

National Trends in Incidence and Outcomes of Patients With Heart Failure Requiring Respiratory Support



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Despite increasing medical complexity in patients with heart failure (HF), there are limited data on incidence and outcomes for patients with HF needing respiratory support. This study sought to examine contemporary trends of respiratory support strategies among patients with HF. Using the National Inpatient Sample, we identified adults aged greater than 18 years hospitalized with a primary diagnosis of HF. We assessed for trends in the use of invasive mechanical ventilation (IMV) and noninvasive ventilation (NIV), length of stay, hospital costs, and in-hospital mortality. From 2002 to 2014, we identified 9,508,768 HF hospitalizations, which included 202,340 (2.13%) and 257,549 (2.71%) patients that required IMV and NIV, respectively. Over the study period, the proportion of HF patients requiring IMV significantly decreased (3.25% in 2002 to 1.56% in 2014) whereas the use of NIV significantly increased from 0.95% to 7.25% ($p_{\text{trend}} < 0.001$ for both). In-hospital mortality significantly increased for IMV (31.5% in 2002 to 38.6% in 2014) recipients and decreased for patients requiring NIV (9.0% to 5.6%, $p_{\text{trend}} < 0.0001$ for both). The average length of stay was nearly 7 days longer in the IMV group (12.2 days) and 2 days longer in the NIV group (6.8 days; $p < 0.001$ for both). Hospital charges have nearly tripled for patients requiring IMV (\$99,358 in 2014, $p_{\text{trend}} < 0.001$) and doubled for those requiring NIV (\$37,539 in 2014, $p_{\text{trend}} < 0.001$). In conclusion, respiratory support strategies for patients with HF have significantly evolved with increasing use of NIV as compared with IMV. However, the in-hospital mortality associated with respiratory failure remains unacceptably high. © 2019 Elsevier Inc. All rights reserved. (Am J Cardiol 2019;124:1712–1719)

Growing evidence suggests that the main determinants of in-hospital morbidity and mortality for patients with cardiovascular disease include diagnoses not typically considered cardiac, such as sepsis, acute kidney injury, and respiratory failure.¹ Although recent reports have described the incidence of respiratory failure in patients with acute coronary syndrome,^{2,3} very little evidence is available describing the incidence and outcomes of patients with

heart failure (HF) who require respiratory support.⁴ In an analysis of Medicare data, nearly 15% of patients admitted to the cardiac intensive care unit (CICU) require either invasive (invasive mechanical ventilation [IMV]) or noninvasive ventilation (NIV). Concurrently, the proportion of patients with HF admitted to the CICU has increased from 13.9% in 2003 to 34.4% in 2013.⁵ Although these analyses are suggestive that the growing HF population in the CICU could be contributing to the increased use of respiratory support, a dedicated analysis on incidence, trends, and mortality is lacking for patients with HF requiring respiratory support. To address these gaps in knowledge, we analyzed the National Inpatient Sample (NIS) database.

Methods

We obtained data from 2002 through 2014 from the NIS database, which was developed by the Healthcare Cost and Utilization Project (HCUP).⁶ As previously described, the NIS is the largest, publicly available all-payer inpatient database in the United States. It includes a 20% stratified sample of inpatient hospitalizations (excluding observation status and psychiatric hospitals) as well as all procedural and *International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM)* diagnosis codes.

To identify all hospitalizations with a primary diagnosis of HF, we queried NIS for the following previously

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Funding: None.

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See page 1718 for disclosure information.

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validated (American Heart Association's Get With The Guidelines – Heart Failure registry) *ICD-9-CM* diagnosis codes.⁷ Patients were excluded if they were less than 18 years of age, had missing data on survival, and hospitalizations where both IMV and NIV were coded, which comprised of only 0.17% of the HF cohort. *ICD-9-CM* procedural codes 96.04 (nonoperative endotracheal intubation) and 93.90 were then used to identify the implementation of IMV and NIV consistent with methods published in previous studies.^{3,8} Our final population included 3 groups for comparison: HF hospitalizations with IMV, NIV, and those not requiring respiratory support.

