Underutilization of Coronary Artery Disease Testing Among Patients Hospitalized With New-Onset Heart Failure

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Abstract

BACKGROUND—Although ischemic coronary artery disease (CAD) is the most common etiology of heart failure (HF), the extent to which patients with new-onset HF actually undergo an ischemic work-up and/or revascularization is not well defined.

OBJECTIVES—This study sought to analyze the patterns of testing for ischemic CAD and revascularization in patients with new-onset HF.

METHODS—This was a retrospective cohort study using Truven Health MarketScan Commercial and Medicare databases from 2010 to 2013. The occurrence of noninvasive and invasive ischemic CAD testing and revascularization procedures were examined among patients with new inpatient HF diagnoses during the index hospitalization and within 90 days of admission.

RESULTS—Among 67,161 patients identified with new-onset HF during an inpatient hospitalization, only 17.5% underwent testing for ischemic CAD during the index hospitalization, increasing to 27.4% at 90 days. Among patients with new-onset HF, only 2.1% underwent revascularization during the index hospitalization for HF; by 90 days, the revascularization rate had increased to 4.3%. Of the tests performed for ischemic CAD, stress testing (nuclear stress testing or stress echocardiography) was performed in 7.9% of new-onset HF patients during the index hospitalization (14.6% within 90 days), whereas coronary angiography was performed in 11.1% of patients during the index hospitalization (16.5% within 90 days). In adjusted analyses, HF patients carrying a baseline diagnosis of CAD had greater odds of noninvasive ischemic

testing (odds ratio: 1.25; 95% confidence interval: 1.17 to 1.33; p < 0.0001), as well as invasive ischemic testing (odds ratio: 1.93; 95% confidence interval: 1.83 to 2.05; p < 0.0001), at the index hospitalization than those without baseline CAD.

CONCLUSIONS—The majority of patients hospitalized for new-onset HF did not receive testing for ischemic CAD either during hospitalization or within 90 days, which suggests significant underutilization of ischemic CAD assessment in new-onset HF patients.

Keywords

angiography; invasive; ischemic CAD; noninvasive; revascularization; stress testing

Heart failure (HF) is a major cause of morbidity and mortality in an increasingly aging population, resulting in a high burden to patients and to the health care system (1,2). In fact, HF is one of the only cardiovascular diseases for which the rates of hospitalization and mortality have progressively worsened over the past 25 years (3,4). More than 915,000 new cases of HF are diagnosed in the United States each year (1,5), and at age 40, there is a 20% overall lifetime risk of developing HF (6).

Many patients with HF also have concomitant coronary artery disease (CAD) (7,8). The estimated prevalence of CAD in patients with HF ranges from 50% to 65% (9,10). The presence of CAD is common, not only in patients with HF with reduced ejection fraction (HFrEF), but also in patients with HF with preserved ejection fraction (11,12). Epidemiological data further demonstrate that the most common cause of HF is no longer hypertension or valvular heart disease, but rather ischemic CAD (6). This is relevant, not only because ischemic CAD represents a potentially treatable (or reversible) cause of HF, but also because the presence of CAD can be synergistically and independently associated with worsened long-term outcomes. The recently reported 10-year outcomes of the STICH (Surgical Treatment for Ischemic Heart Failure) trial demonstrated a mortality benefit of revascularization with coronary artery bypass graft (CABG) surgery over optimal medical therapy for patients with ischemic cardiomyopathy (13). Thus, identification of an underlying ischemic etiology of HF is integral to clinical management strategies for HF. The 2013 American College of Cardiology (ACC)/American Heart Association (AHA) guidelines for the management of HF currently designate a Class IIa indication to both noninvasive and invasive assessment of ischemic CAD in HF patients (14). However, there are limited data available on how many patients with new-onset HF actually undergo an ischemic work-up and/or revascularization following an HF diagnosis, particularly in a contemporary real-world setting.

Therefore, we sought to perform an analysis of a large commercial administrative claims database in order to assess the patterns of ischemic testing and revascularization for patients hospitalized with new-onset HF.

METHODS

Adult inpatients admitted with a principal diagnosis of HF between 2011 and 2013 were identified in the Truven Health MarketScan Commercial and Medicare Supplemental

databases (Truven Health Analytics, Ann Arbor, Michigan), which include health plan enrollment data and detailed patient-level administrative claims for inpatient, outpatient, and pharmacy services. The MarketScan research databases consist of fully adjudicated and paid claims, including both the patient and health plan payments, for approximately 35 million commercially insured patients annually. All data are linked by unique encrypted identifiers and are compliant with the Health Insurance Portability and Accountability Act privacy standards. Institutional review board approval was not required for this retrospective analysis of de-identified data.

