JACC: HEART FAILURE VOL. 6, NO. 10, 2018

Vaccination Trends in Patients With Heart Failure

Insights From Get With The Guidelines–Heart Failure

Ankeet S. Bhatt, MD, MBA,[a] Li Liang, PhD,[b] Adam D. DeVore, MD, MHS,[a,b] Gregg C. Fonarow, MD,[c] Scott D. Solomon, MD,[d] Orly Vardeny, PharmD, MS,[e] Clyde W. Yancy, MD,[f] Robert J. Mentz, MD,[a,b] Yevgeniy Khariton, MD,[g] Paul S. Chan, MD, MSc,[g] Roland Matsouaka, PhD,[b] Barbara L. Lytle, MS,[b] Ileana L. Piña, MD, MPH,[h] Adrian F. Hernandez, MD, MHS[a,b]

ABSTRACT

OBJECTIVES This study sought to evaluate and contribute to the limited data on U.S. hospital practice patterns with respect to respiratory vaccination in patients hospitalized with heart failure (HF).

BACKGROUND Respiratory infection is a major driver of morbidity in patients with HF, and many influenza and pneumococcal infections may be prevented by vaccination.

METHODS This study evaluated patients hospitalized at centers participating in the Get With The Guidelines-HF (GWTG-HF) registry from October 2012 to March 2017. The proportion of patients receiving vaccination was described for influenza and pneumococcal vaccination, respectively. The association of hospital-level vaccination rates with individual GWTG-HF performance measures and defect-free care was evaluated using multivariable modeling.

RESULTS This study evaluated 313,761 patients discharged from 392 hospitals during the study period. The proportion of patients receiving influenza vaccination was 68% overall and declined from 70% in 2012 to 2013 to 66% in 2016 to 2017 ($p < 0.001$), although this was not statistically significant after adjustment (odds ratio: 1.05 per flu season; 95% confidence interval [CI]: 0.94 to 1.18). The proportion of patients receiving pneumococcal vaccination was 66% overall and decreased over the study period from 71% in 2013 to 60% in 2016 ($p < 0.001$), remaining significant after adjustment (odds ratio: 0.75 per calendar year; 95% CI: 0.67 to 0.84). Hospitals with higher vaccination rates were more likely to discharge patients with higher performance on defect-free care and individual GWTG-HF performance measures ($p < 0.001$). In a subset of patients with linked Medicare claims, vaccinated patients had similar rates of 1-year all-cause mortality (adjusted hazard ratio: 0.96 [95% CI: 0.89 to 1.03] for influenza vaccination; adjusted hazard ratio: 0.95 [95% CI: 0.89 to 1.01] for pneumococcal vaccination) compared with those not vaccinated.

CONCLUSIONS Nearly 1 in 3 patients hospitalized with HF at participating hospitals were not vaccinated for influenza or pneumococcal pneumonia, and vaccination rates did not improve from 2012 to 2017. Hospitals that exhibited higher vaccination rates performed well with respect to other HF quality of care measures. Vaccination status was not associated with differences in clinical outcomes. Further randomized controlled data are needed to assess the relationship between vaccination and outcomes. (J Am Coll Cardiol HF 2018;6:844–55) © 2018 Published by Elsevier on behalf of the American College of Cardiology Foundation.

From the [a]Department of Medicine, Duke University School of Medicine, Durham, North Carolina; [b]Duke Clinical Research Institute, Durham, North Carolina; [c]Ahmanson-UCLA Cardiomyopathy Center, University of California, Los Angeles, Los Angeles, California; [d]Division of Cardiology, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts; [e]University of Wisconsin, School of Pharmacy, Madison, Wisconsin; [f]Division of Cardiology, Feinberg School of Medicine, Northwestern University, Chicago, Illinois; [g]Department of Cardiovascular Outcomes Research, University of Missouri-Kansas City, St. Luke's Mid-America Heart Institute, Kansas City, Missouri; and the [h]Division of Cardiology, Albert Einstein College of Medicine/Montefiore Medical Center, Bronx, New York. The Get With The Guidelines-Heart Failure (GWTG-HF) program is provided by the American Heart Association. GWTG-HF has been funded in the past through support from Medtronic, GlaxoSmithKline, Ortho-McNeil, and the American Heart Association Pharmaceutical Roundtable. This project was supported by the GWTG-HF program. The content of this paper is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. Dr. DeVore has received research support from the American Heart Association, Amgen, the National Heart,

ISSN 2213-1779/$36.00 https://doi.org/10.1016/j.jchf.2018.04.012

Heart failure (HF) is a chronic disorder characterized by frequent acute exacerbations requiring hospitalization. The condition is highly prevalent in the United States and is expected to continue to increase over time (1,2). HF continues to be associated with significant morbidity, mortality, and economic cost (1). There is a need for routine implementation of cost-effective interventions that could favorably alter the trajectory of HF exacerbations.

There is substantial overlap between HF and respiratory disease. Data suggest that over 50% of exacerbations could be triggered in part by respiratory infection, making this the leading precipitating cause of HF admission (3,4). Influenza infection has also been shown to directly depress myocardial contractility via the action of proinflammatory cytokines (5). Vaccination for influenza and pneumococcal pneumonia represents a potential cost-effective means by which to prevent lower respiratory infection and thereby reduce HF readmission. Recent analyses have found that respiratory vaccination can improve outcomes in patients with cardiovascular disease (6–9), and major cardiovascular societies now support respiratory vaccination in patients with HF (10–12).

SEE PAGE 856

There are limited data that describe contemporary vaccination practice patterns, temporal trends, and factors associated with vaccination in patients with HF in the usual care setting. We used the Get With The Guidelines-Heart Failure (GWTG-HF) registry, linked with the American Hospital Association Annual Survey, to examine vaccination trends over time.

METHODS

DATA SOURCES. The GWTG-HF registry is part of a voluntary, in-hospital quality improvement initiative by the American Heart Association, the details of which have been published previously (13). The registry was created in 2005 and collects clinical information on patients hospitalized with a primary discharge diagnosis of HF. Clinical data are used in compliance with The Joint Commission and Centers for Medicare and Medicaid Service (CMS) standards, using an Internet-based patient management tool (Quintiles, Cambridge, Massachusetts).

GWTG-HF collects patient demographics, medical history, information concerning medication use and in-hospital treatment. In 2012, GWTG-HF added a required reporting measure for sites to provide information on the status of vaccination for influenza and pneumococcal pneumonia. Data on hospital characteristics were obtained for all enrolling hospitals based on hospital self-reporting and from the 2015 American Hospital Association Annual Survey (Health Forum, L.L.C., Washington, DC). Hospitals participating in GWTG-HF are required to comply with local regulatory and privacy guidelines and to obtain institutional review board approval when necessary. Quintiles served as the registry coordinating center, and the Duke Clinical Research Institute (Durham, North Carolina) served as the data analytic center.

We linked registry patients with fee-for-service (FFS) Medicare claims data from October 2, 2012, to December 31, 2015, for outcome analyses. Patients who did not have CMS FFS Medicare Parts A and B at the time of discharge were excluded. For patients with multiple index admissions, only the first admission was kept as the index admission.

