\$, median, Q1, Q3)—stroke	42 496 (18 565, 89 788)	
Inpatient and ED charges (\$, median, Q1, Q3)—bleeding	34 108 (10 313, 71 057)	
Inpatient and ED charges (\$, median, Q1, Q3)—infection	40 744 (17 356, 90 998)	
Inpatient and ED charges (\$, median, Q1, Q3)—cardiac	26 021 (10 855, 60 101)	
Procedures		
Blood transfusion	5315 (12.07%)	12 034 631 (1.36%)
Catheterization	1759 (3.99%)	6 052 027 (0.69%)
Right heart only	1513 (3.44%)	157 674 (0.02%)
Left heart/combined	256 (0.58%)	5 904 626 (0.67%)
Endoscopy	2785 (6.32%)	4 204 925 (0.48%)
Device exchange	296 (0.67%)	N/A
Orthotopic heart transplant	135 (0.31%)	1405 (0%)

ED indicates emergency department; N/A, Not Applicable; NEDS, Nationwide Emergency Department Sample; and VADs, ventricular assist devices.
*Available for 2017 data only.

the total cumulative charges for OHT encounters was \$724 349 983 (n=21 999) (Table 5).

Change in ED Visits and Outcomes Over a Decade

During the 8 years studied, overall annual ED visits increased by 14% from 103 450 324 to 118 034 396. In contrast, VAD-related ED visits increased 16-fold from 824 annual visits in 2010 to 13 155 annual visits in 2017 (P for trend in proportion of ED visits that were VAD visits <0.0001) (Table 6, Figure 2). The proportion of those VAD-related ED visits resulting in admission or transfer decreased over the course of the study, from 81.8% in 2010 to 70.6% in 2017 (P for trend=0.0010) (Figure 3). Overall charges per encounter also decreased (P for trend <0.0001) and correlated with annual fluctuations in admission/transfer rate. Mortality showed an initial increase, from 3.43% 2010 to a peak of 5.24% in 2012, and then decreased over the past 3 years of the study to 2.41% in 2017 (P for trend <0.0001) (Figure 4). To assess for the possible impact of the transition from *ICD-9* to *ICD-10* impacting identification of VAD-related ED

encounters, we evaluated 2015 by quarter and found similar rates of encounters and mortality.

DISCUSSION

This is the largest study published to date on the epidemiology and financial impact of ED visits of patients with VAD. In this study, we leveraged a large administrative database allowing us to assess >44 000 unique VAD-related ED encounters over an 8-year period and to describe emergency resource utilization of the ambulatory VAD population, leading to several major findings. First, our study demonstrates the significant and growing financial burden that ambulatory patients with VADs place on the healthcare system. Second, VAD-related complications are a leading reason for these patients seeking emergency care. Finally, our study demonstrates the high-risk nature of ambulatory patients with VADs, with >3% of ED encounters resulting in death compared with a 0.67% mortality rate in non-VAD patients.

Our study clearly outlines that ambulatory patients with VADs contribute substantially to the healthcare system