Heart failure was identified as the presence of one International Classification of Diseases-Ninth Revision-Clinical Modification (ICD-9-CM) code 428.xx as a principal (i.e., admitting) diagnosis on an inpatient hospitalization. Patients with a principal diagnosis of HF on an inpatient admission in the preceding 12 months were excluded. Baseline clinical characteristics were assessed in the 6 months before and including the date of the index HF hospitalization, with details for CAD, hypertension, hyperlipidemia, diabetes, smoking (assessed using claims for smoking cessation or counseling), prior stroke, arrhythmia, renal disease, chronic obstructive pulmonary disease (COPD), malignancy, and dementia. Performance of an echocardiogram, stress echocardiogram, nuclear stress test (single-photon emission computed tomography or thallium), right heart catheterization, and diagnostic coronary angiography at the index HF hospitalization and during the first 90 days post-index were evaluated, as was revascularization with percutaneous coronary intervention (PCI) or CABG surgery. A noninvasive assessment for ischemic CAD was defined as either stress echocardiography or nuclear stress testing; invasive assessment for ischemic CAD was defined as diagnostic coronary angiography.

Procedures were identified by the presence of either a relevant Medicare Severity Diagnosis Related Group or an ICD-9-CM code, Current Procedure Terminology, or Health Care Common Procedure Coding System procedure code. Billing codes for these relevant procedures were reviewed by 2 independent reviewers (D.D., A.J.K.) before data queries.

STATISTICAL ANALYSES.

Standard statistical tests were used for descriptive comparisons, including the Fisher exact test for dichotomous outcomes and Student *t* test for continuous outcomes. Logistic regression was used to identify demographic and clinical predictors of receiving noninvasive testing in patients with new-onset HF. All analyses were conducted using Stata version 12 (StataCorp LP, College Station, Texas).

RESULTS

Of the 81,526,366 patient cases available in the MarketScan Commercial and Medicare Supplemental databases from 2010 to 2014, 98,264 patients with a diagnosis of new-onset HF as the primary diagnosis on an inpatient claim were identified (Figure 1). Among these patients, 79,057 patients had contin-ous insurance coverage at least 12 months before the index date (ensuring that they did not have an HF diagnosis that was missed), and 67,161 patients had at least 90-day post-index continuous follow-up. A total of 42,479 of these

patients had a baseline diagnosis of CAD as specified with a CAD ICD-9-CM code in their chart preceding or on the same day as their hospitalization; 36,578 patients did not.

The mean age of the study population was 73.7 years with a slight male predominance (52.4%) (Table 1). With regard to cardiovascular comorbidities, 83.3% of all patients had hypertension, whereas around one-half had hyperlipidemia, diabetes mellitus, or baseline CAD. The most common noncardiac comorbidity was renal disease of any kind, which affected 49.5% of patients. Approximately one-third of patients had either HFrEF, HF with preserved ejection fraction, or mixed or unspecified HF.

TESTING FOR ISCHEMIC CAD.

Overall, a minority of patients received any testing for ischemic CAD either during the index hospitalization or within the subsequent 90 days (Table 2). Patients with no history of CAD at baseline were less likely to undergo testing for ischemic CAD (rate of testing during index hospitalization: 16.5% in those without CAD vs. 18.3% with known CAD; $p < 0.001$; rate of testing within 90 days: 26.9% in those without CAD vs. 27.8% with known CAD; $p = 0.009$).

During the index HF hospitalization, fewer than 1 in 10 patients (7.9%) received noninvasive ischemic testing for CAD, which was defined as exercise or pharmacological testing with or without an imaging modality such as myocardial perfusion imaging or echocardiography. This rate increased to 14.6% at 90 days following the index admission (Table 2). Notably, there were no differences in the unadjusted rates of noninvasive testing if a patient had a previously known diagnosis of CAD or not. By contrast, patients with baseline CAD were more likely to undergo an invasive CAD assessment (defined as coronary angiography) compared with those without baseline CAD during the index hospitalization (9.7% in those without CAD vs. 12.3% with known CAD; $p < 0.001$) and within 90 days (15.4% vs. 17.5%; $p < 0.001$).

When examining various noninvasive testing modalities utilized for the work-up of new-onset HF, a standard 2-dimensional echocardiogram was the most commonly performed test, occurring in 63.6% of patients during the index hospitalization and 72.9% of patients within 90 days (Central Illustration). Performance of a nuclear stress test came in a distant second at both time periods, whereas stress echocardiography utilization barely registered, reaching a high of only 0.8% of patients within 90 days. In regard to invasive testing modalities, coronary angiography alone was utilized more frequently than right heart catheterization alone or the combination of both coronary angiography and right heart catheterization Central Illustration).

MULTIVARIABLE ANALYSES.