STUDY POPULATION AND STUDY DEFINITIONS. We evaluated patients from hospitals with at least 75% complete data on medical history enrolled in the GWTG-HF registry from October 1, 2012, to March 31, 2017. We excluded patients who died in the hospital, were discharged to hospice, left against medical advice, and were designated as "comfort measures only." Given the temporality of the influenza season, we used separate eligible populations for our

ABBREVIATIONS AND ACRONYMS

CI = confidence interval

CMS = Centers for Medicare and Medicaid Services

COPD = chronic obstructive pulmonary disease

CY = calendar year

FFS = fee for service

GWTG-HF = Get With The Guidelines-Heart Failure

HF = heart failure

HR = hazard ratio

LVEF = left ventricular ejection fraction

OR = odds ratio

Lung, and Blood Institute, and Novartis; and consulting fees from Novartis. Dr. Fonarow has received research support from the National Institutes of Health and consulting fees from Amgen, Janssen, Medtronic, Novartis, and St. Jude Medical; and has served on the GWTG Steering Committee. Dr. Solomon has received research support from Novartis and Sanofi Pasteur. Dr. Mentz has received research support from the National Institutes of Health (grants U10HL110312 and R01AG045551-01A1), Amgen, AstraZeneca, Bristol-Myers Squibb, GlaxoSmithKline, Gilead, Merck, Novartis, Otsuka, and ResMed; and honoraria from HeartWare, Janssen, Luitpold Pharmaceuticals, Novartis, ResMed, and Thoratec/St. Jude. Dr. Khariton is supported by the National Heart, Lung, and Blood Institute, National Institutes of Health, under award number T32HL110837. Dr. Hernandez has received research support from AstraZeneca, Bristol-Myers Squibb, GlaxoSmithKline, Luitpold Pharmaceuticals, Merck, Sanofi, and Novartis; and honoraria from Bayer, Boston Scientific, and Novartis. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

Manuscript received March 11, 2018; revised manuscript received April 4, 2018, accepted April 4, 2018.

influenza and pneumococcal vaccination cohorts. The influenza vaccination cohort included patients admitted in the first (January through March) and fourth (October through December) quarters of the year, as defined by the Centers for Disease Control and Prevention based on peak influenza activity from 1982 through 2016. The eligible population for the pneumococcal vaccination cohort included patients admitted in all time periods of the year. Patients who refused vaccination, had allergy or insensitivity to vaccination, and who had vaccination was contraindicated were excluded from the eligible population analyses. Patients admitted to hospitals where influenza vaccination was not available were also excluded. To obtain reliable estimates of hospital-level vaccination rates, we excluded patients at hospitals with <15 eligible patients for either vaccination. Vaccination rates were defined as the number of patients who either received vaccination during the index hospitalization or before admission divided by the number of eligible patients.

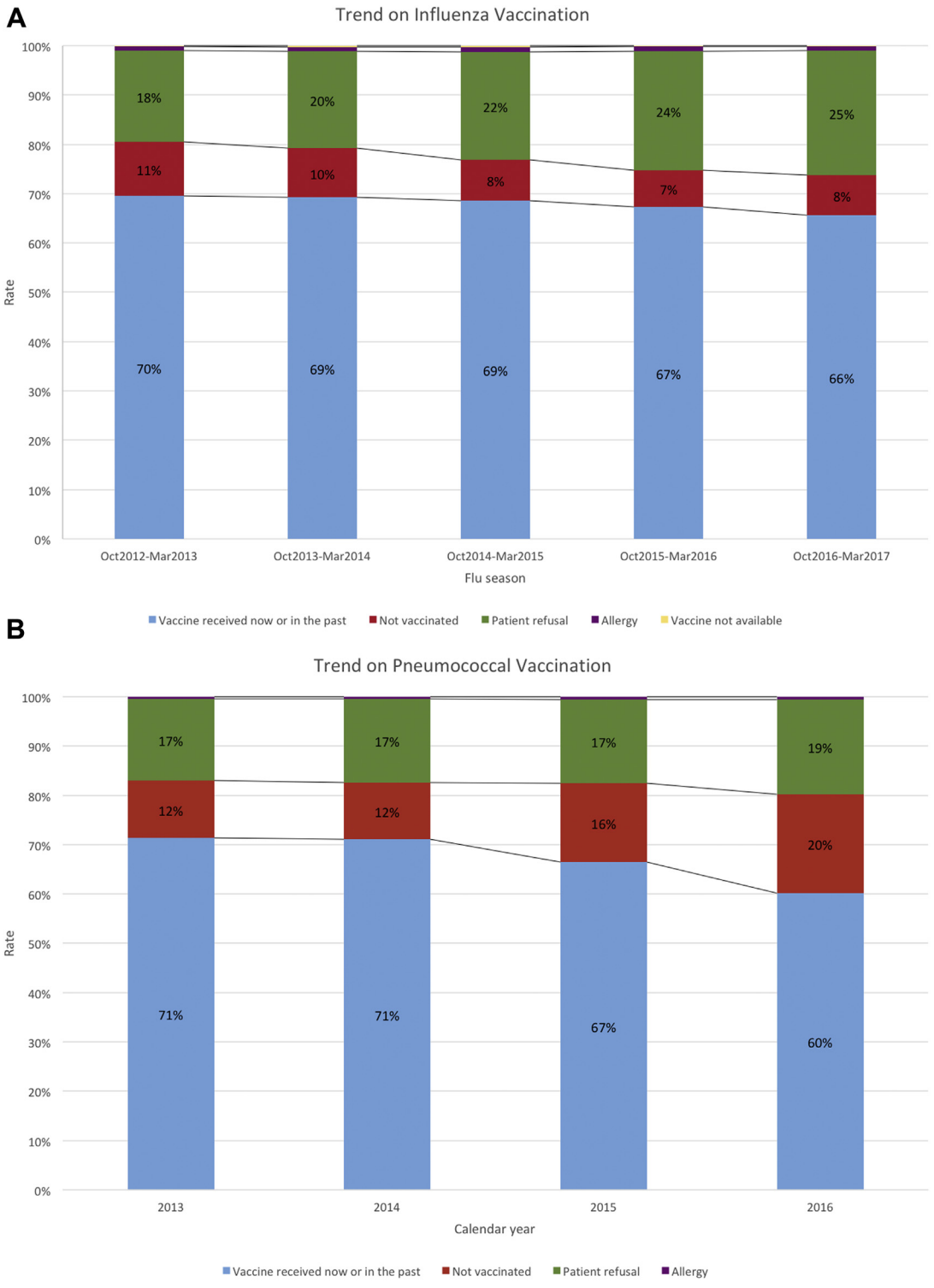
We assessed 5 GWTG-HF achievement measures used in previous analyses: 1) angiotensin-converting enzyme inhibitor or angiotensin receptor blocker at discharge in patients with a left ventricular ejection fraction (LVEF) <40%; 2) β-blocker at discharge in patients with an LVEF <40%; 3) complete discharge instructions; 4) LVEF assessment performed or planned during or after discharge; and 5) smoking cessation counseling (14). The outcome of "defect-free care" was defined as hospital achievement of all 5 GWTG-HF achievement measures. We also assessed 4 additional GWTG-HF quality measures on discharge: 1) patients with atrial fibrillation discharged on anticoagulation; 2) evidence-based β-blocker use; 3) implantable cardioverter-defibrillator inserted or prescribed for patients with an LVEF of <35% without known contraindications; and 4) blood pressure control (<140/90 mm Hg). Our secondary outcomes comprised these individual achievement and quality measures.

STATISTICAL METHODS. Patient and hospital characteristics were summarized by vaccination status (overall, vaccinated, and not vaccinated). Continuous variables were reported as median (25th, 75th percentile) and categorical variables as percentages. Chi-square tests were used to compare categorical variables and Wilcoxon rank sum tests for continuous variables.