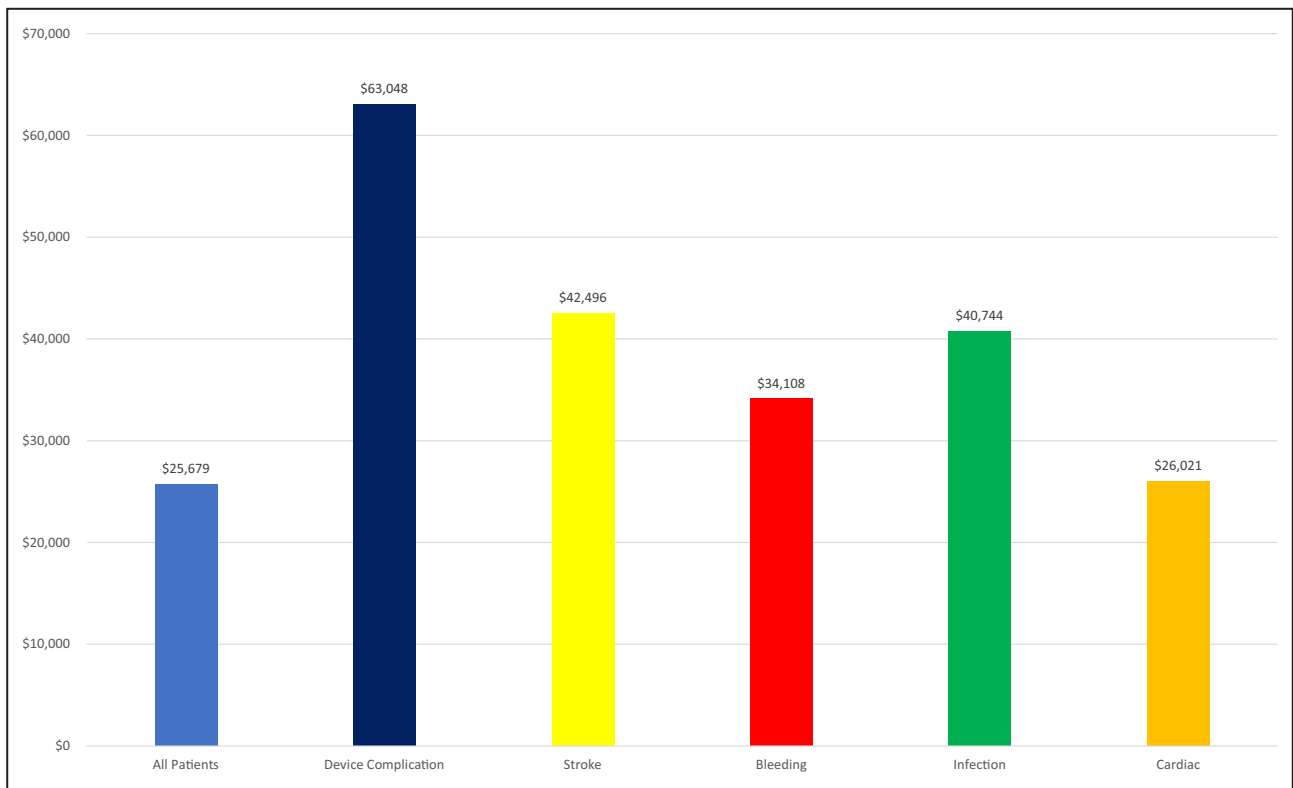


Figure 1. Overall charges of emergency department and associated admissions by primary diagnosis. Charges were higher in visits associated with VAD-related complications, and highest in those with device complications. VAD indicates ventricular assist device.

burden, with almost three fourths of ED visits resulting in hospital admission or transfer, and a median charge of >\$25 000 per ED encounter. For context, these charges are nearly double those observed for ED encounters of OHT recipients. We observed an exponential increase in VAD-related encounters during the study period, which was driven by increases in annual VAD implants and likely further amplified by growth in destination therapy VAD use.¹⁹ By 2017, annual charges for VAD-related ED encounters surpassed three-fourths billion dollars, a figure that is likely to continue to rise in the coming years as the expansion of VAD implantation has shifted the burden of care from earlier mortality to ongoing resource use in the outpatient, ED, and inpatient settings.

This study also demonstrates that VAD-related complications are a major contributor to ED visits,

with almost 30% of encounters because of bleeding, stroke, or device complications, and 12% of encounters resulted in a blood transfusion, suggesting that hemocompatibility remains a critical issue. Given the impact of adverse events on overall survival, these results are especially meaningful.¹¹ Bleeding remains a frequent complication because of altered coagulation profiles from multiple factors including the combined antiplatelet and anticoagulation therapy, acquired von Willebrand disease, shear stress, and the generation of arteriovenous malformations in the gastrointestinal tract.^{20–22}

As a unique category, cardiac-related complaints were the most common reason (~20%) for patients with VAD presenting to the ED over the past decade. Although this patient population has advanced heart

Table 5. A Comparison of the Financial Burden of VAD-Related and OHT-Related ED Visits, NEDS 2010 to 2017