In multivariable analysis, baseline CAD (odds ratio [OR]: 1.25; 95% confidence interval [CI]: 1.17 to 1.33; $p < 0.001$) was associated with greater odds of noninvasive testing in patients with new-onset HF. Hypertension, hyperlipidemia, HFrEF, and mixed or unspecified HF were also associated with greater odds of noninvasive testing, whereas elderly age (>70 years), prior stroke, peripheral arterial disease (PAD), prior arrhythmias, renal disease, COPD, dementia, and prior noninvasive and invasive work-up for ischemia were associated

with lesser odds of undergoing noninvasive testing (Table 3). With regard to invasive testing, multivariable analysis demonstrated that baseline CAD (OR: 1.93; 95% CI: 1.83 to 2.05; $p < 0.0001$) was associated with greater odds of invasive ischemic CAD testing. Smoking and HFrEF were also associated with greater odds of invasive ischemic CAD, whereas elderly age, earlier year of enrollment, hypertension, diabetes, prior stroke, PAD, nonmajor arrhythmia, renal disease, COPD, malignancy, dementia, and prior invasive work-up for ischemia were associated with lesser odds (Table 4).

A total of 2.1% of all patients underwent coronary revascularization during the index HF hospitalization, whereas 4.3% experienced revascularization within 90 days (Table 2). Patients more frequently underwent revascularization if they had a prior known diagnosis of CAD than if they did not. PCI was more commonly used as a revascularization modality than CABG. In multivariable analysis, baseline CAD (OR: 9.27; 95% CI: 7.74 to 11.10; $p < 0.0001$), male sex, diabetes, smoking, and PAD were associated with greater odds for revascularization in patients with new-onset HF, whereas elderly age, COPD, malignancy, and dementia were associated with lesser odds of revascularization (Table 5).

SENSITIVITY ANALYSES.

In order to mitigate the effects of any ischemic evaluation performed before the diagnosis of new onset HF, we repeated the aforementioned analyses but excluded any patient who had any previously coded ischemic evaluation. The total population for these sensitivity analyses consisted of 50,737 patients, of whom 27,711 (54.6%) did not carry a diagnosis of CAD.

Patients without any prior ischemic evaluation who developed new onset HF had comparable rates of noninvasive or invasive testing during the index hospitalization (18.7%) and at 90 days (28.6%) when compared with the entire study population (Online Table 1). Patients with known CAD were once again more likely to undergo both noninvasive and invasive ischemic testing than those without known CAD. Among patients without any form of prior ischemic evaluation with new-onset HF, only 1.9% underwent revascularization during the index hospitalization for HF and only 4.1% within 90 days.

Of the tests performed for ischemic CAD in patients without any prior ischemic evaluation, nuclear stress testing was performed in 8.8% of patients during their index hospitalization (15.5% within 90 days) and stress echocardiogram in 0.4% during their index hospitalization (0.8% within 90 days), whereas coronary angiography was performed in 11.5% during their index hospitalization and 16.8% within 90 days (Online Table 2). Once again, in multivariable analyses, HF patients carrying a baseline diagnosis of CAD had greater odds of noninvasive ischemic testing (OR: 1.24; 95% CI: 1.16 to 1.32; $p < 0.001$), as well as invasive ischemic testing (OR: 2.06; 95% CI: 1.93 to 2.19; $p < 0.0001$) than those without baseline CAD (Online Table 3).

DISCUSSION

The current study represented the largest and most contemporary analysis of the patterns of ischemic testing and revascularization in patients with new-onset HF. The principal finding of this analysis was that almost three-quarters of patients with new-onset HF did not receive

any ischemic CAD testing within 90 days of index admission. This finding was particularly striking both given how prevalent CAD is among patients with HF, as well as in light of the adverse outcomes associated with concomitant CAD and HF. Notably, the rates of revascularization procedures following an index HF admission were even lower (occurring in <5% of patients within 90 days of an index HF admission), which in part may reflect the low rates of upstream ischemic testing. Both of these findings, based upon analyses from an administrative claims database, suggested a significant diagnostic testing and treatment gap for a high-risk patient population with one of the highest prevalence rates of CAD.

The present findings were in agreement with a comparable, albeit smaller, observational study reporting patterns of diagnostic testing among patients with new-onset HF (15). In the aforementioned study, Farmer et al. (15) examined cardiovascular imaging utilization patterns in 37,099 patients in the Cardiovascular Research Network Heart Failure study who presented with de novo HF and showed that only 36.9% of patients had a CAD assessment. These findings, as well as those in the current analysis, are sobering, given the Class IIa indication afforded to ischemic testing in both the 2013 ACC/AHA guidelines for the management of HF (14) as well as other consensus documents (16,17). In these guidelines, stress nuclear imaging or stress echocardiography are acceptable options for assessing ischemic CAD in patients presenting with HF who have known CAD and no angina unless they are ineligible for revascularization. Despite these recommendations, most patients with new-onset HF—even those with a known diagnosis of CAD—did not receive a work-up for ischemic CAD. Even assuming incomplete reporting of testing within the current database, when combining the present findings with the prevalence of CAD in patients with HF and the reported annual incidence of 915,000 patients with new-onset HF (18), it can be estimated that every year more than 325,000 patients with new-onset HF and CAD might not be adequately assessed for ischemic CAD.