Temporal trends in the proportion of patients who received or refused vaccination were tested with the Cochran-Mantel-Haenszel row-mean scores statistic. For influenza vaccination, trends were assessed across sequential influenza seasons, with the initial season being October 2012 through March 2013 and the final season being October 2016 through March 2017. For pneumococcal vaccination, trends were assessed by calendar year (CY) from 2013 to 2016. Data from October 1, 2012, through December 31, 2012, and from January 1, 2017, through March 31, 2017, were excluded from the analysis for pneumococcal vaccination because they represented only a quarter of the CY, given concern for temporality of pneumococcal vaccination administration. A multivariable logistic regression model was performed to assess the trend of vaccination over influenza seasons or CYs, respectively. Generalized estimation equations were used to account for within-hospital clustering. The model was adjusted for demographic characteristics (age, sex, and race), insurance medical history (atrial fibrillation, chronic obstructive pulmonary disease [COPD] or asthma, diabetes mellitus, dyslipidemia, hypertension, peripheral vascular disease, stroke, implantable cardioverter-defibrillator, anemia, dialysis, renal insufficiency, depression, valvular heart disease, cardiac resynchronization therapy [pacing only], cardiac resynchronization therapy defibrillator, ischemic heart disease, smoking status, prior history of HF, and left ventricular dysfunction). Patient variables had <4% missing, and simple imputation was used to handle missingness. Missing information on medical history was imputed to "no," and missing data on other categorical variables was imputed to the most likely category. The model was also adjusted for hospital characteristics, including teaching hospital status, number of beds, region, rural versus urban setting, adult cardiology services, cardiac surgery services, interventional and heart transplantation capability, number of cardiac intensive care beds, mobile health services, established medical home, and adult diagnostic and interventional catheterization services. Age, number of beds, and number of cardiac intensive care unit beds were modeled as continuous variables and other variables as categorical variables. Multiple imputation was conducted at the hospital level to handle the any missingness on hospital characteristics.

Hospitals were grouped into quartiles by vaccination rates for pneumococcal and influenza vaccination. Differences in baseline patient characteristics, hospital characteristics, and performance on HF achievement or quality measures were compared. The association of hospital quartiles by vaccination rate with defect-free care and HF achievement or quality measures was assessed using a multivariable logistic regression patient-level model. Generalized estimation equations were used to adjust for

FIGURE 1 **Temporal Trends in Vaccination Among Patients Hospitalized for Heart Failure**



Percentage of patients who received vaccination during or before hospitalization for heart failure and the percentage of patients who refused vaccination. **(A)** Influenza vaccination and refusal rates are shown by influenza season from the October 2012 to March 2013 period through the October 2016 to March 2017 period. **(B)** Pneumococcal vaccination and refusal rates are shown by calendar year from January 1, 2013, through December 31, 2016.

TABLE 1 Patient Characteristics in Patients Who Received Versus Did Not Receive Influenza Vaccination

	Overall (N = 136,924)	Received Vaccination (n = 121,317)	Did Not Receive Vaccination (n = 15,607)	p Value*
Demographics				
Age, yrs	75 (63, 84)	75 (64, 84)	72 (60, 82)	<0.001
Sex				
Female	48.5	48.7	47.0	<0.001
Male	51.5	51.3	53.0	
Race				
White	69.4	70.4	61.3	<0.001
Other	2.3	2.3	2.8	
Asia/Pacific Islander	2.2	2.2	1.9	
Black	17.4	17.0	20.3	
Hispanic	8.1	7.4	13.1	
Insurance				
No insurance/not documented	2.7	2.6	3.9	<0.001
Medicare	49.6	50.8	40.5	
Medicaid	12.2	12.1	13.5	
Other	22.6	23.0	19.8	
Weight at admission, kg	83.9 (69.0, 104.0)	83.4 (69.0, 103.9)	84.0 (69.0, 104.3)	0.12
Medical history				
Atrial fibrillation/flutter	41.4	42.1	35.8	<0.001
COPD or asthma	35.5	36.1	31.0	<0.001
Diabetes mellitus	47.2	47.4	45.1	<0.001
Hypertension	83.7	84.4	78.5	<0.001
ICD	9.5	9.5	9.9	0.084
CRT-D	6.3	6.4	5.5	<0.001
Dialysis (chronic)	4.3	4.2	4.5	0.15
Smoking	14.7	14.6	16.2	<0.001
Admission vital signs/laboratory results				
Heart rate, beats/min	83 (71, 97)	82 (71, 97)	84 (72, 99)	<0.001
Systolic blood pressure, mm Hg	140 (121, 160)	140 (121, 160)	140 (120, 160)	0.80
BNP, pg/ml	814.0 (408.0, 1,614.5)	815.0 (409.0, 1,619.0)	804.0 (392.0, 1,572.0)	0.094
NT-proBNP, pg/ml	4,979 (2,226, 11,120)	4,970 (2,244, 11,062)	5,103 (2,068, 11,653)	0.81
Serum creatinine, mg/dl	1.3 (1.0, 1.8)	1.3 (1.0, 1.8)	1.3 (1.0, 1.8)	0.001
Ejection fraction, %	45 (29, 58)	45 (30, 58)	43 (27, 56)	<0.001

Values are % or median (25th, 75th percentiles). *p values are based on Pearson chi-square tests for all categorical row variables and on Wilcoxon rank sum test for all continuous/ordinal row variables.

BNP = B-type natriuretic peptide; COPD = chronic obstructive pulmonary disease; CRT-D = cardiac resynchronization therapy defibrillator; ICD = implantable cardioverter-defibrillator; NT-proBNP = N-terminal pro-B-type natriuretic peptide.

within-hospital clustering. Models were adjusted for the aforementioned patient and hospital characteristics. The conservative Bonferroni correction was used to account for multiple testing with this primary analysis. With 18 main outcomes of interest, we used a Bonferroni critical level of 0.0028 (0.056/18) to declare statistical significance from the different p-values we obtained. Hospitals in the lowest vaccination rate quartile were used as the reference group.

Correlation between hospital-specific influenza vaccination rate and pneumococcal vaccination rate was described with the Spearman correlation statistic. We defined a binary definition for high-performing hospitals as those that achieved the top quartile in both influenza and pneumococcal vaccination rate. A multivariable logistic hospital-level regression was used to identify hospital characteristics independently associated with high-performing hospital status.

Patients 65 years of age or older admitted from October 2012 through December 2015 in the study cohort were linked to Medicare claims data. In this subset, we assessed the association between vaccination status (yes vs. no) in eligible patients and both 1-year all-cause mortality and 1-year all-cause rehospitalization using a multivariable proportional hazard model. The robust SEs were used to account for the clustering of patients by hospital. The multivariable proportional hazard models were adjusted for the same set of covariates as in the primary analyses.

All statistical tests were 2-sided. Values of $p < 0.05$ were generally considered significant, except for a Bonferroni critical p value of 0.0028 for the main outcomes of interest. Analyses were conducted with SAS version 9.4 (SAS Institute, Cary, North Carolina).

RESULTS

ANALYSIS COHORT. From October 1, 2012, to March 31, 2017, 628,939 patients were discharged from 612 fully participating GWTG-HF hospitals. After exclusions, our study population comprised 313,761 patients from 392 hospitals. An additional 40,072 and 55,705 patients refused influenza and pneumococcal vaccination, respectively. After exclusion of refusals and patients with other contraindications, the population eligible for influenza vaccination included 136,924 HF patients discharged over 5 influenza seasons, and the population eligible for pneumococcal vaccination included 256,460 HF patients from CY2013 to CY2016 (Online Figure 1).