	ED Encounters of Adults Supported With VAD	ED Encounters of Adults After OHT	P Value
	(N=44 042)	(N=140 698)	
Inpatient and ED charges (\$, median, Q1, Q3)	25 679 (7449.87, 63 119)	12 913 (3774, 35 351)	<0.0001
Inpatient and ED charges among admitted patients (\$, median, Q1, Q3)	39 975 (19 953, 83 273)	29 158 (14 636, 57 006)	<0.0001

ED indicates emergency department; NEDS, Nationwide Emergency Department Sample; OHT, orthotopic heart transplant; and VAD, ventricular assist device.

Table 6. Trends in VAD-Related ED Visits Over Time, NEDS 2010 to 2017

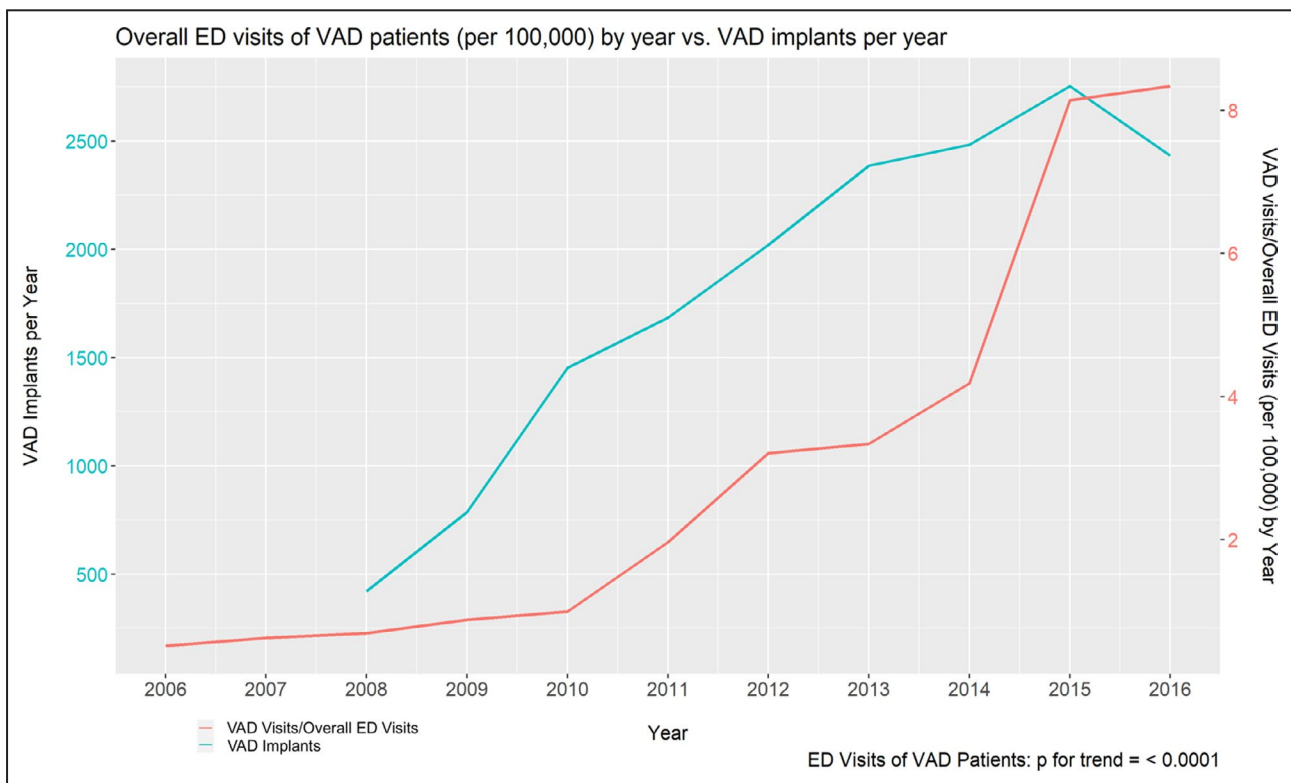
Year	Number of VAD-Related ED Visits	Admit Rate (95% CI)	Median Overall Charges (IQR)	Mortality (%)
2010	824	81.75 (77.85–85.65)	30 448 (10 097–58 146)	3.43
2011	1793	80.44 (76.21–84.67)	24 813 (9806.11–61 040)	4.71
2012	3135	77.85 (70.41–85.28)	33 534 (13 715–68 981)	5.35
2013	3333	78.37 (71.63–85.11)	31 389 (11 982–81 804)	4.53
2014	4312	75.19 (66.64–83.74)	25 401 (7525–60 888)	5.02
2015	8787	75.96 (72.49–79.42)	31 955 (11 308–74 681)	2.08
2016	8703	63.55 (56.95–70.15)	18 094 (4774–51 124)	2.17
2017	13 155	70.57 (66.04–75.11)	23 311 (6439–57 897)	2.41
	$P<0.0001$	$P=0.0010$	$P<0.0001$	<0.0001

