JACC: CARDIOVASCULAR IMAGING
VOL. 7, NO. 7, 2014

ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC.
http://dx.doi.org/10.1016/j.jcmg.2014.02.008

Hospital-Level Variation in Use of Cardiovascular Testing for Adults With Incident Heart Failure

Findings From the Cardiovascular Research Network Heart Failure Study

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ABSTRACT

OBJECTIVES This study aimed to characterize the use of cardiovascular testing for patients with incident heart failure (HF) hospitalization who participated in the National Heart, Lung, and Blood Institute sponsored Cardiovascular Research Network (CVRN) Heart Failure study.

BACKGROUND HF is a common cause of hospitalization, and testing and treatment patterns may differ substantially between providers. Testing choices have important implications for the cost and quality of care.

METHODS Crude and adjusted cardiovascular testing rates were calculated for each participating hospital. Cox proportional hazards regression models were used to examine hospital testing rates after adjustment for hospital-level patient case mix.

RESULTS Of the 37,099 patients in the CVRN Heart Failure study, 5,878 patients were hospitalized with incident HF between 2005 and 2008. Of these, evidence of cardiovascular testing was available for 4,650 (79.1%) patients between 14 days before the incident HF admission and ending 6 months after the incident discharge. We compared crude and adjusted cardiovascular testing rates at the hospital level because the majority of testing occurred during the incident HF hospitalization. Of patients who underwent testing, 4,085 (87.9%) had an echocardiogram, 4,345 (93.4%) had a systolic function assessment, and 1,714 (36.9%) had a coronary artery disease assessment. Crude and adjusted testing rates varied markedly across the profiled hospitals, for individual testing modalities (e.g., echocardiography, stress echocardiography, nuclear stress testing, and left heart catheterization) and for specific clinical indications (e.g., systolic function assessment and coronary artery disease assessment).

CONCLUSIONS For patients with newly diagnosed HF, we did not observe widespread overuse of cardiovascular testing in the 6 months following incident HF hospitalization relative to existing HF guidelines. Variations in testing were greatest for assessment of ischemia, in which testing guidelines are less certain. (J Am Coll Cardiol Img 2014;7:690–700) © 2014 by the American College of Cardiology Foundation.

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Manuscript received February 14, 2014; accepted February 20, 2014.

Over the past several decades, advances in the prevention and treatment of cardiovascular disease have led to important declines in age-adjusted, cardiovascular-related mortality (1). At the same time, cardiovascular imaging has proliferated (2,3). A recent review of Medicare billing data revealed a doubling of expenditures on medical imaging, from $6.89 billion in 2000 to $14.1 billion in 2005, approximately one-third of this involved cardiovascular imaging (4). Medicare expenditures for diagnostic imaging have grown more rapidly than any other component of medical care (5). However, relatively few data link cardiovascular imaging to improved patient outcomes, and concern is growing that these tests have been adopted at extraordinary cost with insufficient evidence of benefit (6,7).

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In response to this dramatic growth in imaging, professional groups have promulgated clinical practice guidelines and appropriate use criteria (AUC) (8–12). However, the AUC are not supported by randomized trial evidence, and guidelines rarely consider cost effectiveness (13). AUC are limited in their discussion of how multiple testing modalities are most efficiently combined where multiple overlapping testing indications exist. Noninvasive imaging techniques may be interchangeable in some instances, and diminishing returns to overlapping imaging studies are likely. Therefore, there is a critical need to better understand how imaging combinations are used in clinical practice.

There are more than 1 million hospitalizations for acute heart failure (HF) annually, and the inpatient cost for these patients was estimated at $20.1 billion in 2009 (1,14). Testing and treatment patterns for newly diagnosed HF may differ substantially between providers and may have important implications for the cost and quality of care (15–17). In this study, we describe the type and frequency of cardiovascular testing in the first 6 months following hospitalization for incident HF in a large, diverse cohort of patients derived from the Cardiovascular Research Network (CVRN) Heart Failure study.

METHODS

SOURCE POPULATION. The source population included members from 3 participating health plans within the National Heart, Lung, and Blood Institute (NHLBI) sponsored CVRN (1,18,19). Sites included hospitals participating in the Kaiser Permanente Northern California, Kaiser Permanente Colorado, and Kaiser Permanente Northwest regions. These sites are integrated healthcare delivery systems that provide comprehensive care to ethnically, socioeconomically, and geographically diverse populations across various practice settings. They systematically track care provided and outcomes experienced within and outside of owned facilities. Each site has a virtual data warehouse that serves as the primary data source for patient identification and characterization (19). The virtual data warehouses are comprised of electronic datasets populated with linked demographic, administrative, and healthcare utilization data. Utilization data include ambulatory visits, as well as network and nonnetwork hospitalizations with diagnoses and procedures. Institutional review boards at participating sites approved the study.