VACCINATION TRENDS. The proportion of patients receiving vaccination for influenza before or during the index hospitalization during the overall study period was 68%. Of all patients who received influenza vaccination (n = 121,317), 16% (n = 19,429) received vaccination during hospitalization, whereas 84% (n = 101,888) received vaccination before hospitalization. Of the 13,480 patients in whom a respiratory condition (COPD/pneumonia) was reported as a cause for their HF exacerbation, 71% received influenza vaccination before or during

hospitalization. The proportion of patients who received influenza vaccination decreased across the 5 influenza seasons, from 70% in the October 2012 through March 2013 influenza season to 66% in the October 2016 through March 2017 influenza season (p for trend <0.001). The proportion of patients who refused influenza vaccination increased from 18% to 25% over the same time period (p for trend <0.001), as seen in Figure 1A. Among eligible patients, after adjustment for patient- and hospital-level factors, hospital rates of influenza vaccination did not change over time (odds ratio [OR]: 1.05 per flu season; 95% confidence interval [CI]: 0.94 to 1.18; p = 0.34).

The proportion of patients receiving pneumococcal vaccination before or during the index hospitalization during the overall study period was 66%. Of the 23,054 patients in whom a respiratory condition (COPD/pneumonia) was reported as a cause for their HF exacerbation, 71% received pneumococcal vaccination before or during hospitalization. The proportion of patients receiving pneumococcal vaccination similarly declined across the study period, from 71% in CY2013 to 60% in CY2016, whereas refusals increased from 17% in CY2013 to 19% in CY2016 (p for trend <0.001), as seen in Figure 1B. Among eligible patients, after adjustment, pneumococcal vaccination rates decreased over the study period (OR: 0.75 per CY; 95% CI: 0.67 to 0.84; p < 0.001).

BASELINE CHARACTERISTICS AND VACCINATION. Patients who received vaccination (either influenza or pneumococcal) during the respective study periods were more likely to be older, white, and women and to have insurance compared with those who did not receive vaccination (Tables 1 and 2). Patients vaccinated were also more likely to have medical comorbidities including atrial fibrillation, diabetes mellitus, and COPD or asthma, but were less likely to be smokers. Patients who were vaccinated had a higher LVEF than did those not vaccinated.

TABLE 2 Patient Characteristics in Patients Who Received vs. Did Not Receive Pneumococcal Vaccination

	Overall (N = 256,460)	Received Vaccination (n = 207,331)	Did Not Receive Vaccination (n = 49,129)	p Value*
Demographics				
Age, yrs	74 (63, 84)	75 (64, 84)	69 (58, 81)	<0.001
Sex, %				<0.001
Female	48.6	49.5	45.1	
Male	51.4	50.5	54.9	
Race				<0.001
White	69.2	70.3	64.6	
Other	2.2	2.1	2.8	
Asia/Pacific Islander	2.1	2.2	1.9	
Black	17.9	17.5	19.6	
Hispanic	8.1	7.4	10.7	
Insurance				<0.001
No insurance/not documented	2.9	2.4	4.9	
Medicare	49.2	51.7	38.4	
Medicaid	12.7	12.4	14.0	
Other	22.9	22.1	26.2	
Medical history				
Atrial fibrillation/flutter	41.2	42.7	34.7	<0.001
COPD or asthma	35.8	37.2	29.8	<0.001
Diabetes mellitus	46.8	47.8	42.5	<0.001
Hypertension	83.4	84.6	78.5	<0.001
ICD	9.8	10.0	9.0	<0.001
CRT-D	6.4	6.7	5.5	<0.001
Dialysis (chronic)	4.2	4.3	3.6	<0.001
Smoking	15.2	14.6	17.8	<0.001
Admission vital signs/laboratory results				
Heart rate, beats/min	83 (71, 97)	82 (71,96)	86 (73, 100)	<0.001
Systolic blood pressure, mm Hg	139 (120, 160)	139 (120, 159)	140 (120, 160)	0.017
Weight at admission, kg	84.0 (69.0, 104.0)	83.5 (68.9, 103.0)	86.0 (70.0, 107.0)	<0.001
BNP, pg/ml	823.0 (407.0, 1,634.0)	823.0 (408.0, 1,638.0)	825.0 (401.0, 1,618.0)	0.16
NT-proBNP, pg/ml	4,970 (2,217, 11,262)	4,917 (2,208, 11,188)	5,171 (2,246, 11,599)	0.067
Serum creatinine, mg/dl	1.3 (1.0, 1.8)	1.3 (1.0, 1.9)	1.2 (0.9, 1.7)	<0.001
Ejection fraction, %	45 (28, 58)	45 (29, 58)	41 (25, 56)	<0.001

Values are % or median (25th, 75th percentiles). *p values are based on Pearson chi-square tests for all categorical row variables and on Wilcoxon rank sum test for all continuous/ordinal row variables.

Abbreviations as in Table 1.

ASSOCIATION BETWEEN HOSPITAL VACCINATION RATES AND HF ACHIEVEMENT MEASURES. There was wide variation of vaccination rates across all GWTG-HF hospitals for influenza and pneumococcal vaccination (Online Figures 2A and 2B). Mean hospital influenza vaccination rates ranged from 63% in quartile 1 to 99% in quartile 4. Mean hospital pneumococcal vaccination rates ranged from 42% in quartile 1 to 98% in quartile 4. HF achievement measures were generally high in both populations. Overall, 91% and 92% of patients achieved defect-free care in the influenza vaccination-eligible population and pneumococcal vaccination-eligible population, respectively (Online Tables 1 and 2).

Rates of defect-free care were 94% in the top quartile compared with 86% in the bottom quartile of influenza vaccination rate. Patients discharged from hospitals in the top quartile of influenza vaccination rates had significantly higher rates of defect-free care after multivariable adjustment (OR: 2.72; 95% CI: 1.88 to 3.94; p < 0.001) than patients at hospitals in the lowest quartile (Table 3).

TABLE 3 Association Between Hospital-Level Influenza Vaccination and Defect-Free Care

	Unadjusted		Adjusted	
	OR (95% CI)	p Value	OR (95% CI)	p Value
GWTG-HF Achievement Measures (Q4 vs. Q1)				
Defect-free care: 100% compliance with achievement measures	2.54 (1.81–3.58)	<0.001	2.72 (1.88–3.94)	<0.001
Discharged home with 6 instructions*	2.60 (1.61–4.21)	<0.001	2.76 (1.54–4.92)	<0.001
Documentation of LV function	6.02 (2.95–12.30)	<0.001	7.48 (3.62–15.50)	<0.001
LVSD discharged on ACE or ARB	2.04 (1.36–3.05)	<0.001	2.72 (1.76–4.21)	<0.001
LVSD discharged on BB	2.05 (1.40–3.01)	<0.001	2.17 (1.46–3.23)	<0.001
Smoker discharged with smoking cessation	2.06 (1.28–3.31)	0.003	1.99 (1.19–3.32)	0.009
GWTG-HF quality measures				
Chronic or recurrent atrial fibrillation discharged on anticoagulation	1.90 (1.50–2.40)	<0.001	2.03 (1.58–2.61)	<0.001
LVSD discharged on specific evidence-based BB	1.12 (0.86–1.45)	0.42	1.37 (1.06–1.77)	0.016
ICD placed or prescribed at discharge	1.67 (1.24–2.23)	<0.001	1.87 (1.37–2.57)	<0.001
Blood pressure control (140/90 mm Hg) at discharge	1.01 (0.90–1.13)	0.91	1.00 (0.90–1.12)	0.97