ED indicates emergency department; IQR, interquartile range; NEDS, Nationwide Emergency Department Sample; and VAD, ventricular assist device.

failure, only 9.6% of the ED visits of patients with VAD were because of heart failure, which is similar to findings of previous studies.^{14,23}

Finally, and most importantly, our findings show that patients with VADs who present to the ED are at high risk of death (1 in 33), but notably this mortality rate has improved over recent years. Multiple factors have likely contributed to the improvement in mortality. First, device design has improved through

multiple iterative processes,²⁴ contributing to a better-supported patient with VAD. Second, there is a growing effort to provide emergency care providers with the knowledge and resources to care for patients with VADs who present to the ED, including an expert consensus on the management of patients with VADs targeted directly to emergency providers.^{25,26} Third, an increased awareness of a subpopulation of patients who are likely too sick to benefit

**Figure 2. Trends in VAD-related emergency department encounters.**

VAD-related ED visits increased 16-fold during the 8 years of the study. This trend mirrored the overall increase in VAD implants from 2010 to 2017, highlighting the growing resource burden of VAD-supported patients. Of note, VAD implants per year are abstracted from the Society of Thoracic Surgeons Intermacs Database Annual Report 2019, which does not include VADs implanted as part of a clinical trial. Thus, this may underestimate the true annual VAD implantation rate. ED indicates emergency department; and VAD, ventricular assist device. Adapted from Kormos et al¹⁹ with permission. Copyright © 2019, Elsevier.