We included patient demographics, primary payer, index admission characteristics, and discharge disposition. Age was further grouped into 18 to 64 years, 65 to 74 years, 75 to 84 years, and >84 years. Discharge disposition was grouped into home, short-term hospital or skilled nursing facility, and against medical advice or unknown. We used the Elixhauser Comorbidity Index, which has shown superiority over other indices (e.g., Charlson Comorbidity Index) to estimate baseline co-morbidities from administrative claims data.^{9,10} Total hospital charges were converted to costs using the HCUP Cost-to-Charge Ratios based on hospital accounting reports from the Centers for Medicare and Medicaid Services. Annual costs were inflation adjusted using the US Bureau of Labor Statistics Consumer Price Index with 2018 as the index base.¹¹

We identified patient co-morbidities categorized by Clinical Classification Software (CCS) codes. CCS codes group *ICD-9-CM* codes into mutually exclusive categories with the number of CCS categories serving as an indicator of co-morbidity burden. Procedural *ICD-9-CM* codes were also used to capture procedures of interest ([Supplemental Table 1](#)).

Our outcomes of interest included temporal trends of IMV and NIV utilization for patients admitted with a primary diagnosis of HF. We also compared trends of mortality, length of stay, total hospital charges, and total hospital cost for these groups. Given the available data from the NIS, we were unable to assess for admission to a specific ICU or ICU length of stay.

We followed recommended methodological standards for NIS analyses using specific statements, such as SURVEY-FREQ, to obtain descriptive statistics.⁶ Wald chi-square test was utilized for examining the baseline characteristics for categorical variables (expressed in percentages); the unpaired, 2-tailed *t* test for normally distributed continuous variables reported as mean (\pm SE); and the Wilcoxon signed rank test if continuous variables were not normally distributed in the study population. We used the Cochran-Armitage trend test to evaluate the trend of respiratory support (IMV and NIV) in patients hospitalized with HF.

We used a propensity scoring method to establish matched cohorts to reduce bias due to confounding covariates in patient- and hospital-level characteristics between the 3 groups of interest (IMV, NIV, and neither). Before propensity matching was done, analyses were done on weighted numbers. However, after propensity matching, raw unweighted numbers are presented. Details of our propensity-matching method are described in the [Supplemental Methods](#). After propensity matching, we analyzed the

association between ventilation strategies and in-hospital mortality using Cox proportional hazards model censoring at the end of follow-up (hospital discharge or 30 days of hospital stay), whichever came first. Cox proportional hazards modeling were used to calculate univariate and multivariate hazard ratios (HRs) and the associated 95% confidence intervals and p values. The proportional hazards assumption was met in all cases. Survival curves for the 3 groups were plotted by the Kaplan Meier method, and the log-rank test was used to test group differences in mortality. Given the prolonged time period included in this study and the landmark NIV trial published in 2018,¹² we repeated our analyses during two time periods (2002 to 2008 and 2009 to 2014).

In addition, we preformed several sensitivity analyses. First, we assessed for differences in mortality stratified by diastolic versus systolic HF as well as ischemic versus non-ischemic HF using methods consistent with previous studies.^{13,14} Second, we assessed for trends in utilization, mortality, and charges for patients who required NIV and then IMV. Third, to assess for associations between procedure type ([Supplemental Table 1](#)) and mortality, procedures were compared with mortality as the outcome for each group (IMV vs neither, NIV vs neither, and IMV vs NIV) among our propensity-matched population. We excluded patients who underwent more than 1 procedure so as to ensure the outcome was not confounded by multiple procedures. Finally, we evaluated for associations between age, insurance, and hospital type with respiratory support utilization.

Data were complete for all covariates except race (17.6% missing), median household income (12.9% missing), hospital bed size (0.2% missing), hospital type (0.2% missing) hospital region (0.3% missing), and primary expected payer (0.1% missing). We performed multiple imputations for missing values using the fully conditional specification method (an iterative Markov Chain Monte Carlo algorithm) in STATA statistical software, version 11.0 (STATA Corp College Station, Texas). Results with and without multiple imputations were not significantly different; therefore, only the former are presented.

With the exception of the imputation analyses, we used SAS 9.4 (SAS Institute Inc., Cary, North Carolina) for all other analyses. We performed all association and trend analyses with the use of the weight values designated by HCUP to produce nationally representative estimates. We considered a 2-tailed p value of ≤ 0.05 to be statistically significant.