Significance level was $p < 0.0028$ using Bonferroni correction for multiple testing. Multivariable models adjusted for the following patient characteristics: age, sex, race (black, Hispanic, other races vs. white), insurance (Medicare, Medicaid, other insurance vs. no insurance), medical histories (atrial fibrillation/flutter, COPD, diabetes mellitus, dyslipidemia, hypertension, peripheral vein disease, stroke, anemia, pacemaker, dialysis, renal insufficiency, depression, valvular disease, ICD, cardiac resynchronization therapy pacemaker, CRT-D, ischemic heart disease (combined coronary artery disease, myocardial infarction, PCI, coronary artery bypass graft), smoker, and LV dysfunction. Multivariable models adjusted for the following hospital characteristics: teaching hospital, number of beds, region, rural vs. urban, PCI, surgical, interventional and heart transplantation capability, number of cardiac intensive care beds, adult cardiology service, mobile health service, established medical home, has adult diagnostic catheterization capability, and has adult interventional catheterization capability. Multiple imputation was conducted on the hospital level to impute the missing hospital characteristic variables. *Discharge instructions include activity level, diet, discharge medications, follow-up appointment, weight monitoring, and what to do if symptoms worsen.

ACE = angiotensin-converting enzyme; ARB = angiotensin receptor blocker; BB = β-blocker; CI = confidence interval; GWTG-HF = Get With the Guidelines-Heart Failure; ICD = implantable cardioverter-defibrillator; LV = left ventricular; LVSD = left ventricular systolic dysfunction; OR = odds ratio; PCI = percutaneous coronary intervention.

Similar results were seen with respect to pneumococcal vaccination (Table 4). Rates of defect-free care were 95% in the top quartile compared with 88% in the lowest quartile of pneumococcal vaccination rate. Patients discharged from hospitals within the top quartile of pneumococcal vaccination rate were associated with higher rates of defect-free care after adjustment (OR: 4.52; 95% CI: 3.06 to 6.68; $p < 0.001$) than patients at hospitals in the lowest quartile. Compliance with individual achievement or quality measures was also significantly higher in patients discharged from hospitals in the top quartile for both vaccination types. Results were largely unchanged even after Bonferroni correction.

HOSPITAL CHARACTERISTICS ASSOCIATED WITH HIGH-PERFORMING HOSPITALS. A strong correlation was found between hospital-level performance on influenza vaccination and pneumococcal vaccination (Spearman correlation coefficient = 0.750; $p < 0.001$). In general, individual hospitals performed better with respect to influenza vaccination than pneumococcal vaccination (Figure 2).

Hospitals with higher rates of influenza or pneumococcal vaccination, independently, tended to be smaller, rural, and nonacademic centers more likely to be located in the Northeast. These hospitals were less likely to have advanced cardiology capabilities such as percutaneous coronary intervention and cardiac transplantation services. In a hospital-level analysis, 64 hospitals were identified as high-performing hospitals. After multivariable adjustment, smaller size and Northeast region (vs. West) were significantly associated with hospitals designated as high performers. Other hospital characteristics were not significantly associated with high performance after adjustment (Table 5).

ASSOCIATION BETWEEN VACCINATION STATUS AND CLINICAL OUTCOMES. Of the overall study population (n = 313,761), 85,365 patients were linked to CMS data (index to end of 2015). After further exclusions, including multiple index admissions and patients without Medicare FFS A and B coverage at discharge, the final matched FFS Medicare cohort included 64,614 patients from October 2, 2012, to December 31, 2015.

Of matched FFS Medicare cohort, 29,002 were eligible for influenza vaccination, and 25,873 (89%) received vaccination. Patients receiving influenza vaccination had similar rates of all-cause death (adjusted hazard ratio [HR]: 0.96; 95% CI: 0.89 to 1.03; $p = 0.25$) and all-cause hospitalization (adjusted HR: 0.97; 95% CI: 0.92 to 1.03; $p = 0.36$) at 12 months compared with those not receiving vaccination, after multivariate adjustment (Figures 3A and 3B). Similarly, 54,796 patients of the matched FFS Medicare cohort were eligible for pneumococcal vaccination, and 47,353 (86%) received vaccination. There were no significant differences in all-cause death (adjusted HR: 0.95; 95% CI: 0.89 to 1.01; $p = 0.08$) and all-cause

TABLE 4 Association Between Hospital-Level Pneumococcal Vaccination and Defect-Free Care

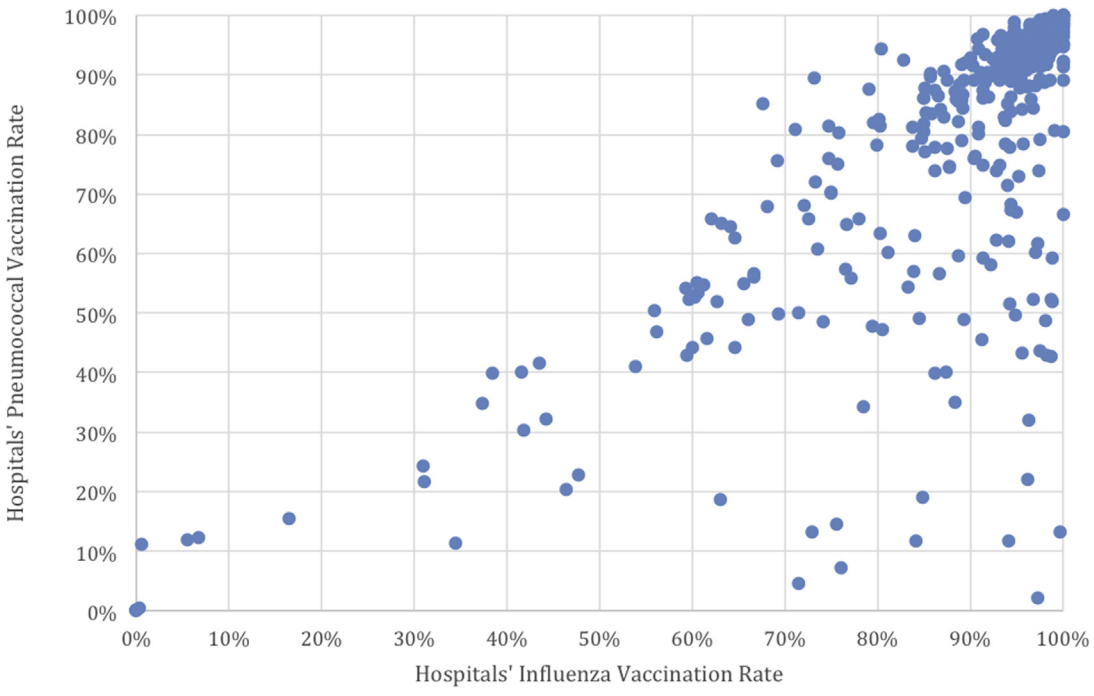
	Unadjusted		Adjusted	
	OR (95% CI)	p Value	OR (95% CI)	p Value
GWTG-HF achievement measures, Q4 vs. Q1				
Defect-free care: 100% compliance with achievement measures	2.97 (2.17–4.07)	<0.001	4.52 (3.06–6.68)	<0.001
Discharged home with 6 instructions*	2.85 (1.84–4.41)	<0.001	2.33 (1.28–4.24)	0.006
Documentation of LV function	7.57 (3.82–15.00)	<0.001	7.44 (3.66–15.10)	<0.001
LVSD discharged on ACE or ARB	2.68 (1.87–3.85)	<0.001	3.55 (2.36–5.35)	<0.001
LVSD discharged on BB	1.95 (1.40–2.72)	<0.001	2.37 (1.66–3.39)	<0.001
Smoker discharged with smoking cessation	2.93 (1.82–4.70)	<0.001	2.91 (1.83–4.65)	<0.001
GWTG-HF quality measures				
Chronic or recurrent atrial fibrillation discharged on anticoagulation	1.63 (1.29–2.06)	<0.001	1.81 (1.38–2.36)	<0.001
LVSD discharged on specific evidence-based BB	1.15 (0.91–1.45)	0.25	1.38 (1.09–1.74)	0.007
ICD placed or prescribed at discharge	1.48 (1.11–1.98)	0.008	1.55 (1.11–2.15)	0.010
Blood pressure control (<140/90 mm Hg) at discharge	1.03 (0.93–1.14)	0.58	1.06 (0.96–1.16)	0.27