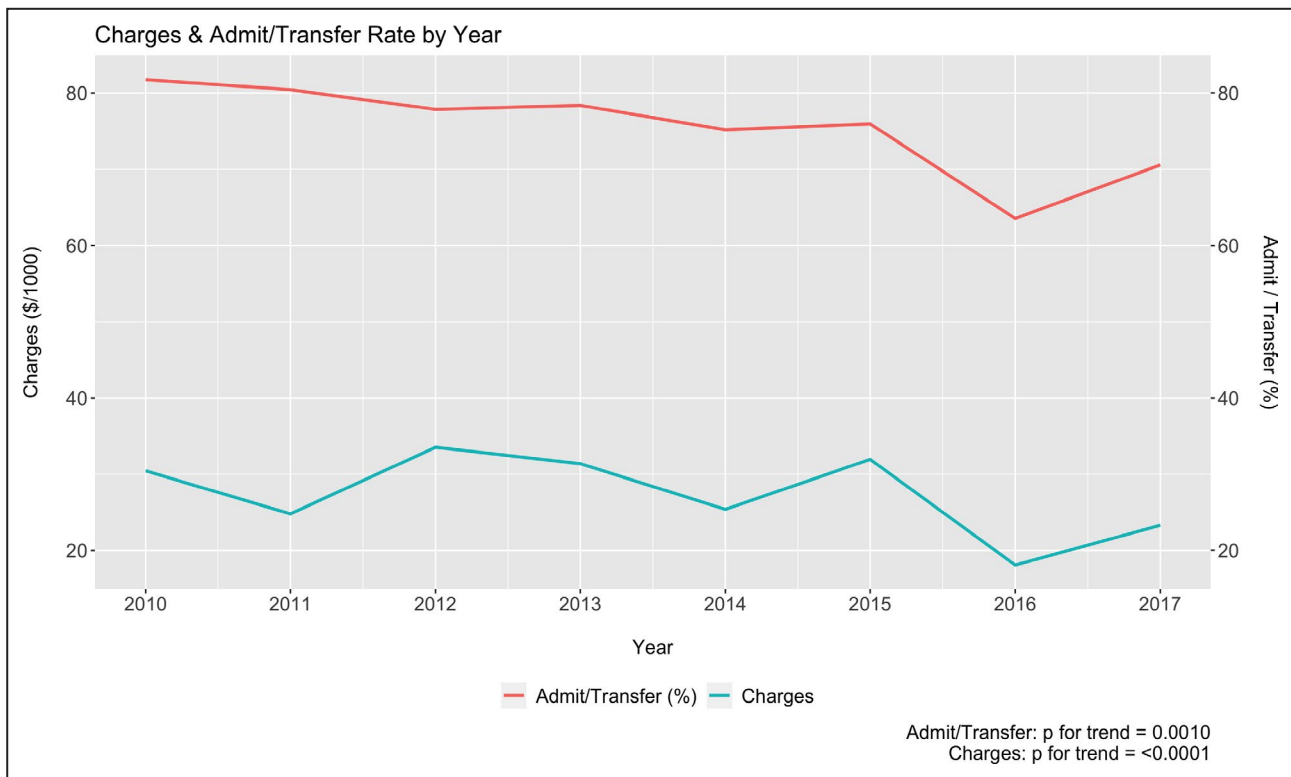


Figure 3. Trends in charges per encounter.

Overall charges of VAD-related encounters decreased, with annual fluctuations correlating with changes in admission/transfer rate. VAD indicates ventricular assist device.

from VAD implant, and resultant changes in patient selection, may also have resulted in an improved survival.^{19,27–30} Moreover, our results align with the current INTERMACS-STS data showing improved long-term survival of patients with VAD.¹¹ Yet, despite these improvements, the overall mortality in this large nationally representative cohort remains high, indicating that increased attention to recognize death risk factors for patients with VADs who present to the ED, and methods by which to identify those patients at the highest risk, are urgently needed.

Close outpatient follow-up procedures and proactive approaches to clinical screening have been shown to improve outcomes in patients with heart failure who are at high risk for admission,³⁰ and have the potential to offer a similar benefit to patients with advanced heart failure supported by VADs. Moreover, intensive and generalizable outpatient follow-up protocols may prove to be a critical tactic to curb the increasing burden that VADs are placing on the ED and requires further prospective research.

Study Limitations

This study has limitations inherent in the design of retrospective studies and those using large administrative claims data. The findings in a retrospective analysis

may differ from those in a prospectively enrolled cohort. Patients were identified using *ICD-9* and *ICD-10* codes, thus excluding and including patients who were either misdiagnosed or miscoded. The de-identification of data limits our ability to assess patients longitudinally or assess for repeat ED visits. A single patient may therefore be represented multiple times. Chronic conditions were identified during ED encounters and therefore may not fully reflect the range of comorbidities in this population. While the Healthcare Cost and Utilization Project performs several analyses to ensure internal consistency and data validity, some encounters may contain misclassified information. Additionally, the NEDS database includes information from 37 states, which may limit our ability to completely assess resource utilization and outcomes in the United States. Finally, we evaluated charges, which serve as proxies for actual direct healthcare costs and resource utilization.