The potential underuse of ischemic CAD testing in patients with new-onset HF has several potential implications beyond the empiric desire to establish a definitive etiology for HF. The omission of ischemic CAD testing may prevent patients from being treated with aggressive guideline-directed medical therapies for CAD, which can both alleviate symptoms and reduce hard cardiovascular events (19). In the OPTIMIZE-HF (Organized Program to Initiate Lifesaving Treatment in Hospitalized Patients With Heart Failure) registry, performance of coronary angiography during the index hospitalization for acute HF was associated with an increased utilization of aspirin, statins, and myocardial revascularization as well as a reduced risk of death 60 to 90 days after discharge (20). Additionally, upfront ischemic testing can lead to lower resource utilization in terms of emergency department visits and rehospitalization for complications of CAD and HF (20,21). Lastly, a significant proportion of patients with HF and left ventricular dysfunction have the potential for clinically important improvements in left ventricular function after the appropriate use of coronary revascularization (22-24). A number of observational studies have demonstrated both improved survival and left ventricular function with revascularization compared with medical therapy alone (25-27). The recently reported 10-year outcomes of the STICH trial demonstrated an all-cause mortality benefit to surgical revascularization compared with optimal medical therapy among patients with depressed ventricular function (13,28,29). Further, quality of life was improved through surgical

revascularization (30). The undertesting identified in the present analysis was not just limited to ischemic CAD testing: more than one-quarter of patients with newly diagnosed HF did not even undergo a 2-dimensional transthoracic echocardiogram, despite the fact that the ACC/AHA guidelines establish echocardiography as a Class I recommendation in the work-up for new-onset HF (14). This speaks to a larger issue at hand, namely that patients being hospitalized for new-onset HF may not be receiving an appropriate HF work-up in general. In an increasingly cost-conscious era where there is concern for excessive testing in lower-risk patients, there certainly appears to be concomitant underutilization of appropriate testing in higher-risk patients as well, consistent with a treatment-risk paradox.

STUDY LIMITATIONS.

The analysis relied exclusively upon claims data to track diagnoses, testing, and procedures. As such, errors in coding or non-submission of claims may have resulted in the omission of diagnostic tests and procedures. Nevertheless, given how closely physician and hospital reimbursements within the United States are tied to testing and procedural coding, the effect of undercoding/miscoding was likely somewhat mitigated within this analysis. Additionally, administrative codes have been shown to be fairly accurate for cardiovascular diagnoses, perhaps due to their relationship with levels of reimbursement (31,32). Another potential limitation related to an inability to separate routine exercise treadmill testing (without adjunctive imaging) from other forms of stress testing due to overlapping Current Procedure Terminology codes. Claims data are limited in that they lack granular information surrounding each patient's HF admission, such as the severity of HF symptoms, ventricular function, other comorbidities, and medication usage, which could have helped to further explain differences in ischemic CAD testing and revascularization. Furthermore, outcomes data were incompletely captured by these databases, particularly if adverse outcomes occurred outside of a hospital setting. This information would have been useful to determine whether patients who did or did not undergo ischemic CAD testing and/or revascularization had disparate outcomes. Lastly, the rates of more specialized imaging modalities, such as cardiac computed tomography, magnetic resonance imaging, and positron emission tomography were not assessed; however, the fact that these imaging modalities are not as commonly available as the imaging modalities assessed in our study suggests that including these modalities would not have appreciably altered our results.

CONCLUSIONS

Within the context of a large administrative claims database, the great majority of patients hospitalized for new-onset HF did not receive any testing for ischemic CAD, either during the index hospitalization or within the subsequent 90 days. These data suggested significant underutilization of guideline-recommended assessments for ischemic CAD in new-onset HF patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

ABBREVIATIONS AND ACRONYMS

ACC	American College of Cardiology
AHA	American Heart Association
CABG	coronary artery bypass graft
CAD	coronary artery disease
CI	confidence interval
COPD	chronic obstructive pulmonary disease
HF	heart failure
HFrEF	heart failure with reduced ejection fraction
ICD-9-CM	International Classification of Diseases-Ninth Revision-Clinical Modification
OR	odds ratio
PAD	peripheral arterial disease
PCI	percutaneous coronary intervention

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PERSPECTIVES

COMPETENCY IN PRACTICE-BASED LEARNING AND IMPROVEMENT:

Despite the potential reversibility of heart failure in patients with ischemic heart disease, most are not evaluated for coronary disease during the 90 days after hospitalization for new-onset HF.