Study sample. We identified all persons aged $21 years who were hospitalized with newly diagnosed HF from 2005 to 2008. We used the following International Classification of Diseases-9th Edition (ICD-9) codes: 398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, and 428.9. Previous studies showed a positive predictive value of >95% for admissions with a primary discharge diagnosis of HF on the basis of these codes compared with chart review and Framingham clinical criteria (20–22). Hospitalizations for HF were identified from each site's virtual data warehouse on the basis of a primary ICD-9 discharge diagnosis for HF. We defined incident HF as an eligible HF hospitalization within the sampling frame that was not preceded by any other inpatient or outpatient HF diagnosis within the previous 5 years.

We excluded patients who did not have continuous health plan membership and pharmacy drug benefits during the 12 months before their index HF admission. We excluded patients who did not have at least 1 outpatient visit within 3 months of their index HF admission to ensure more complete data on post-discharge medical care. Finally, we excluded patients with a diagnosis of systemic cancer, because serial imaging may be indicated to assess the safety of chemotherapy administration, even in the absence of symptomatic HF (Fig. 1) (8,23).

We identified all cardiovascular testing that occurred between 14 days before and 180 days after the incident HF hospitalization. Administrative

ABBREVIATIONS AND ACRONYMS

ACC = American College of Cardiology

ACR = American College of Radiology

AHA = American Heart Association

AUC = appropriate use criteria

CAD = coronary artery disease

CTA = computed tomography angiography

CMR = cardiac magnetic resonance

CMS = Centers for Medicare and Medicaid Services

CVRN = Cardiovascular Research Network

HF = heart failure

MPI = myocardial perfusion imaging

NHLBI = National Heart, Lung, and Blood Institute

PET = positron emission tomography

SPECT = single-photon emission tomography

TEE = transesophageal echocardiography

TTE = transthoracic echocardiography

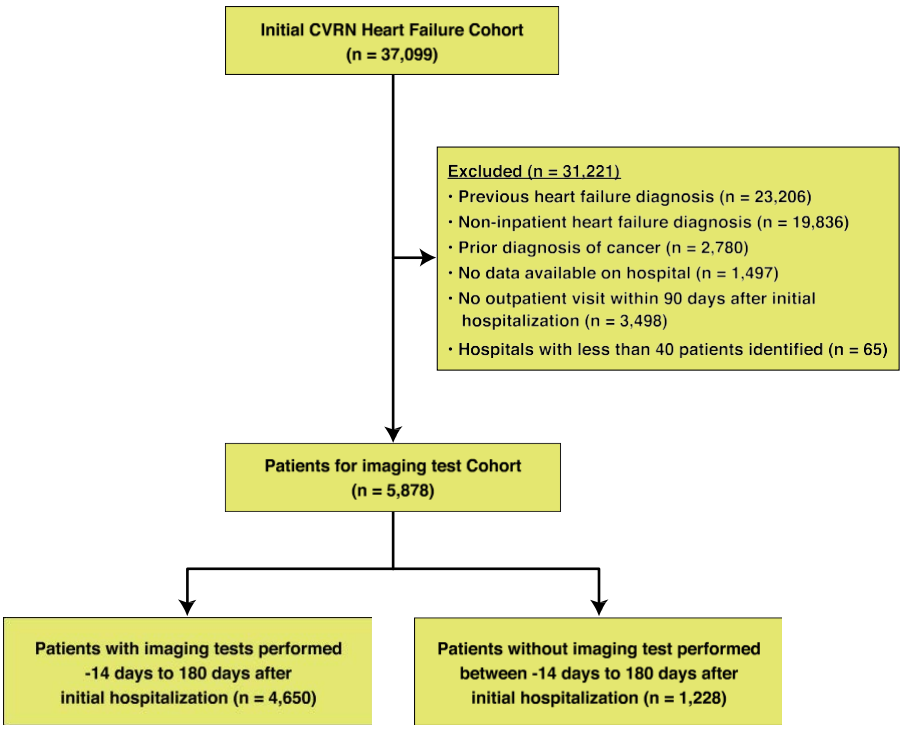

FIGURE 1 Cohort Assembly for Patients With Incident Heart Failure From the CVRN Heart Failure Study

CVRN ¼ Cardiovascular Research Network.