Results

From 2002 to 2014, we identified 9,508,768 hospitalizations with a primary diagnosis of HF, which included 202,340 (2.13%) and 257,549 (2.71%) hospitalizations that required either IMV or NIV, respectively ([Table 1](#)). Compared with a mean (\pm SE) age of 72.0 (± 0.1) years for those not requiring respiratory support, recipients of IMV and NIV were younger with a mean age of 70.0 (± 0.1) and 70.9 (± 0.1) years ($p < 0.0001$ for both). Recipients of IMV and NIV were more likely to be black or Hispanic and to have chronic kidney, pulmonary, and liver disease ($p < 0.0001$ for all). Compared with those patients not requiring respiratory support, the use of IMV was more often seen in urban

Table 1
Baseline patient and hospital characteristics for patients with heart failure requiring respiratory support (n = 9,508,768)

	No ventilation (n = 9,048,879)	NIV (n = 257,549)	IMV (n = 202,340)	p value		
				NIV vs no ventilation	IMV vs no ventilation	IMV vs NIV
Age (years)	72 (±0.05)	70.9 (±0.06)	70 (±0.1)	<0.0001	<0.0001	<0.0001
18-64	2,457,409 (27.2%)	80,149 (31.1%)	63,397 (31.3%)	<0.0001	<0.0001	<0.0001
65-74	1,898,564 (20.9%)	59,623 (23.1%)	51,548 (25.5%)			
75-84	2,679,040 (29.6%)	69,252 (26.9%)	60,047 (29.7%)			
>84	2,013,867 (22.3%)	48,525 (18.8%)	27,348 (13.5%)			
Race				<0.0001	<0.0001	<0.0001
White	4,837,173 (53.5%)	148,836 (57.8%)	101,018 (49.9%)			
Black	1,401,750 (15.5%)	49,167 (19.0%)	37,974 (18.8%)			
Hispanic	599,673 (6.6%)	19,269 (7.5%)	16,314 (8.0%)			
Other	318,235 (3.5%)	13,187 (5.1%)	8,826 (4.4%)			
Gender				<0.0001	<0.0001	<0.0001
Men	4,397,324 (48.6%)	122,070 (47.4%)	102,706 (50.8%)			
Women	4,650,397 (51.4%)	135,465 (52.6%)	99,599 (49.2%)			
Income quartiles*				<0.0001	<0.0001	
0-25th	2,679,195 (29.6%)	72,083 (27.9%)	57,461 (28.4%)			
26-50th	2,113,585 (23.4%)	61,940 (24.0%)	42,133 (20.8%)			
51-75th	1,710,095 (18.9%)	55,316 (21.5%)	34,888 (17.2%)			
76-100th	1,342,226 (14.8%)	52,276 (20.3%)	29,308 (14.5%)			
Diabetes mellitus						
Uncomplicated	2,906,520 (32.1%)	94,173 (36.6%)	57,670 (28.5%)	<0.0001	<0.0001	<0.0001
Complicated	834,816 (9.2%)	32,793 (12.7%)	20,417 (10.1%)	<0.0001	<0.0001	<0.0001
Hypertension	5,049,026 (55.8%)	152,954 (59.4%)	92,315 (45.6%)	<0.0001	<0.0001	<0.0001
Peripheral vascular disease	873,856 (9.7%)	30,417 (11.8%)	19,310 (9.5%)	<0.0001	0.04	<0.0001
Chronic kidney disease	2,423,683 (26.8%)	101,687 (39.5%)	65,553 (32.4%)	<0.0001	<0.0001	<0.0001
Chronic pulmonary disease	3,122,613 (34.5%)	136,929 (53.2%)	79,598 (39.3%)	<0.0001	<0.0001	<0.0001
Liver disease	190,652 (2.1%)	5,859 (2.3%)	6,095 (3.0%)	<0.0001	<0.0001	<0.0001
Obesity	1,010,173 (11.2%)	69,439 (26.9%)	19,871 (9.8%)	<0.0001	<0.0001	<0.0001
Smoking	1,516,839 (16.8%)	65,281 (25.3%)	25,248 (12.5%)	<0.0001	<0.0001	<0.0001
Dyslipidemia	2,621,267 (28.9%)	92,969 (36.1%)	37,651 (18.6%)	<0.0001	<0.0001	<0.0001
CAD	4,004,534 (44.3%)	113,525 (44.1%)	76,479 (37.8%)	0.60	<0.0001	<0.0001
Family history of CAD	103,684 (1.1%)	3,687 (1.4%)	1,016 (0.5%)	<0.0001	<0.0001	<0.0001
Depression	648,135 (7.2%)	24,127 (9.4%)	8,822 (4.4%)	<0.0001	<0.0001	<0.0001
Previous myocardial infarction	1,051,845 (11.6%)	32,116 (12.5%)	18,112 (8.9%)	0.0002	<0.0001	<0.0001
Coagulation disorder	298,827 (3.3%)	12,573 (4.9%)	17,513 (8.7%)	<0.0001	<0.0001	<0.0001
Fluid and electrolyte disorder	2,020,375 (22.3%)	95,262 (36.9%)	86,451 (42.7%)	<0.0001	<0.0001	<0.0001
Elixhauser Comorbidity Index	1.9 (±0.005)	2.3 (±0.005)	2 (±0.01)	<0.0001	<0.0001	<0.0001
Charlson Comorbidity Index				<0.0001	<0.0001	<0.0001
2	5,229,686 (57.8%)	100,530 (39.0%)	107,982 (53.4%)			
3-4	2,903,527 (32.1%)	105,530 (40.9%)	70,382 (34.8%)			
≥5	915,666 (10.1%)	51,489 (19.9%)	23,977 (11.8%)			
Primary payer type				<0.0001	<0.0001	<0.0001
Medicare	6,764,575 (74.8%)	190,054 (73.8%)	145,244 (71.8%)			
Medicaid	700,073 (7.7%)	24,312 (9.4%)	19,696 (9.7%)			
Private	1,114,445 (12.3%)	32,031 (12.4%)	27,466 (13.6%)			
Self-pay or other	456,832 (5.0%)	10,834 (4.2%)	9,738 (4.8%)			
Admission characteristics						
Hospital bed size				0.002	<0.0001	<0.0001
Small	1,406,611 (15.5%)	35,948 (13.9%)	19,760 (9.8%)			
Medium	2,335,687 (25.8%)	72,092 (27.9%)	51,450 (25.4%)			
Large	5,288,726 (58.4%)	148,862 (57.8%)	130,874 (64.7%)			
Hospital type				<0.0001	<0.0001	<0.0001
Rural	1,629,606 (18.0%)	27,641 (10.7%)	20,884 (10.3%)			
Urban teaching	3,943,957 (43.6%)	102,680 (39.9%)	95,003 (46.9%)			
Urban nonteaching	3,457,461 (38.2%)	126,581 (49.1%)	86,197 (42.6%)			
Hospital region				<0.0001	<0.0001	<0.0001
Northeast	1,717,070 (18.9%)	74,477 (28.9%)	42,559 (21.0%)			
Midwest	2,097,393 (23.2%)	43,125 (16.7%)	39,688 (19.6%)			
South	3,764,016 (41.6%)	95,361 (37.0%)	86,276 (42.6%)			