TRANSLATIONAL OUTLOOK:

Additional research is needed to explore the factors responsible for the limited implementation of guideline-recommended diagnostic evaluation of patients with new-onset heart failure and to develop measures that enhance the detection of potentially reversible causes.
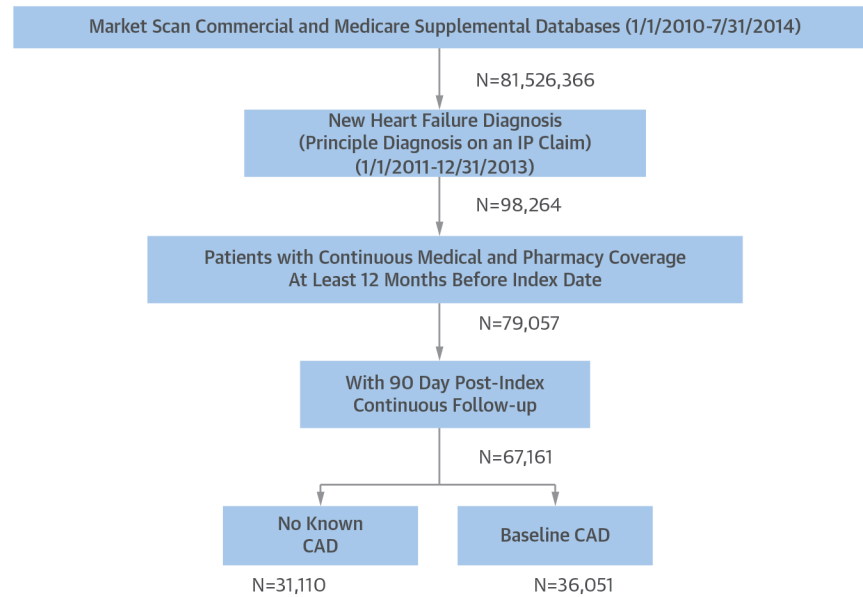
FIGURE 1. Patient Flow

From databases containing >81 million patient records, a total of 67,161 heart failure patients were included in this analysis. CAD = coronary artery disease; IP = inpatient.

A. Use of Noninvasive Imaging Among Patients Hospitalized for New-onset Heart Failure

During Index Hospitalization:
- Echocardiogram: 63.6
- Stress Echocardiogram: 0.3
- Nuclear Stress Test: 7.8

Within 90 Days:
- Echocardiogram: 72.9
- Stress Echocardiogram: 0.8
- Nuclear Stress Test: 14.3

Legend: Echocardiogram, Stress Echocardiogram, Nuclear Stress Test
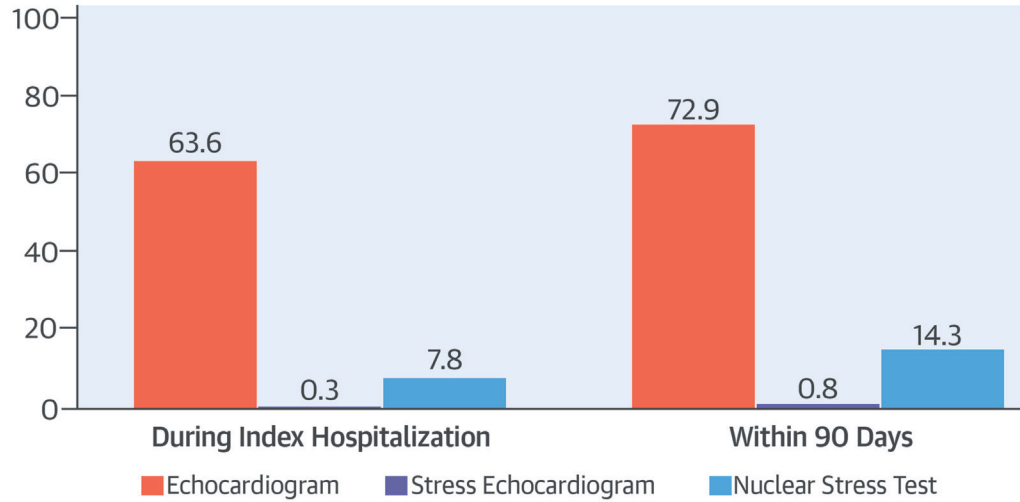
B. Use of Invasive Testing Among Patients Hospitalized for New-onset Heart Failure

During Index Hospitalization:
- Right Heart Catheterization: 7.1
- Diagnostic Coronary Angiography: 11.1
- Both: 5.4

Within 90 Days:
- Right Heart Catheterization: 10.8
- Diagnostic Coronary Angiography: 16.5
- Both: 8.4

Legend: Right Heart Catheterization, Diagnostic Coronary Angiography, Both
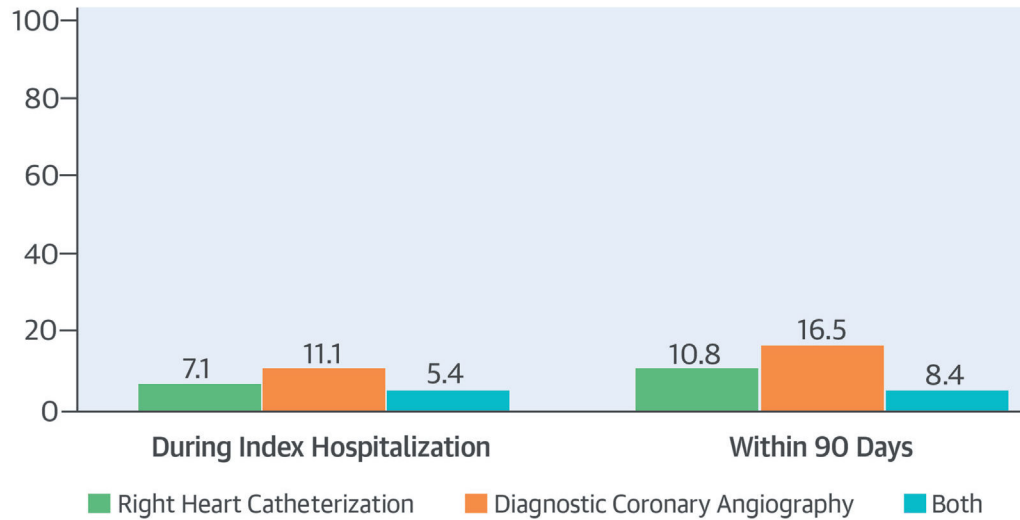
CENTRAL ILLUSTRATION. Ischemic Work-Up in HF