records were searched for any evidence of testing. Imaging reports were also searched for evidence of an associated report from an imaging study that was performed despite no available administrative bill. For cases where no evidence of testing was identified through either administrative records or study report, the medical record was manually reviewed to identify if any testing occurred. This procedure was intended to capture studies that may have been performed at another hospital. Cardiovascular testing included transthoracic echocardiography (TTE), transesophageal echocardiography (TEE), stress echocardiography, single-photon emission computed tomography (SPECT), positron emission tomography (PET), cardiac magnetic resonance (CMR) imaging, nuclear scintigraphy, left ventriculography, left heart catheterization, right and left heart catheterization, and cardiac computed tomography angiography (CTA). We considered all tests performed between 14 days before and 30 days after the incident HF admission to represent the initial testing strategy. We included testing before the index admission because outpatient testing may have prompted the index hospitalization. The Centers for Medicare & Medicaid Services (CMS) use a similar rationale to bundle payment for HF episodes of care in their Bundled Payments for Care Initiative (24). A systolic function assessment included any of the following tests individually or in combination: TTE, TEE, stress echocardiography, SPECT, PET, CMR, nuclear scintigraphy, or left ventriculography. A coronary artery disease (CAD) assessment included stress echocardiography, SPECT, PET, left heart catheterization, right and left heart catheterization, or cardiac CTA. Administrative data were searched for the following procedural codes: 76620, 76625, 76627, 76628, 76632, 93303, 93304, 93306, 93307, 93308, 93320, 93321, 93325, X3307, 7662A, 7662B, 7662C, 7662D, 7662E, 7662F, 7662G, 7663A, 7663B, 9331B, 9332A, X3308, 93350, 93312, 93313, 93314, 93318, 9331A, X3312, 93510, 93511, 93539, 93540, 93545, 93543, 75552, 75553, 75554, 75555, 75556, 75557, 75558, 75559, 75560, 75561, 75562, 75563, 75564, 78496, 78459, 78491, 78492, 93526, 78464, 78465, 78468, 78469, 78472, 78473, 78478, 78480, 78481, 78483, 78494, 93015, 93016, 93017, and 93018.

TABLE 1 Baseline Characteristics Among Patients Hospitalized for Incident HF (2005 to 2008)

	Overall (N ¼ 5,878)	Imaging Test Available (n ¼ 4,650)	Imaging Test Not Available (n ¼ 1,228)	p Value
Age, yrs	73.4 ± 13.8	72.2 ± 13.9	78.1 ± 12.6	<0.001
Female	3,039 (51.7)	2,319 (49.9)	720 (58.6)	<0.001
Medical history				
Acute myocardial Infraction	350 (6.0)	239 (5.1)	111 (9.0)	<0.001
Unstable angina	193 (3.3)	140 (3.0)	53 (4.3)	0.02
Coronary artery bypass surgery	169 (2.9)	131 (2.8)	38 (3.1)	0.61
Percutaneous coronary intervention	318 (5.4)	239 (5.1)	79 (6.4)	0.07
Ischemic stroke or transient ischemic attack	421 (7.2)	296 (6.4)	125 (10.2)	<0.001
Cerebrovascular disease	977 (16.6)	710 (15.3)	267 (21.7)	<0.001
Other thromboembolic event	37 (0.6)	25 (0.5)	12 (1.0)	0.08
Atrial fibrillation or atrial flutter	1,744 (29.7)	1,294 (27.8)	450 (36.6)	<0.001
Ventricular fibrillation or ventricular tachycardia	85 (1.4)	68 (1.5)	17 (1.4)	0.84
Mitral and/or aortic valvular disease	728 (12.4)	510 (11.0)	218 (17.8)	<0.001
Peripheral arterial disease	418 (7.1)	302 (6.5)	116 (9.4)	<0.001
Rheumatic heart disease	179 (3.0)	142 (3.1)	37 (3.0)	0.94
Cardiac resynchronization therapy	3 (0.1)	2 (0.0)	1 (0.1)	0.60
Implantable cardioverter defibrillator	28 (0.5)	24 (0.5)	4 (0.3)	0.39
Pacemaker	202 (3.4)	141 (3.0)	61 (5.0)	0.001
Dyslipidemia	3,481 (59.2)	2,741 (58.9)	740 (60.3)	0.40
Hypertension	4,536 (77.2)	3,484 (74.9)	1052 (85.7)	<0.001
Diabetes mellitus	1,079 (18.4)	845 (18.2)	234 (19.1)	0.48
Hospitalized bleeds	291 (5.0)	200 (4.3)	91 (7.4)	<0.001
Chronic lung disease	2,037 (34.7)	1,583 (34.0)	454 (37.0)	0.06
Chronic liver disease	212 (3.6)	173 (3.7)	39 (3.2)	0.36
Baseline estimated GFR category				<0.001
>130	13 (0.2)	10 (0.2)	3 (0.2)	
90–130	703 (12.0)	610 (13.1)	93 (7.6)	
60–89	2,107 (35.8)	1,704 (36.6)	403 (32.8)	
45–59	1,255 (21.4)	967 (20.8)	288 (23.5)	
30–44	831 (14.1)	601 (12.9)	230 (18.7)	
15–29	343 (5.8)	250 (5.4)	93 (7.6)	
<15	64 (1.1)	52 (1.1)	12 (1.0)	
Dialysis	150 (2.6)	87 (1.9)	63 (5.1)	
Missing	412 (7.0)	369 (7.9)	43 (3.5)	
Baseline estimated hemoglobin category				<0.001
$16.0	343 (5.8)	299 (6.4)	44 (3.6)	
15.0–15.9	503 (8.6)	419 (9.0)	84 (6.8)	
14.0–14.9	924 (15.7)	747 (16.1)	177 (14.4)	
13.0–13.9	1,083 (18.4)	846 (18.2)	237 (19.3)	
12.0–12.9	1,006 (17.1)	777 (16.7)	229 (18.6)	
11.0–11.9	689 (11.7)	502 (10.8)	187 (15.2)	
10.0–10.9	455 (7.7)	339 (7.3)	116 (9.4)	
9.0–9.9	182 (3.1)	131 (2.8)	51 (4.2)	
<9.0	107 (1.8)	76 (1.6)	31 (2.5)	
Missing	586 (10.0)	514 (11.1)	72 (5.9)	
Systolic blood pressure category, mm Hg				0.02
$180	250 (4.3)	201 (4.3)	49 (4.0)	
160–179	571 (9.7)	430 (9.2)	141 (11.5)	
140–159	1,332 (22.7)	1,038 (22.3)	294 (23.9)	
130–139	1,294 (22.0)	1,038 (22.3)	256 (20.8)	
121–129	857 (14.6)	686 (14.8)	171 (13.9)	
110–120	1,100 (18.7)	866 (18.6)	234 (19.1)	
100–109	211 (3.6)	168 (3.6)	43 (3.5)	
<100	90 (1.5)	69 (1.5)	21 (1.7)	
Missing	173 (2.9)	154 (3.3)	19 (1.5)	