(continued)

Table 1 (Continued)

	No ventilation (n = 9,048,879)	NIV (n = 257,549)	IMV (n = 202,340)	p value		
				NIV vs no ventilation	IMV vs no ventilation	IMV vs NIV
West	1,376,209 (15.2%)	44,471 (17.2%)	33,782 (16.7%)			
Admission timing				<0.0001	<0.0001	0.01
Weekday	7,038,376 (77.8%)	192,954 (74.9%)	153,000 (75.6%)			
Weekend	2,010,503 (22.2%)	64,595 (25.1%)	49,340 (24.4%)			
Discharge disposition				<0.0001	<0.0001	<0.0001
Home	5,218,156 (57.7%)	106,917 (41.5%)	47,486 (23.5%)			
Short-term hospital or skilled nursing home	3,460,899 (38.2%)	128,384 (49.8%)	78,059 (38.6%)			
Discharge against medical advice or unknown	102,728 (1.13%)	2,905 (1.1%)	1,398 (0.7%)			

Values are mean \pm SE or n (%).

* Household income quartiles based on patient zip code.

CAD = coronary artery disease.

hospitals with a larger bed size ($p < 0.0001$ for both). In adjusted analysis, older age (75 to 84 and >84 years) was associated with lower odds of IMV and NIV use (Supplemental Table 2). Further, we found higher odds of respiratory support use among Medicare and Medicaid payers as well as larger, urban hospitals, in the northeast.

Over the study period, there was a temporal decrease until 2006 followed by a plateau in the use of IMV (from 3.3% in 2002 to 1.6% in 2014) for HF hospitalizations ($p_{\text{trend}} < 0.0001$; Figure 1). Alternatively, there has been a significant increase in the use of NIV (from 1.0% in 2002 to 7.3% in 2014, $p_{\text{trend}} < 0.0001$). Utilization of IMV was more commonly associated with several in-hospital procedures, including left heart catheterization with or without percutaneous intervention, coronary artery bypass grafting, right heart catheterization, and short-term mechanical support ($p < 0.0001$ for all; Table 2).