In this retrospective cohort study, ischemic coronary artery disease (CAD) testing and revascularization procedures were examined among 67,161 patients with new inpatient heart failure (HF) diagnoses during the index hospitalization and within 90 days of admission. Overall, only a minority of patients received any testing for ischemic CAD and those without a history of CAD at baseline received even less. Of the noninvasive **(A)** and invasive **(B)** imaging modalities used during index hospitalization and through 90-day follow-up, a standard 2-dimensional echocardiogram was the most commonly performed test.

TABLE 1

Patient Characteristics (N = 67,161)

Age, yrs	73.68 ± 13.7
Sex	
Female	31,959 (47.6)
Male	35,202 (52.4)
Index year	
2011	24,412 (36.4)
2012	23,485 (35.0)
2013	19,264 (28.7)
Heart failure type	
With preserved ejection fraction	21,163 (31.5)
With reduced ejection fraction	23,134 (34.5)
Mixed/unspecified	22,864 (34.0)
Cardiovascular characteristics	
CAD	36,051 (53.7)
Hypertension	55,912 (83.3)
Hyperlipidemia	31,412 (46.8)
Diabetes	31,268 (46.6)
Smoking	7,332 (10.9)
Prior stroke	6,952 (10.4)
PAD	15,201 (22.6)
Major arrhythmia	8,360 (12.5)
Nonmajor arrhythmia	40,082 (59.7)
Prior noninvasive ischemic work-up	11,842 (17.6)
Prior invasive ischemic work-up	7,885 (11.7)
Comorbid conditions	
Renal disease	33,211 (49.5)
Chronic obstructive pulmonary disease	28,464 (42.4)
Malignancy	12,487 (18.6)
Dementia	3,737 (5.6)

Values are mean ± SD or n (%).

CAD = coronary artery disease; PAD = peripheral arterial disease.

TABLE 2

Ischemic CAD Testing and Revascularization

	No CAD (n = 31,110)	CAD (n = 35,051)	All Patients (N = 67,161)	p Value
Noninvasive assessment for ischemia				
During index hospitalization	2,472 (8.0)	2,851 (7.9)	5,323 (7.9)	0.86
Within 90 days post-index	4,576 (14.7)	5,203 (14.4)	9,779 (14.6)	0.31
Invasive assessment for ischemia				
During index hospitalization	3,002 (9.7)	4,424 (12.3)	7,426 (11.1)	<0.0001
Within 90 days post-index	4,775 (15.4)	6,293 (17.5)	11,068 (16.5)	<0.0001
Invasive or noninvasive assessment for ischemia				
During index hospitalization	5,146 (16.5)	6,601 (18.3)	11,747 (17.5)	<0.0001
Within 90 days post-index	8,364 (26.9)	10,018 (27.8)	18,382 (27.4)	0.009
Neither invasive nor noninvasive assessment for ischemia				
During index hospitalization	25,964 (83.5)	29,450 (81.7)	55,414 (82.5)	<0.0001
Within 90 days post-index	22,746 (73.1)	26,033 (72.2)	48,779 (72.6)	0.009
Noninvasive assessment for ischemia during baseline	2,809 (9.0)	9,033 (25.1)	11,842 (17.6)	<0.0001
Invasive assessment for ischemia during baseline	854 (2.8)	7,031 (19.5)	7,885 (11.7)	<0.0001
Invasive or noninvasive assessment for ischemia during baseline	3,399 (10.9)	13,025 (36.1)	16,424 (24.5)	<0.0001
With revascularization during index hospitalization	146 (0.5)	1,230 (3.4)	1,376 (2.1)	<0.0001
PCI only	116 (0.4)	901 (2.5)	1,017 (1.5)	
CABG only	30 (0.1)	317 (0.9)	347 (0.5)	
Hybrid revascularization	0 (0.0)	12 (0.0)	12 (0.0)	
With revascularization within 90 days post-index	635 (2.0)	2,260 (6.3)	2,895 (4.3)	<0.0001
PCI only	406 (1.3)	1,578 (4.4)	1,984 (3.0)	
CABG only	225 (0.7)	646 (1.8)	871 (1.3)	
Hybrid revascularization	4 (0.0)	36 (0.1)	40 (0.1)	

Values are n (%).