Continued on the next page

TABLE 1 Continued

	Overall (N ¼ 5,878)	Imaging Test Available (n ¼ 4,650)	Imaging Test Not Available (n ¼ 1,228)	p Value
Diastolic blood pressure category, mm Hg				<0.001
$110	110 (1.9)	98 (2.1)	12 (1.0)	
100–109	197 (3.4)	161 (3.5)	36 (2.9)	
90–99	475 (8.1)	387 (8.3)	88 (7.2)	
85–89	370 (6.3)	304 (6.5)	66 (5.4)	
81–84	457 (7.8)	371 (8.0)	86 (7.0)	
#80	4,096 (69.7)	3,175 (68.3)	921 (75.0)	
Missing	173 (2.9)	154 (3.3)	19 (1.5)	
HDL cholesterol category, g/dl				0.25
$60	1,057 (18.0)	809 (17.4)	248 (20.2)	
50–50.9	1.046 (17.8)	840 (18.1)	206 (16.8)	
40–49.9	1.471 (25.0)	1.167 (25.1)	304 (24.8)	
35–39.9	698 (11.9)	546 (11.7)	152 (12.4)	
<35	720 (12.2)	577 (12.4)	143 (11.6)	
Missing	886 (15.1)	711 (15.3)	175 (14.3)	
LDL cholesterol category, g/dl				0.12
$200	62 (1.1)	55 (1.2)	7 (0.6)	
160–199.9	263 (4.5)	206 (4.4)	57 (4.6)	
130–159.9	668 (11.4)	522 (11.2)	146 (11.9)	
100–129.9	1.362 (23.2)	1.087 (23.4)	275 (22.4)	
70–99.9	1.789 (30.4)	1.411 (30.3)	378 (30.8)	
<70	798 (13.6)	610 (13.1)	188 (15.3)	
Missing	936 (15.9)	759 (16.3)	177 (14.4)	

Values are mean ± SD or n (%).
GFR ¼ glomerular filtration rate; HDL ¼ high-density lipoprotein; LDL ¼ low-density lipoprotein.

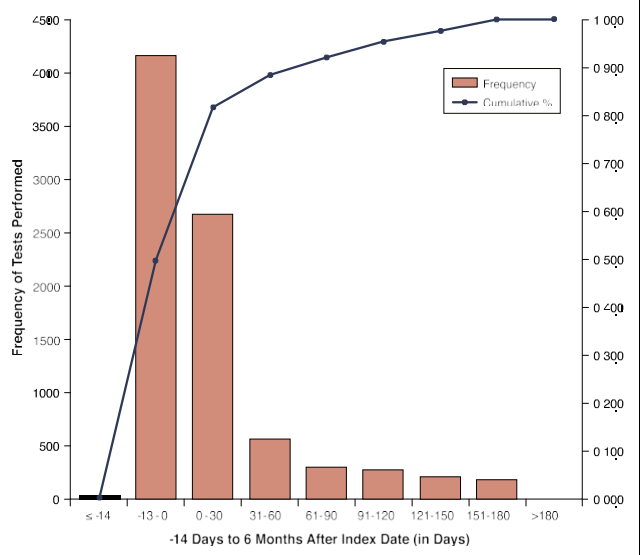

FIGURE 2 Frequency of Cardiovascular Testing Between 14 Days Before and 180 Days Following the Incident Heart Failure Admission

Pareto chart of cardiovascular testing (in days) from 14 days before the incident heart failure admission through 180 days following the incident heart failure admission. The frequency of testing is represented in the bar charts. The cumulative percent of testing is represented in the plot.