The in-hospital mortality for patients requiring IMV increased from 31.5% in 2002 to a peak of 46.1% in 2012 ($p_{\text{trend}} < 0.0001$; Figure 1). Since 2012, there has been a decrease in mortality to 38.6% in 2014 (Table 3). For HF hospitalizations utilizing NIV, there has been a temporal decrease in mortality from 9.0% in 2002 to 5.6% in 2014 ($p_{\text{trend}} < 0.0001$, Figure 1). Hospitalizations with either IMV or NIV were more likely to be associated with renal failure, cardiogenic shock, and delirium than those not requiring respiratory support ($p < 0.0001$ for all).

We identified 30,366 propensity-matched hospitalizations among our 3 main groups of interest (Supplemental Table 3). Compared with HF patients with no respiratory support, utilization of IMV or NIV was associated with increased adjusted in-hospital mortality (HR 6.9 [95% confidence interval: 6.4 to 7.4] and 2.7 [95% confidence interval: 2.5 to 2.9], both $p < 0.0001$, respectively). Figure 2 shows a Kaplan-Meier survival curve for 30-day in-hospital mortality for each of the 3 groups. From 2002 to 2008, the adjusted in-hospital mortality for IMV and NIV (HR 6.2 and 2.7, both $p < 0.0001$, respectively) was similar to the overall time period. From 2009 to 2014, the adjusted in-hospital mortality for IMV was higher (HR 9.3, $p < 0.0001$) and NIV (2.8, $p < 0.0001$) was similar to the overall cohort. In sensitivity analyses by procedure, utilization of IMV and

NIV remained associated with a significantly higher in-hospital mortality (Supplemental Table 4).

The average length of stay was 12.2 (± 0.1) days for IMV recipients and 6.8 (± 0.1) days for NIV, which represents an extra 7.1 and 1.7 days compared with HF hospitalizations without ventilator support (mean 5.1 days, $p < 0.0001$ for both; Table 3). Since 2002, the mean total hospital charges for HF hospitalizations including IMV have nearly tripled (Figure 1) from \$36,945 in 2002 to \$99,358 in 2014 ($p_{\text{trend}} < 0.0001$). Utilization of NIV was associated with a doubling in charges from \$18,729 in 2002 to \$37,539 in 2014 ($p_{\text{trend}} < 0.0001$). The overall mean hospital charges (SE) were \$87,408 (\pm \$742) for IMV, \$48,751 (\pm \$386) for NIV, and \$33,548 (\pm \$240) for HF hospitalizations without respiratory support ($p < 0.0001$ for both).

Patients who initially received NIV before IMV are detailed in Supplemental Table 5, and remained a small subset in our HF population (0.12% in 2002 to 0.29% in 2014; Supplemental Figure 1A). Compared with IMV alone, the combined cohort had a similar trend in in-hospital mortality, but higher overall charges (Supplemental Figure 1B and C). Trends in NIV and IMV in-hospital mortality between patients with acute diastolic and systolic HF were similar over the study period (Supplemental Figure 2). Finally, Supplemental Figure 3A and B show trends in mortality stratified by ischemic versus nonischemic HF etiologies.

Discussion

In this national study of patients hospitalized with HF from 2002 through 2014, we found that nearly 5% of HF hospitalizations required the use of respiratory support. Over the study period, there was a significant change in ventilator strategy utilization with an increase in NIV and decrease in IMV. Among those requiring IMV, the in-hospital mortality was nearly 40%. Mortality among NIV recipients improved whereas cost increased significantly for both types of respiratory support. These findings highlight the substantial morbidity, mortality, and health care spending associated with respiratory support among patients hospitalized with HF as well as the need to identify optimal treatment strategies.