Significance level was $p < 0.0028$ using Bonferroni correction for multiple testing. Multivariable models adjusted for the following patient characteristics: age, sex, race (black, Hispanic, other races vs. white), insurance (Medicare, Medicaid, other insurance vs. no insurance), medical histories (atrial fibrillation/flutter, COPD, diabetes mellitus, dyslipidemia, hypertension, peripheral vein disease, stroke, anemia, pacemaker, dialysis, renal insufficiency, depression, valvular disease, ICD, cardiac resynchronization therapy pacemaker, CRT-D, ischemic heart disease (combine coronary artery disease, myocardial infarction, PCI, coronary artery bypass graft), smoker, and LV dysfunction. Multivariable models adjusted for the following hospital characteristics: teaching hospital, number of beds, region, rural vs. urban, PCI, surgical, interventional and heart transplantation capability, number of cardiac intensive care beds, adult cardiology service, mobile health service, established medical home, has adult diagnostic catheterization capability, and has adult interventional catheterization capability. Multiple imputation was conducted on the hospital level to impute the missing hospital characteristic variables. *Discharge instructions must include activity level, diet, discharge medications, follow-up appointment, weight monitoring, and what to do if symptoms worsen.

Abbreviations as in Table 1 and 3.

rehospitalization (adjusted HR: 1.01; 95% CI: 0.97 to 1.06; p = 0.62) at 12 months between those who did and did not receive pneumococcal vaccination. Similar results were observed when the composite of mortality and rehospitalization was used as the clinical endpoint (p = 0.21 and p = 0.11 for influenza and pneumococcal vaccination, respectively) (Figures 4A and 4B).

FIGURE 2 Correlation Between Hospital-Specific Influenza Vaccination Rates and Pneumococcal Vaccination Rates



Individual hospital performance with regard to influenza vaccination and pneumococcal vaccination over the study period.

TABLE 5 Hospital Characteristic Variables Associated With Hospitals Rated as High Performing on Both Influenza and Pneumococcal Vaccinations

Hospital Characteristics	Adjusted OR (95% CI)	p Value
Number of beds (per 50)	0.83 (0.73–0.94)	0.004
Region: West vs. Northeast	0.22 (0.06–0.79)	0.021
Region: South vs. Northeast	1.27 (0.59–2.74)	0.55
Region: Midwest vs. Northeast	0.49 (0.18–1.28)	0.15
Teaching hospital	1.08 (0.49–2.40)	0.85
Rural vs. urban	1.66 (0.51–5.47)	0.40
Capable of PCI	1.48 (0.32–6.89)	0.60
Capable of cardiac surgery	1.65 (0.51–5.37)	0.40
Capable of heart transplantation	0.52 (0.21–1.30)	0.16
Interventional hospital	0.43 (0.11–1.74)	0.23
Number of cardiac intensive care beds	1.01 (0.99–1.04)	0.32
Adult cardiology service	2.96 (0.22–40.40)	0.38
Mobile health service	1.07 (0.28–4.10)	0.92
Established medical home	0.63 (0.31–1.27)	0.20
Adult diagnostic catheterization	1.27 (0.28–5.79)	0.75
Adult interventional catheterization	1.07 (0.26–4.48)	0.93

Multivariable models included the following hospital characteristics: number of beds, teaching/academic hospital, rural vs. urban, regions (Midwest, West, South vs. Northeast), PCI, surgical, interventional and heart transplantation capability, number of cardiac intensive care beds, adult cardiology service, mobile health service, established medical home, has adult diagnostic catheterization capability, and has adult interventional catheterization capability. Multiple imputation was conducted on the hospital level to impute the missingness on the hospital characteristic variables.

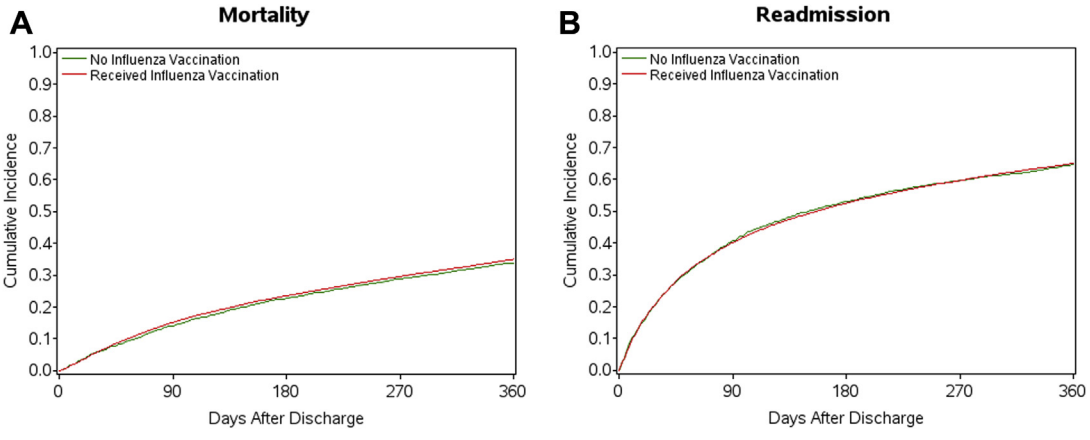
Abbreviations as in Table 3.

DISCUSSION

This is the first analysis, to the best of our knowledge, to assess influenza and pneumococcal vaccination rates in HF patients using a large, national registry. Over the study period, the proportion of patients who received vaccination before or during an acute HF hospitalization did not increase, whereas refusal rates increased from 2012 to 2017. Hospitals with high performance on influenza and pneumococcal vaccination rates were associated with higher rates of HF achievement or quality measures. There was a strong correlation between within-hospital performance on influenza vaccination and performance on pneumococcal vaccination. Receiving vaccination was not associated with observed changes in clinical outcomes. These findings provide insights into the gaps, variations, and disparities in vaccination use and highlight potential opportunities to improve HF care quality.