We identified hospital characteristics from the American Heart Association (AHA) Hospital Statistics for 2009 (25). We ascertained characteristics of hospitals not included in the AHA database by manually calling hospital administrators at the included sites.

COVARIATES. Information on coexisting illnesses was on the basis of relevant ICD-9 and Current Procedural Terminology codes, laboratory results, or filled outpatient prescriptions from health plan pharmacy databases. We chose laboratory values closest to the index date. Information was also obtained from site-specific cancer registries (26). We collected baseline data on diagnoses of acute myocardial infarction, unstable angina, coronary artery revascularization, hypertension, diabetes mellitus, chronic lung disease, and systemic cancer on the basis of ICD-9 and Current Procedural Terminology codes (26).

Statistical analysis. All analyses were conducted using SAS statistical software, version 9.3 (SAS Institute, Cary, North Carolina). Because most cardiovascular testing occurred during the incident HF hospitalization, the hospital was designated as the unit of analysis. To create statistically valid hospital testing profiles, we restricted the analysis to the 31 hospitals

TABLE 2 Frequency of Testing Combinations Used for Patients With Incident Heart Failure

Echo	2,453 (52.8)
Stress Echo þ SPECT	528 (11.4)
Echo þ SPECT	244 (5.2)
SPECT	212 (4.6)
Stress Echo	212 (4.6)
RHC þ LHC	148 (3.2)
LHC	146 (3.1)
Echo þ LHC	141 (3.0)
Echo þ RHC þ LHC	122 (2.6)
Other	441 (9.5)

Values are n (%).

Echo ¼ transthoracic echocardiogram; LHC ¼ left heart catheterization; RHC ¼ right heart catheterization; SPECT ¼ single-photon emission computed tomography; Stress Echo ¼ stress echocardiogram or dobutamine stress echocardiogram.

with a minimum of 40 incident HF admissions. This threshold was chosen because 96.7% of cardiovascular tests were performed in these 31 hospitals, and the number of incident HF admissions per hospital dropped sharply below this cutpoint (data not shown). Crude and adjusted cardiovascular testing rates were calculated for each hospital in the final dataset. Cox proportional hazards regression models were used to examine hospital testing rates after adjustment for hospital-level patient case mix and to account for differential time of follow-up and censoring. Patients who died, disenrolled, ended participation in the CVRN Heart Failure study, or had a transplant were censored. Adjusted hospital testing rates were compared with the facility that had the highest rate of echocardiography testing. Case mix was defined using administrative data. Covariates included age, sex, diabetes, hypertension, dyslipidemia, coronary disease, and end-stage renal disease.

RESULTS

Of the 37,099 patients included in the CVRN Heart Failure study, we identified 5,878 patients hospitalized for incident HF between 2005 and 2008. Of these, cardiovascular testing was performed for 4,650 (79.1%) patients beginning 14 days before the incident HF admission and ending 6 months after discharge. Patients with and without testing differed from each other in a number of important respects. Patients with identifiable testing were younger, more likely to be men, and had fewer comorbidities (Table 1). For those patients with available testing, the majority of tests were completed during or immediately following the index HF admission (Fig. 2).

TABLE 3 Frequency and Timing of Hospital Readmissions

30-day hospital readmission	712 (12.1)
180-day hospital readmission	2,236 (38.0)
Frequency of hospital readmission	
0	3,642 (62.0)
1	1,378 (23.4)
2	507 (8.6)
3	228 (3.9)
$4	123 (2.1)

Values are n (%).

All but 2 of the hospitals were not-for-profit, and 13 (42%) were teaching facilities. Eighteen (58%) offered on-site cardiac catheterization, and 17 (55%) offered on-site cardiac surgery. All hospitals without onsite cardiac catheterization had referral agreements with centers that offered this service. The mean ± SD hospital bed size was 165.8 ± 99.1, with median of 150 (interquartile range: 96.2). Median household income for the county in which the hospital was located ranged from $41,390 to $78,009. All but 3 hospitals were located in counties above the median household income nationwide ($46,326) and all in counties below the 80th percentile. Twenty-four of the hospitals were located in California, 3 were located in Oregon, 2 were located in Colorado, and 2 were located in Washington state.