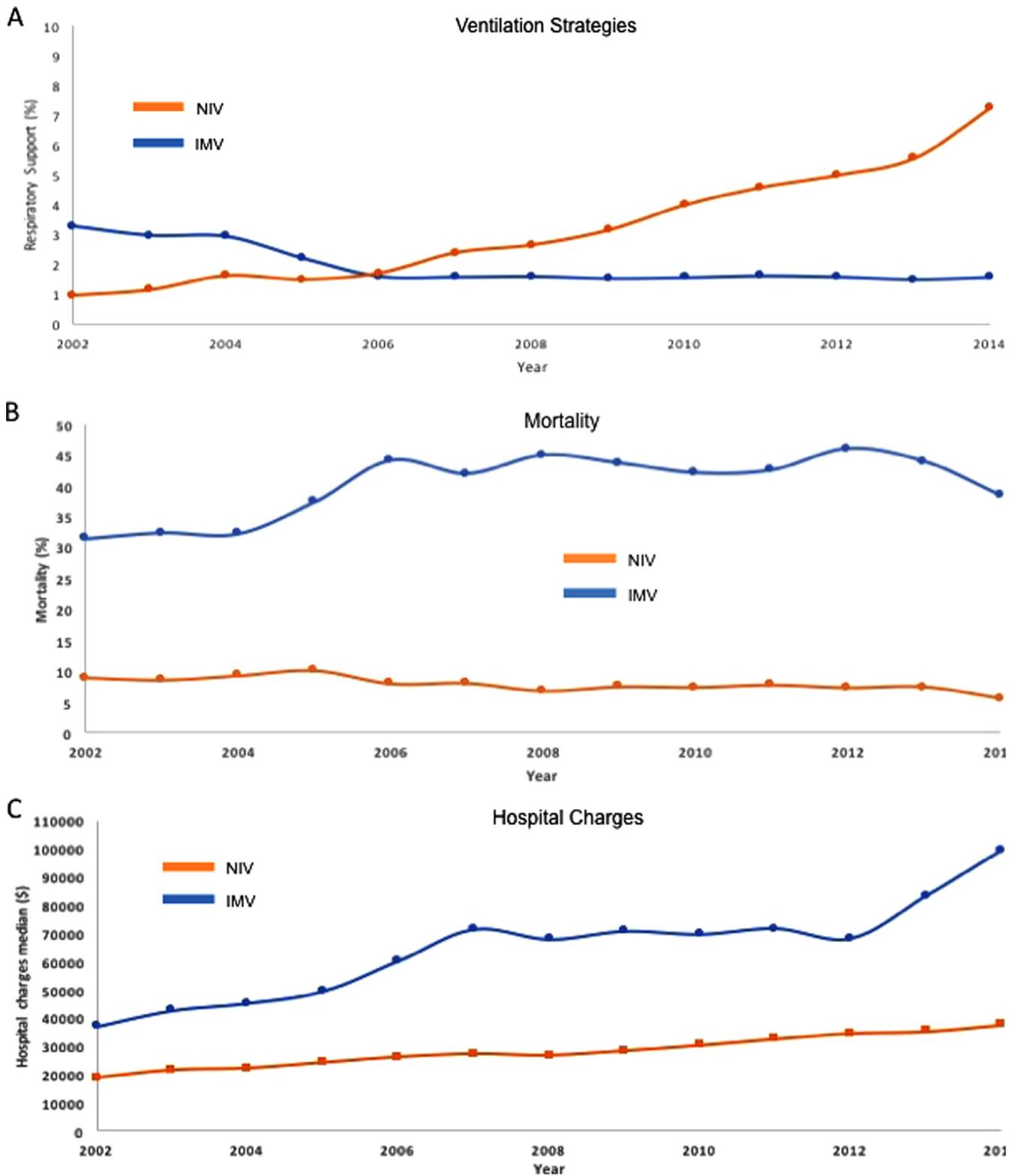


Figure 1. (A-C) Trends in ventilation strategies (A), in-hospital mortality (B), and charges (C) for patients with heart failure requiring respiratory support. IMV = invasive mechanical ventilation; NIV = noninvasive ventilation.

Previous research into MV due to HF is sparse.⁴ In an analysis of Medicare beneficiaries from 1998 to 2008, Chen et al analyzed patients with a primary discharge diagnosis of HF and described national trends in hospitalizations and

mortality. Over this period, they reported an increased trend of respiratory failure from 4.7% to 8.1%, but did not specify type of respiratory support.¹⁵ In our study, older age was associated with lower odds of respiratory support use after