CONCLUSIONS

Ambulatory patients with durable VADs who present to the ED are placing an increasingly large financial burden on the healthcare system, and much of this burden appears to be related to the VAD or to VAD-associated complications. This study demonstrates

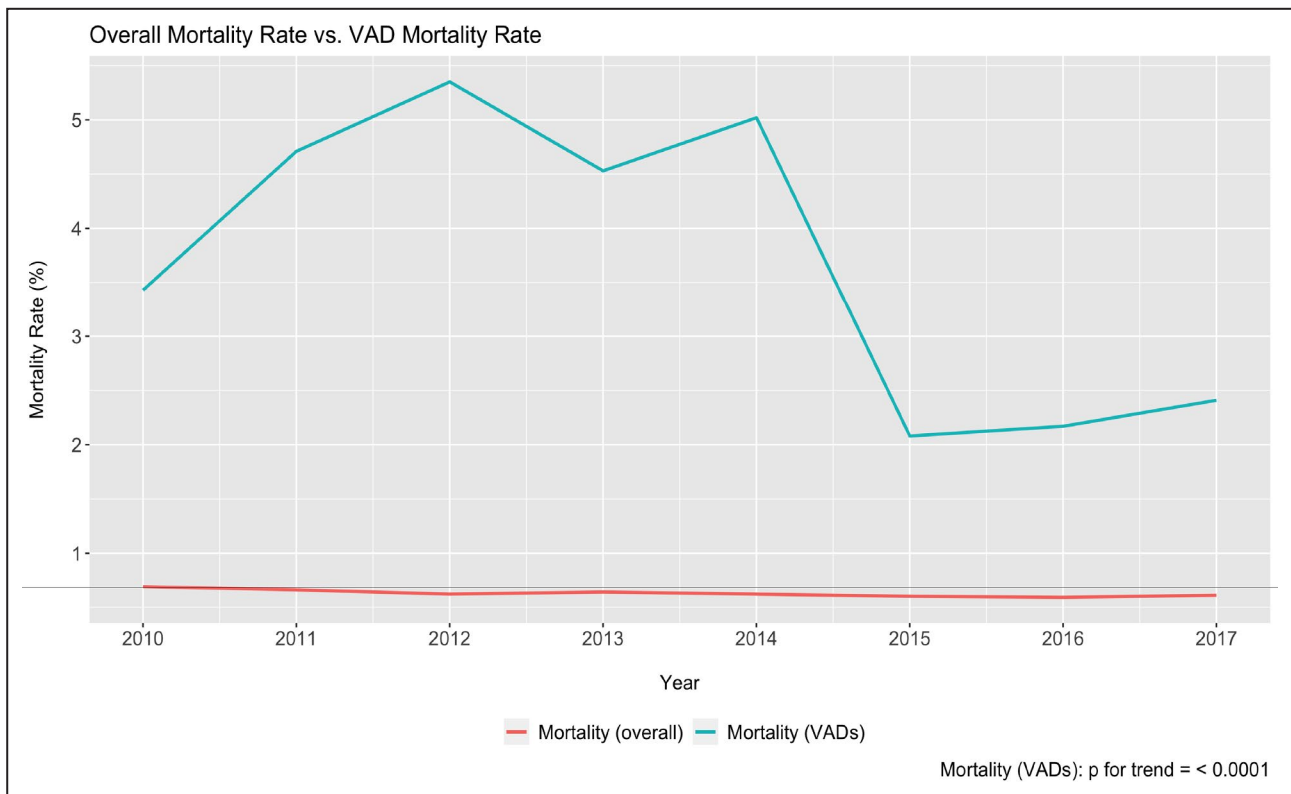


Figure 4. Changes in mortality over time.

Among VAD-supported patient encounters, mortality increased from 2010 to 2012 and then decreased during the past 3 years of the study. In contrast, overall mortality for emergency department encounters remained stable during the same time period. VAD indicates ventricular assist device.

the high-risk nature of ambulatory patients with VADs who present to the ED; despite improvements in mortality in the recent years, ≈ 1 in 40 encounters of patients supported with VADs who present to the ED result in death. Given that these high-risk and high-resource use patients are becoming an increasing proportion of ED encounters, characterizing risk factors for death—including the mechanisms for the recent improvement in mortality—and implementing evidence-based care strategies to mitigate that risk are urgently needed.

ARTICLE INFORMATION

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Supplementary Material

Table S1

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