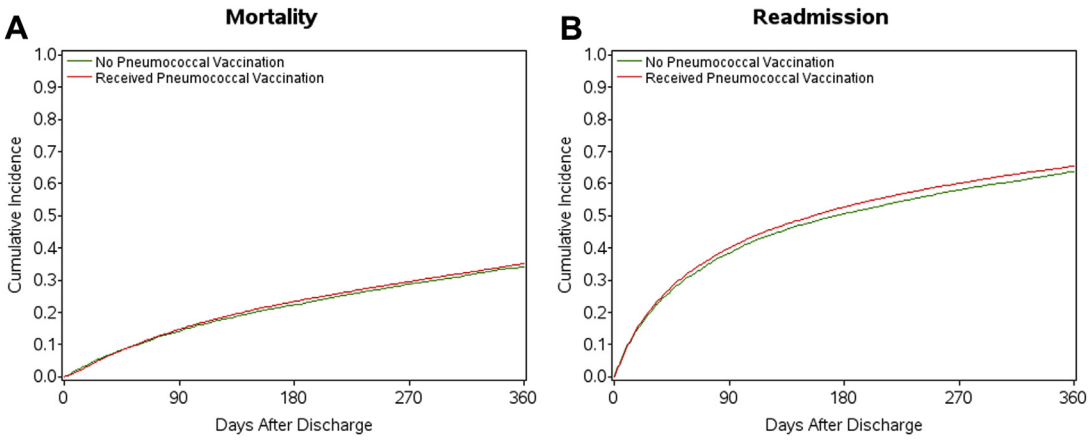
There are limited data on influenza and pneumococcal vaccination rates in HF patients. A recent subanalysis of the PARADIGM-HF (Prospective Comparison of ARNI With ACEI to Determine Impact on Global Mortality and Morbidity in Heart Failure) chronic HF trial found influenza vaccination rates of 55% among a U.S. cohort, with a greater proportion of whites vaccinated than other ethnic groups (15). A smaller, single-center analysis found lower rates of vaccination in a primarily indigent patient population in Miami, Florida (16). Pneumococcal vaccination rates among patients with chronic HF have not been described before the current analysis. Our data show a discrepancy between those eligible for vaccination and those who actually receive vaccine. Furthermore, we found considerable variation among U.S. hospitals in terms of vaccination rates, which adds to the

FIGURE 3 Clinical Outcomes by Influenza Vaccination Status in CMS FFS-Linked Patients



Rates of **(A)** mortality and **(B)** readmission in vaccination-eligible patients who did versus did not receive influenza vaccination using linked Centers for Medicare and Medicaid Services fee-for-service claims (CMS FFS).

FIGURE 4 Clinical Outcomes by Pneumococcal Vaccination Status in CMS FFS–Linked Patients



Rates of mortality **(A)** and readmission **(B)** in vaccination-eligible patients who did versus did not receive pneumococcal vaccination using linked Centers for Medicare and Medicaid Services fee-for-service claims (CMS FFS).

significant international variation reported on by the PARADIGM-HF investigators. Our data are the first to describe practice patterns with respect to respiratory vaccination in a large U.S. cohort collected in a usual-care setting.

Despite multiple national vaccination campaigns, rates of vaccination in patients with HF did not increase across the study period, whereas the proportion of refusals did. This lack of improvement in vaccination rates in HF patients is observed despite growing evidence that influenza vaccination can be beneficial in patients with atherosclerotic heart disease. Further troubling is that pneumococcal vaccination rates decreased over the study period, despite revised recommendations from the Advisory Committee on Immunization Practices, which advocated for sequential administration of PCV13 (13-valent pneumococcal conjugate vaccine) and PPSV23 (23-valent pneumococcal polysaccharide vaccine) in all adults ≥65 years of age (10) after the CAPiTA (Community-Acquired Pneumonia Immunization Trial in Adults) trial showed efficacy in reducing vaccine-type community-acquired pneumonia in over 84,000 patients (17). Declining rates of vaccination were seen despite guideline recommendations for respiratory vaccination from major cardiovascular societies (11,12,18). Increasing media attention surrounding a vocal contingent that actively opposes routine vaccination, as well as a fear of contracting disease with vaccination (16), may in part explain the increase in refusals over the study period.

Our findings contrast with previous findings of an association between vaccination and improved clinical outcomes and provide insights into the need for more randomized controlled studies in this area. A prospective cohort study of Israeli HF patients found that receipt of influenza vaccination was associated with lower rates of all-cause mortality at 1 and 4 years (19). Similarly, influenza vaccination in PARADIGM-HF was associated with a reduced risk for all-cause mortality in a propensity-adjusted analysis (15). Given substantial differences between those who received and did not receive vaccination, our findings and those of previous studies are subject to both measured and unmeasured confounding. Our contradictory findings in a large HF dataset underscore the challenges associated with determining the clinical benefit of vaccination in observational or retrospective analyses. INVESTED (Influenza Vaccine to Effectively Stop Cardio Thoracic Events and Decompensated Heart Failure; NCT02787044) trial, a large randomized clinical trial, will investigate high-dose, trivalent versus standard dose, quadrivalent influenza vaccination on clinical outcomes in patients with myocardial infarction and HF and could provide more clarity with respect to a causal relationship between influenza vaccination dose and outcomes. Further randomized data are needed to evaluate for a causative impact of influenza and pneumococcal vaccination on long-term mortality and rehospitalization.

Our finding of stagnant to declining rates of respiratory vaccination, with the lowest rates found

among large, academic, urban centers, is surprising and hypothesis generating. The reasons for these findings are unclear but may reflect a larger primary care presence at smaller, rural centers, with potentially greater focus on preventive care strategies. Further investigation is needed to determine differences in practice patterns by hospital size and location. Although other quality measures in the GWTG-HF registry have improved over time (20), vaccination for influenza and pneumococcal vaccination have not. In the current climate of large financial penalties for 30-day rehospitalization, hospitals might have shifted focus to interventions that they perceive can improve these short-term metrics, with diminished focus on long-term preventative interventions such as vaccination.

We found a strong association between hospitals that performed highly on vaccination and improved performance on HF achievement and quality metrics. These findings suggest that hospitals might have designed systems to integrate vaccination into care planning during an acute HF episode of care. These interventions could include decision support tools (21), clinical reminders (22), and incentive programs (23) successful in other environments.

Further work is needed to understand the practices of high performers that are not readily available through the American Hospital Association Annual Survey and to understand how these practices can be applied to other centers that treat HF patients. These insights would offer an opportunity for a new area of study to evaluate quality improvement interventions that could improve care delivery and guideline adherence. Such interventions, if applied broadly, may prove cost-effective.

STUDY LIMITATIONS. First, given that the GWTG-HF is a voluntary process improvement program, the program may be biased to include hospitals with a higher likelihood of following evidence-based recommendations. Second, because the GWTG-HF initiative is a registry of patients hospitalized for decompensated HF, our study might miss those patients vaccinated for influenza after hospital discharge but during the same influenza season or those vaccinated before October each year, and therefore might underestimate the number of patients vaccinated. Third, our decision to exclude patients who refused vaccination as part of the eligible population could have decreased the eligible population and therefore changed the observed hospital-level vaccination rate, but this was intended to be more reflective of the actual care delivered and designed to not penalize hospitals that had a higher proportion of refusals. Fourth, GWTG-HF does not collect data on the specific influenza or pneumococcal formulations (PPSV23 or PCV-13) administered. Fifth, the American Hospital Association Annual Survey provides hospital characteristics at a single point in time and does not capture all the relevant variables that can drive higher performance on vaccination or seminal changes over time (e.g., the adoption of electronic health records with best practice advisories). Outcome analysis was limited to patients with Medicare claims data and therefore might have represented a distinct study population from the rest of the analyses. Residual measured and unmeasured confounding could have influenced our findings given the differences in baseline characteristics between those who did and did not receive vaccination. Virulence of influenza during the years studied and the match between vaccine antigens and circulating influenza strains could have affected the outcome analysis. Other relevant indications of risk, socioeconomic status, and access to care might not be sufficiently collected in this dataset to allow for adjustment. Finally, our hospital-level analysis on high-performing hospitals might have limited statistical power given the relatively small sample size. Given multiple comparisons, some of the statistically significant findings could have been related to chance. Bonferroni correction was used to account for multiple testing.