For patients with available results, 4,085 (87.9%) had an echocardiogram, 4,345 (93.4%) had a systolic function assessment, and 1,714 (36.9%) had a CAD assessment. A total of 1,213 (26.1%) had multiple tests during the study (Table 2). Repeat testing was infrequent in the 6 months following incident HF admission across all sites. Between 30 and 180 days after their incident HF admission, only 51 (1.1%) patients had a repeat echocardiogram and 677 (14.6 %) patients had any additional cardiovascular test. The rate of repeat testing was low, although 712 (12.1%) patients were readmitted within 30 days following discharge and 2,236 (38.0%) patients were readmitted within 6 months following discharge (Table 3). Only

TABLE 4 Testing Rates for Individual Testing Modalities

	Crude Rate per 100 Patient-Years	Adjusted Rate per 100 Patient-Years
Echocardiography	24.8–62.0	22.3–161.8
Stress echocardiography	3.1–27.9	3.5–37.2
SPECT	3.1–27.9	1.3–63.9
LHC	5.8–27.4	9.3–63.4

Abbreviations as in Table 2.

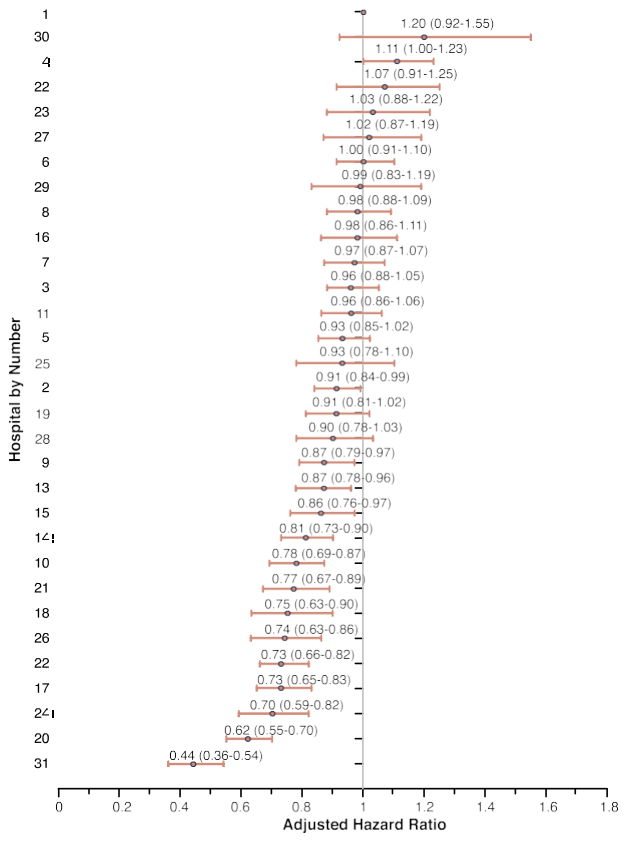

FIGURE 3 Adjusted Hazard Ratio and 95% Confidence Interval of Any Cardiovascular Test Use Among 5,878 Adults With Incident Heart Failure by Hospital (2005 to 2008)

Adjusted hazard ratio of cardiovascular testing relative to the hospital with the highest rate of echocardiography.

710 (36.7%) of readmitted patients had more than 1 test performed during the study.

Crude testing proportions varied substantially across the hospitals for individual testing modalities and for testing by indication; these differences persisted following multivariable adjustment for potential confounders (Table 4). When all testing methods were considered together, rates of systolic function assessment ranged from 53.9 to 242.7 per 100 patient-years (adjusted hazard ratio: 0.69 to 1.29), and rates of ischemia assessment ranged from 31.1 to 140.5 per 100 patient-years (adjusted hazard ratio: 0.76 to 1.98) (Figs. 3 to 5).

DISCUSSION

In this study, we examined hospital-level variations in the use of cardiovascular testing for patients hospitalized for incident HF. To our knowledge, no previous published study has comprehensively examined patterns of use of all major testing modalities simultaneously among newly diagnosed HF patients. Similar to previous work on geographic variations in healthcare utilization, our findings demonstrate wide hospital variations in testing (27,28). Our study extends previous work by assessing both individual testing modalities and clinical indications (e.g., assessment of systolic function, assessment of CAD) in adults with incident HF.

One of the 4 core HF performance measures promoted by the Joint Commission is the "documentation in the hospital record that left ventricular systolic function was evaluated before arrival, during hospitalization, or is planned for after discharge" (29). Recent Medicare reimbursement reductions for outpatient echocardiography and nuclear stress testing reflect a widespread belief that these tests are generally overused (30,31). However, we found <1 evaluation of systolic function per patient, very low rates of multiple testing, and very infrequent repeat testing in the initial 6 months following incident HF hospitalization within the participating healthcare delivery systems. Our findings do not represent overuse relative to existing HF guidelines for systolic function assessment (32).