CABG = coronary artery bypass grafting; CAD = coronary artery disease; PCI = percutaneous coronary intervention.

TABLE 3

Multivariable Analysis for Noninvasive Testing

| | Noninvasive Testing | | | |
	No (n = 61,838)	Yes (n = 5,323)	Adjusted OR (95% CI)	p Value
Age group				
18–70 yrs	22,700 (36.71)	2,538 (47.68)	Reference group	
71–85 yrs	25,098 (40.59)	2,224 (41.78)	0.85 (0.793–0.901)	<0.0001
>85 yrs	14,040 (22.70)	561 (10.54)	0.36 (0.327–0.399)	<0.0001
Sex				
Female	29,580 (47.83)	2,379 (44.69)	Reference group	
Male	32,258 (52.17)	2,944 (55.31)	1.05 (0.986–1.111)	0.13
Index year				
2011	22,501 (36.39)	1,911 (35.90)	Reference group	
2012	21,578 (34.89)	1,907 (35.83)	1.04 (0.973–1.112)	0.25
2013	17,759 (28.72)	1,505 (28.27)	0.99 (0.925–1.068)	0.87
Heart failure type				
Preserved ejection fraction	19,514 (31.56)	1,649 (30.98)	Reference group	
Reduced ejection fraction	21,118 (34.15)	2,016 (37.87)	1.38 (1.282–1.491)	<0.0001
Mixed/unspecified	21,206 (34.29)	1,658 (31.15)	1.31 (1.208–1.422)	<0.0001
Cardiovascular characteristics				
CAD	33,200 (53.69)	2,851 (53.56)	1.25 (1.172–1.329)	<0.0001
Hypertension	51,484 (83.26)	4,428 (83.19)	1.11 (1.024–1.202)	0.01
Hyperlipidemia	28,866 (46.68)	2,546 (47.83)	1.09 (1.026–1.160)	0.005
Diabetes	28,608 (46.26)	2,660 (49.97)	1.06 (0.994–1.120)	0.08
Smoking	6,690 (10.82)	642 (12.06)	1.05 (0.956–1.146)	0.3200
Prior stroke	6,532 (10.56)	420 (7.89)	0.82 (0.741–0.914)	<0.0001
PAD	14,159 (22.90)	1,042 (19.58)	0.95 (0.879–1.019)	0.15
Major arrhythmia	7,769 (12.56)	591 (11.10)	0.86 (0.781–0.939)	0.001
Nonmajor arrhythmia	37,377 (60.44)	2,705 (50.82)	0.79 (0.742–0.835)	<0.0001
Prior noninvasive ischemic work-up	11,248 (18.19)	594 (11.16)	0.56 (0.509–0.610)	<0.0001
Prior invasive ischemic work-up	7,529 (12.18)	356 (6.69)	0.49 (0.437–0.550)	<0.0001
Comorbid conditions				
Renal disease	30,754 (49.73)	2,457 (46.16)	0.88 (0.826–0.930)	<0.0001
CABG	26,509 (42.87)	1,955 (36.73)	0.77 (0.728–0.821)	<0.0001
Malignancy	11,593 (18.75)	894 (16.80)	0.96 (0.891–1.038)	0.31
Dementia	3,586 (5.80)	151 (2.84)	0.62 (0.521–0.731)	<0.0001

Values are n (%) unless otherwise indicated.

CI = confidence interval; OR = odds ratio; other abbreviations as in Tables 1 and 2.