CONCLUSIONS

Vaccination for influenza and pneumococcus represents a low-cost, high-access, and low-risk intervention. Our findings demonstrate gaps in vaccination use among eligible HF patients. Our data showing increasing refusal rates and stagnant to declining vaccination rates over the past 5 years are grounds for significant public health concern. Further studies are needed to assess causes for lack of improvement in vaccination rates in patients with HF and reasons for the observed disparities. Randomized controlled studies are needed to establish a relationship between vaccination and relevant clinical outcomes. Further research is needed with regard to the development of targeted, systems-level interventions that could improve respiratory vaccination rates and other performance measures for patients with HF.

ADDRESS FOR CORRESPONDENCE: Dr. Adrian F. Hernandez, Duke Clinical Research Institute, P.O. Box 17969, Durham, North Carolina 27715. E-mail: adrian.hernandez@duke.edu.

PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: Vaccination in patients with HF could improve patient outcomes by preventing respiratory infection and limiting inflammation-induced depression in myocardial contractility. There are large gaps in vaccination practices for patients admitted to the hospital for acute HF.

TRANSLATIONAL OUTLOOK 1: The large, randomized clinical trial INVESTED should provide incremental data on the role of high-dose influenza vaccination in patients with HF.

TRANSLATIONAL OUTLOOK 2: Compliance with guideline-recommended influenza and pneumococcal vaccination in patients with HF is nonsatisfactory. Further research needs to be done to determine how to best integrate vaccination practices into systems of care practices in patients hospitalized with HF.

REFERENCES

1. Heidenreich PA, Albert NM, Allen LA, et al., on behalf of the American Heart Association Advocacy Coordinating Committee; Council on Arteriosclerosis, Thrombosis and Vascular Biology; Council on Cardiovascular Radiology and Intervention; Council on Clinical Cardiology; Council on Epidemiology and Prevention; Stroke Council. Forecasting the impact of heart failure in the United States: a policy statement from the American Heart Association. Circ Heart Fail 2013;6:606–19.

2. Mozaffarian D, Benjamin EJ, Go AS, et al., on behalf of the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics–2015 update: a report from the American Heart Association [published corrections appear in Circulation 2015;131:e535 and Circulation 2016;133:e417]. Circulation 2015;131:e29–322.

3. Alon D, Stein GY, Korenfeld R, Fuchs S. Predictors and outcomes of infection-related hospital admissions of heart failure patients. PLoS One 2013;8:e72476.

4. Fonarow GC, Abraham WT, Albert NM, et al., for the OPTIMIZE-HF Investigators and Hospitals. Factors identified as precipitating hospital admissions for heart failure and clinical outcomes: findings from OPTIMIZE-HF. Arch Intern Med 2008;168:847–54.

5. Fagnoul D, Pasquier P, Bodson L, Ortiz JA, Vincent JL, De Backer D. Myocardial dysfunction during H1N1 influenza infection. J Crit Care 2013;28:321–7.

6. Udell JA, Zawi R, Bhatt DL, et al. Association between influenza vaccination and cardiovascular outcomes in high-risk patients: a meta-analysis. JAMA 2013;310:1711–20.

7. Ciszewski A, Bilinska ZT, Brydak LB, et al. Influenza vaccination in secondary prevention from coronary ischaemic events in coronary artery disease: FLUCAD study. Eur Heart J 2008;29:1350–8.

8. Gurfinkel EP, Leon de la Fuente R, Mendiz O, Mautner B. Flu vaccination in acute coronary syndromes and planned percutaneous coronary interventions (FLUVACS) Study. Eur Heart J 2004;25:25–31.

9. Phrommintikul A, Kuanprasert S, Wongcharoen W, Kanjanavanit R, Chaiwarith R, Sukonthasarn A. Influenza vaccination reduces cardiovascular events in patients with acute coronary syndrome. Eur Heart J 2011;32:1730–5.

10. Tomczyk S, Bennett NM, Stoecker C, et al. Use of 13-valent pneumococcal conjugate vaccine and 23-valent pneumococcal polysaccharide vaccine among adults aged ≥65 years: recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR Morb Mortal Wkly Rep 2014;63:822–5.

11. Yancy CW, Jessup M, Bozkurt B, et al. 2013 ACCF/AHA guideline for the management of heart failure: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2013;62:e147–239.

12. Lindenfeld J, Albert NM, Boehmer JP, et al. HFSA 2010 comprehensive heart failure practice guideline. J Card Fail 2010;16:e1–194.

13. Smaha LA. The American Heart Association Get With The Guidelines program. Am Heart J 2004;148 Suppl:S46–8.

14. DeVore AD, Cox M, Heidenreich PA, et al. Cluster-randomized trial of personalized site performance feedback in Get With The Guidelines-Heart Failure. Circ Cardiovasc Qual Outcomes 2015;8:421–7.

15. Vardeny O, Claggett B, Udell JA, et al., for the PARADIGM-HF Investigators. Influenza vaccination in patients with chronic heart failure: the PARADIGM-HF trial. J Am Coll Cardiol HF 2016;4:152–8.

16. Hebert K, Marzouka G, Arcement L, et al. Prevalence of vaccination rates in systolic heart failure: a prospective study of 549 patients by age, race, ethnicity, and sex in a heart failure disease management program. Congest Heart Fail 2010;16:278–83.

17. Bonten MJM, Huijts SM, Bolkenbaas M, et al. Polysaccharide conjugate vaccine against pneumococcal pneumonia in adults. N Engl J Med 2015;372:1114–25.

18. Perk J, De Backer G, Gohlke H, et al. European guidelines on cardiovascular disease prevention in clinical practice (version 2012): the Fifth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (constituted by representatives of nine societies and by invited experts). Atherosclerosis 2012;223:1–68.

19. Kopel E, Klempfner R, Goldenberg I. Influenza vaccine and survival in acute heart failure. Eur J Heart Fail 2014;16:264–70.

20. Fonarow GC, Sterzing, C. 2017 Get With The Guidelines-Heart Failure Measure Updates. American Heart Association, 2017. Available at: https://www.heart.org/idc/groups/heart-public/@wcm/@hcm/@gwtg/documents/downloadable/ucm_491609.pdf. Accessed December 12, 2017.

21. Garg AX, Adhikari NK, McDonald H, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. JAMA 2005;293:1223–38.

22. Shea S, DuMouchel W, Bahamonde L. A meta-analysis of 16 randomized controlled trials to evaluate computer-based clinical reminder systems for preventive care in the ambulatory setting. J Am Med Inform Assoc 1996;3:399–409.

23. Fairbrother G, Hanson KL, Friedman S, Butts GC. The impact of physician bonuses, enhanced fees, and feedback on childhood immunization coverage rates. Am J Public Health 1999;89:171–5.

KEY WORDS heart failure, influenza, performance measures, pneumococcal, vaccination

APPENDIX For supplemental figures and tables, please see the online version of this paper.