Table 2
Procedures for patients with heart failure requiring respiratory support

n = 9,508,768	No ventilation (n = 9,048,879)	NIV (n = 257,549)	IMV (n = 202,340)	p value		
				NIV vs no ventilation	IMV vs no ventilation	IMV vs NIV
Left heart catheterization	567,289 (6.3%)	14,883 (5.8%)	23,125 (11.4%)	0.0005	<0.0001	<0.0001
Percutaneous coronary intervention	77,128 (0.9%)	1,895 (0.7%)	3,879 (1.9%)	0.01	<0.0001	<0.0001
Thrombolysis	6,000 (0.07%)	374 (0.1%)	789 (0.4%)	<0.0001	<0.0001	<0.0001
Coronary artery bypass grafting	27,079 (0.3%)	534 (0.2%)	3,319 (1.6%)	<0.0001	<0.0001	<0.0001
Pulmonary artery catheter	44,241 (0.5%)	2,040 (0.8%)	10,150 (5.0%)	<0.0001	<0.0001	<0.0001
Blood transfusion	519,991 (5.7%)	25,524 (9.9%)	33,677 (16.6%)	<0.0001	<0.0001	<0.0001
Short-term mechanical support	15,035 (0.17%)	325 (0.1%)	5,263 (2.6%)	0.02	<0.0001	<0.0001

Values are mean \pm SE or n (%).

Table 3
Outcomes, cost, and length of stay for patients with heart failure requiring respiratory support

n = 9,508,768	No ventilation (n = 9,048,879)	NIV (n = 257,549)	IMV (n = 202,340)	p value	
				IMV vs no ventilation	NIV vs no ventilation
Acute renal failure	1,021,185 (11.3%)	61,422 (23.8%)	65,210 (32.2%)	<0.0001	<0.0001
Cardiogenic shock	40,688 (0.4%)	3,299 (1.3%)	18,998 (9.4%)	<0.0001	<0.0001
Delirium	79,531 (0.9%)	6,767 (2.6%)	6,337 (3.1%)	<0.0001	<0.0001
In-hospital cardiac arrest	24,378 (0.3%)	587 (0.2%)	1,190 (0.6%)	<0.0001	<0.0001
In-hospital mortality	252,731 (2.8%)	18,967 (7.4%)	74,664 (36.9%)	<0.0001	<0.0001
Total hospital charges (\$)	28,240 (\pm 810)	46,985 (\pm 1,003)	97,811 (\pm 3,669)	<0.0001	<0.0001
Total hospital cost (\$)	10,898 (\pm 170)	15,555 (\pm 167)	37,504 (\pm 856)	<0.0001	<0.0001
Hospital length of stay (days)	5.1 (\pm 0.02)	6.8 (\pm 0.05)	12.2 (\pm 0.13)	<0.0001	<0.0001
3 days	4,082,560 (45.1%)	80,292 (31.2%)	41,836 (20.7%)	<0.0001	<0.0001
4-6 days	2,903,393 (32.1%)	81,524 (31.7%)	40,145 (19.8%)	<0.0001	<0.0001
>6 days	2,069,926 (22.8%)	95,733 (37.2%)	120,360 (59.5%)	<0.0001	<0.0001

Values are mean \pm SE or n (%).

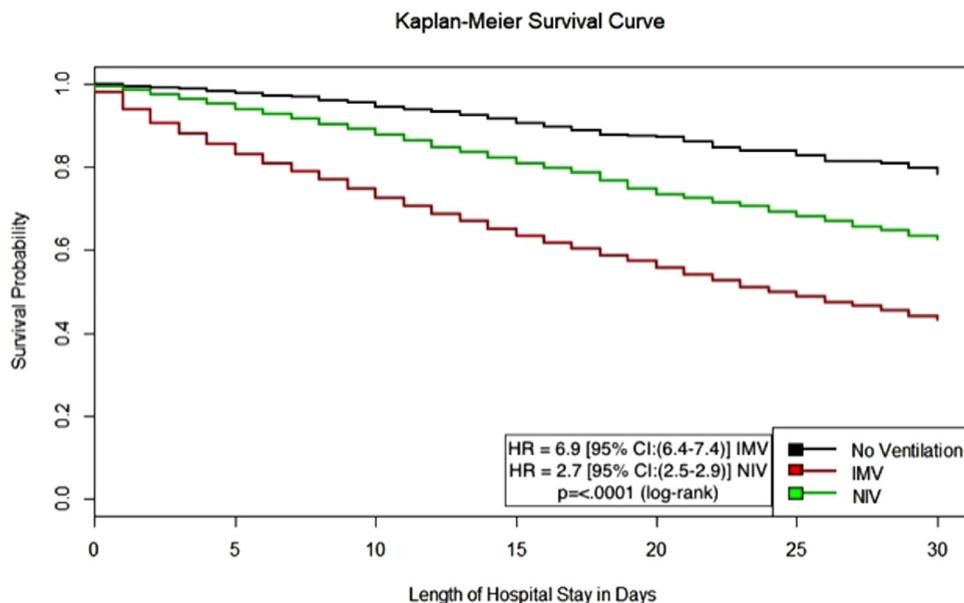


Figure 2. Kaplan-Meier survival curve after propensity matching for patients admitted with heart failure.