Echocardiography is the mainstay of systolic function assessment in incident HF and carries both an American College of Cardiology (ACC)/AHA class IC recommendation (11) and an "appropriate" rating in the American College of Radiology (ACR)/ACC report on appropriate use of cardiovascular imaging in HF (33). Although a recent study suggests that even clinically appropriate studies may not be clinically useful, a complete evaluation of HF requires an assessment of cardiac structure and function, which involves imaging (34,35). The results of imaging are essential for selection of evidence-based therapies for HF and are useful for prognostication (36,37). Although the sensitivity and specificity of ICD-9-Clinical Modification codes is imperfect, not all patients in this cohort appeared to have received an echocardiogram during the ascertainment window of interest. Furthermore, both crude and adjusted rates of echocardiography differed substantially among the 31 hospital sites profiled.

Repeat echocardiographic assessment may be appropriate when there is a change in clinical status, for assessment of response to medical therapy, and to determine eligibility for advanced HF interventions, such as implantable cardioverter defibrillators or biventricular pacing (38). In this study, 38% of patients were readmitted during follow-up, and some

of these hospitalizations may have represented a change in clinical status that justified additional cardiovascular testing (39). Even so, there was a very low rate of repeat imaging for readmitted patients in this cohort, and only 1.1% of patients overall had a repeat echocardiogram during short-term follow-up despite a high rate of hospital readmissions. This low rate of repeat testing may reflect the advanced electronic medical record available in all participating health systems, which readily provided previous imaging results, strong incentives to be treated within a network facility, and close follow-up that characterized the integrated healthcare delivery model.

In this patient population, there was significantly more variation in rates of assessment of CAD than for assessment of systolic function. Although not codified as a quality measure by the Joint Commission, performance of coronary arteriography to exclude CAD as the basis of left ventricular systolic function is an ACC/AHA Class IB recommendation for patients with known or suspected CAD (11,12). The indications for CAD assessment in patients without clinical, electrocardiographic, or imaging findings of CAD are uncertain (9,11,12,33,40). The lack of high-quality evidence has led to imprecise use of cardiovascular imaging in this clinical situation. Not surprisingly, there was marked between-hospital variation in the rate and method of ischemia assessment. Differences in test availability and physician expertise between hospital sites may have played a role in variability of ischemia testing, particularly for cardiac catheterization. Several testing types were rarely used, including PET, CMR, and cardiac CTA. However, stress echocardiography and stress SPECT testing are commonly available, and although most testing occurred during the incident hospitalization, our testing profiles extended to 6 months following incident diagnosis; therefore, all patients had access to cardiac catheterization. Although all patients in this cohort had access to cardiac catheterization within the network, the availability of left heart catheterization at the presenting hospital may have influenced test selection. We were unable to identify which patients had signs, symptoms, or findings of ischemia on initial testing and who were most likely to benefit from an ischemia evaluation.

The ACR/ACC appropriate utilization of cardiovascular imaging in HF guidelines supports a sequential testing approach in newly diagnosed HF. Even so, few patients underwent multiple testing in this patient population. Different cardiovascular testing approaches offer overlapping information, are not clinically interchangeable, and differ considerably with regard to cost and invasiveness. Each modality offers unique information, and a variety of testing combinations are possible, with considerable implications for cost and cost effectiveness. We were unable to assess why 11.4% of patients underwent both a stress echocardiogram and a SPECT study. This combination may reflect poor endocardial definition or failure to reach the target heart rate on the stress echocardiogram, but could also reflect perceived complementarity between these tests. Also, we did not search records for exercise treadmill testing without imaging, and the rates of ischemic evaluation may therefore be higher than those reported here. Further

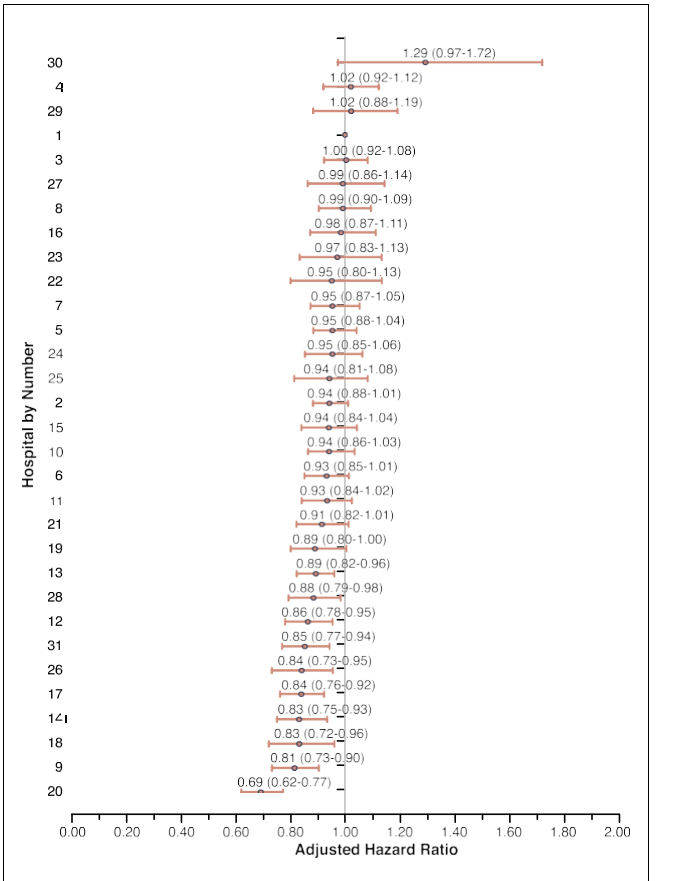

FIGURE 4 Adjusted Hazard Ratio and 95% Confidence Interval of Systolic Assessment Test Use Among 4,650 Adults With Incident Heart Failure and at Least One Available Imaging Test by Hospitals (2005 to 2008)