TABLE 4

Multivariable Analysis for Invasive Testing

	Invasive Testing			
	No (n = 59,735)	Yes (n = 7,426)	Adjusted OR (95% CI)	p Value
Age group				
18–70 yrs	20,555 (34.41)	4,683 (63.06)	Reference group	
71–85 yrs	24,908 (41.70)	2,414 (32.51)	0.45 (0.428–0.480)	<0.0001
>85 yrs	14,272 (23.89)	329 (4.43)	0.11 (0.094–0.119)	<0.0001
Sex				
Female	29,011 (48.57)	2,948 (39.70)	Reference group	
Male	30,724 (51.43)	4,478 (60.30)	1.04 (0.987–1.098)	0.14
Index year				
2011	21,809 (36.51)	2,603 (35.05)	Reference group	
2012	20,913 (35.01)	2,572 (34.64)	1.04 (0.983–1.109)	0.16
2013	17,013 (28.48)	2,251 (30.31)	1.18 (1.105–1.255)	<0.0001
Heart failure type				
Preserved ejection fraction	19,912 (33.33)	1,251 (16.85)	Reference group	
Reduced ejection fraction	19,354 (32.40)	3,780 (50.90)	1.82 (1.705–1.940)	<0.0001
Mixed/unspecified	20,469 (34.27)	2,395 (32.25)	0.75 (0.693–0.815)	<0.0001
Cardiovascular characteristics				
CAD	31,627 (52.95)	4,424 (59.57)	1.93 (1.826–2.049)	<0.0001
Hypertension	50,052 (83.79)	5,860 (78.91)	0.93 (0.874–1.000)	0.049
Hyperlipidemia	28,031 (46.93)	3,381 (45.53)	0.98 (0.930–1.038)	0.53
Diabetes	27,966 (46.82)	3,302 (44.47)	0.80 (0.759–0.845)	<0.0001
Smoking	6,218 (10.41)	1,114 (15.00)	1.15 (1.066–1.239)	<0.0001
Prior stroke	6,461 (10.82)	491 (6.61)	0.76 (0.684–0.835)	<0.0001
PAD	13,934 (23.33)	1,267 (17.06)	0.90 (0.840–0.964)	0.003
Major arrhythmia	7,205 (12.06)	1,155 (15.55)	1.04 (0.963–1.115)	0.34
Nonmajor arrhythmia	36,474 (61.06)	3,608 (48.59)	0.76 (0.719–0.799)	<0.0001
Prior noninvasive ischemic work-up	10,517 (17.61)	1,325 (17.84)	1.02 (0.953–1.093)	0.57
Prior invasive ischemic work-up	7,412 (12.41)	473 (6.37)	0.29 (0.263–0.322)	<0.0001
Comorbid conditions				
Renal disease	30,460 (50.99)	2,751 (37.05)	0.61 (0.576–0.642)	<0.0001
CABG	25,752 (43.11)	2,712 (36.52)	0.79 (0.749–0.834)	<0.0001
Malignancy	11,405 (19.09)	1,082 (14.57)	0.89 (0.828–0.955)	0.0001
Dementia	3,638 (6.09)	99 (1.33)	0.41 (0.335–0.506)	<0.0001

Values are n (%) unless otherwise indicated.

Abbreviations as in Tables 1, 2, and 3.

TABLE 5

Multivariable Analysis for Revascularization

| | Revascularization | | | |
	No (n = 65,785)	Yes (n = 1,376)	Adjusted OR (95% CI)	p Value
Age group				
18–70 yrs	24,500 (37.24)	738 (53.6)	Reference group	
71–85 yrs	26,761 (40.68)	561 (40.8)	0.67 (0.597–0.757)	<0.0001
>85 yrs	14,524 (22.08)	77 (5.6)	0.20 (0.155–0.253)	<0.0001
Sex				
Female	31,484 (47.86)	475 (34.5)	Reference group	
Male	34,301 (52.14)	901 (65.5)	1.16 (1.030–1.302)	0.01
Index year				
2011	23,913 (36.35)	499 (36.3)	Reference group	
2012	23,024 (35.00)	461 (33.5)	0.97 (0.855–1.109)	0.69
2013	18,848 (28.65)	416 (30.2)	1.12 (0.983–1.287)	0.08
Heart failure type				
Preserved ejection fraction	20,921 (31.80)	242 (17.6)	Reference group	
Reduced ejection fraction	22,480 (34.17)	654 (47.5)	1.40 (1.223–1.607)	<0.0001
Mixed/unspecified	22,384 (34.03)	480 (34.9)	0.72 (0.607–0.86 0)	<0.0001
Cardiovascular characteristics				
CAD	34,821 (52.93)	1,230 (89.4)	9.27 (7.743–11.098)	<0.0001
Hypertension	54,782 (83.27)	1,130 (82.1)	0.85 (0.728–0.986)	0.03
Hyperlipidemia	30,707 (46.68)	705 (51.2)	0.88 (0.779–0.983)	0.02
Diabetes	30,475 (46.33)	793 (57.6)	1.14 (1.012–1.275)	0.03
Smoking	7,120 (10.82)	212 (15.4)	1.19 (1.017–1.393)	0.03
Prior stroke	6,831 (10.38)	121 (8.8)	0.86 (0.708–1.041)	0.12
PAD	14,830 (22.54)	371 (27.0)	1.17 (1.032–1.330)	0.01
Major arrhythmia	8,179 (12.43)	181 (13.2)	0.73 (0.617–0.856)	<0.0001
Nonmajor arrhythmia	39,394 (59.88)	688 (50.0)	0.71 (0.636–0.797)	<0.0001
Prior noninvasive ischemic work-up	11,543 (17.55)	299 (21.7)	0.94 (0.818–1.070)	0.33
Prior invasive ischemic work-up	7,722 (11.74)	163 (11.9)	0.51 (0.430–0.606)	<0.0001
Comorbid conditions				
Renal disease	32,528 (49.45)	683 (49.6)	0.90 (0.805–1.010)	0.07
CABG	27,944 (42.48)	520 (37.8)	0.74 (0.662–0.833)	<0.0001
Malignancy	12,306 (18.71)	181 (13.2)	0.71 (0.602–0.831)	<0.0001
Dementia	3,715 (5.65)	22 (1.6)	0.41 (0.270–0.636)	<0.0001

Values are n (%) unless otherwise indicated.

Abbreviations as in Tables 1 to 3.