CI = confidence interval; HR = hazard ratio; IMV = invasive mechanical ventilation; NIV = noninvasive ventilation.

multivariable adjustment. One potential reason is a lower threshold for hospital admission in older populations, which may lower this cohort's overall acuity.

In the Acute Decompensated Heart Failure National Registry, 5% of the total cohort (105,388 patients) and 23% of patients admitted to an ICU required mechanical

ventilation (IMV vs NIV not specified).¹⁶ The EuroHeart Failure Survey II included 3,580 patients hospitalized for acute HF and reported IMV use in 5.1% of patients whereas 13.9% required some form of ventilatory support (NIV or IMV).¹⁷ However, temporal trends in utilization of respiratory support or how its use affected outcomes is limited.

The increased utilization of NIV for patients admitted with HF may be due to several studies in the early 2000s reporting a mortality benefit for patients with acute cardiogenic pulmonary edema treated with NIV.^{18–20} These favorable outcomes have likely led to an increased use and familiarization with NIV management over the last 2 decades. However, in 2008, the largest, randomized trial in this population found NIV was associated with a greater improvement in patient-reported dyspnea, heart rate, acidosis, and hypercapnia, there was no difference in mortality (9.8% vs 9.5%) or MV (2.8% vs 2.9%) compared with oxygen alone.¹² Although this is the largest study assessing NIV in cardiogenic pulmonary edema, it has been criticized for several reasons, including the exclusion of sicker patients, 19.4% of patients did not complete their assigned treatment, and significant treatment group crossover. Further, the inclusion of this study in subsequent meta-analyses continued to report a decrease in intubation rates and in-hospital mortality with NIV.^{21,22}

To date, currently available cardiovascular guidelines offer limited guidance for patients with HF requiring respiratory.^{23,24} However, a recent Council Perspective has offered more detailed guidance on ventilator mode selection, setting adjustments, and troubleshooting for patients requiring respiratory support in the CICU.²⁵ Research into this population is of particular importance given that the majority of previous analyses of MV incidence and strategies have generally focused on other etiologies of respiratory failure.^{26,27}

Due to the physiologic interaction between ventricular dysfunction, lung mechanics, and positive pressure ventilation, there are unique ventilator considerations when managing patients with HF.²⁵ In addition, both ventilator strategies necessitate expertise and significant resources, which may be one potential explanation for finding an increased odds of respiratory support use in larger, urban hospitals. As the prevalence, cost, and co-morbidities of patients with HF continues to increase,²⁸ it will become even more important for intensivists and cardiologists to be experienced with MV for this unique patient population.

Our study needs to be interpreted in light of its limitations. First, this is a retrospective, observational study from the NIS database, which has limitations inherent in such a design. By assessing for associations between respiratory support and HF outcomes, we have selected for a sicker population that is predisposed to poorer outcomes. We have tried to address this issue by performing propensity matching, but we could not remove all residual confounding, which is likely to be substantial. However, these limitations should not affect our main findings of trends over the study period. Second, HF hospitalizations were identified through ICD-9-CM codes, which offers the possibility of misclassification (under- or overcoding), but previous studies have shown a roughly 95% specificity and positive predictive value for identifying HF.²⁹ Third, we are unable to assess for more granular differences in patient care, such as medications, etiology of respiratory

failure, or laboratory values. Fourth, we were only able to identify hospitalizations as opposed to individual patients, which limits our ability to assess for repeat admissions and outcomes after the hospitalization.

In conclusion, we found that nearly 5% of HF hospitalizations require the use of respiratory support. There has been a temporal decrease in the utilization of IMV, which may be partially explained by the increased use of NIV. Although not unexpected that HF hospitalizations requiring respiratory support are associated with a higher mortality, length of stay, and cost, the magnitude of this problem is previously unreported and considerably higher than we anticipated.

Disclosures

The authors have no conflicts of interest to disclose.

Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.amjcard.2019.08.033>.

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