Adjusted hazard ratio of cardiovascular testing relative to the hospital with the highest rate of echocardiography. A systolic function assessment included any of the following tests individually or in combination: echocardiography, transesophageal echocardiography, stress echocardiography, single-photon emission computed tomography; positron emission tomography, cardiac magnetic resonance, nuclear scintigraphy, or left ventriculography.

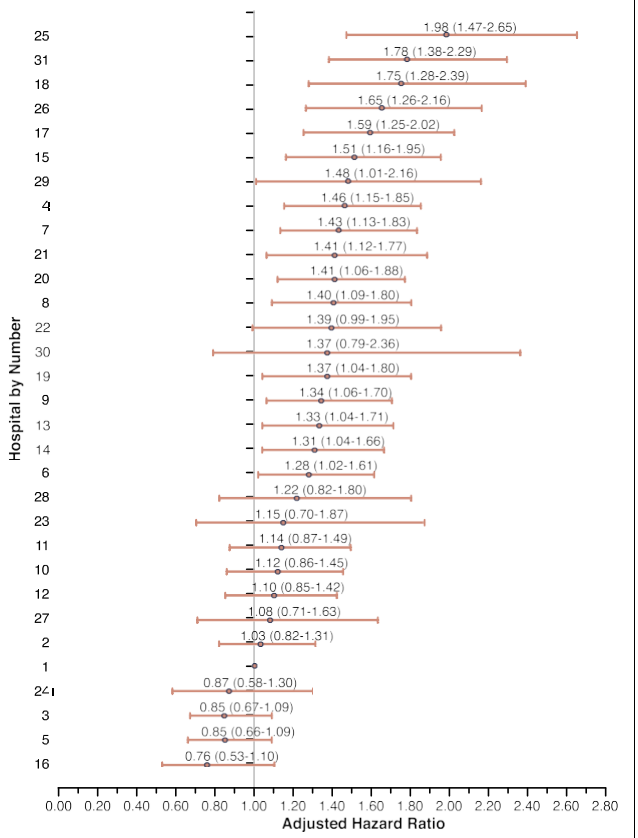

FIGURE 5 Adjusted Hazard Ratio and 95% Confidence Interval of CAD Test Use Among 4,650 Adults With Incident Heart Failure and at Least One Available Imaging Test by Hospitals (2005 to 2008)

Adjusted hazard ratio of cardiovascular testing relative to the hospital with the highest rate of echocardiography. A coronary artery disease assessment included: stress echocardiography, single-photon emission computed tomography; positron emission tomography, left heart catheterization, right and left heart catheterization, or cardiac computed tomographic angiography.

study is needed to determine the most cost-effective approach to initial assessment of incident HF, particularly where CAD is suspected.

STUDY LIMITATIONS. The CVRN Heart Failure cohort offers a source of "real world" data for a large and diverse patient cohort that was hospitalized for incident HF. However, because the majority of patients were treated within integrated healthcare delivery systems with comprehensive coverage plans for many patients, some imaging studies that were actually performed may not have been coded in the electronic databases. To minimize this potential bias, we augmented our analysis of administrative procedure coding data with a review of imaging specific reports and a manual review of patient records. Even so, some cardiovascular testing may have been performed without generating a formal report (e.g., bedside-limited echocardiogram) or documentation, and some tests may not have been available in any of the data sources used. We were unable to identify the reasons behind the testing variations seen in this study. Further, all patients in our sample had health insurance, including a pharmacy drug benefit and the availability of advanced electronic medical record systems, which may have substantially reduced duplicate testing. Therefore, these findings may not be generalizable to other patient populations and settings. However, extensive national investments in electronic medical records with "meaningful use" (41) and pilot programs in "accountable care" may mitigate these historical differences (24,42,43).

CONCLUSIONS

In a contemporary population of adults hospitalized for incident HF, we found significant hospital-level variations in cardiovascular testing that did not appear to be explained by patient case mix. The greatest variations occurred in testing modalities for CAD, in which less rigorous evidence exists for their clinical utility. More research is needed to clarify the most cost-effective test or testing combination for patients with incident HF.

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KEY WORDS cardiovascular testing, geographic variations, heart failure