Clinical Outcomes After Cardiac Stress Testing Among US Patients Younger Than 65 Years

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Background—Scientific statements have championed the measurement of clinical outcomes after cardiac stress testing to better define their value. Using contemporary national data, we sought to describe the characteristics of patients who experience outcomes after stress testing.

Methods and Results—Using administrative claims from a large national private insurer, we conducted an observational cohort study of patients without cardiovascular disease aged 25 to 64 years who underwent stress testing from 2006 to 2011 and had at least 1 year of membership in the insurance company before and after testing. We used Kaplan–Meier time-to-event analyses to determine rates of acute myocardial infarction (AMI), elective coronary revascularization, and coronary angiography without revascularization in the year following testing. We used logistic regression to determine factors associated with outcomes, and stratified the cohort into quintiles based on likelihood of experiencing AMI and/or revascularization to describe the characteristics of patients at highest and lowest risk. Among 553 027 patients who underwent stress testing (mean age 50 years, 49% women, 73% white), 0.8% were hospitalized for AMI, 1.8% underwent elective coronary revascularization, and 2.5% underwent coronary angiography without revascularization within 1 year. Patients who were older, male, and white were more likely to undergo subsequent revascularization. Patients in the lowest likelihood quintile were young (mean age 40 years), frequently women (84.7%), had a low incidence of coexisting conditions (5.2% with diabetes mellitus), and had a 0.5% rate of AMI and/or revascularization.

Conclusions—The proportion of US patients younger than 65 who had AMI and/or coronary revascularization after stress testing was low. Assessing risk of subsequent outcomes may be useful in improving patient referrals for stress testing. (***J Am Heart Assoc***. 2018;7:e007854. DOI: 10.1161/JAHA.117.007854.)

Key Words: outcomes research • quality of care • stress testing

C ardiac stress tests play an important role in the diagnosis and management of cardiovascular disease. However, wide variation in testing rates between regions and healthcare systems raises questions about the effectiveness of testing as used in practice.[1–4] Noninvasive cardiac tests are also a significant contributor to healthcare costs, accounting for >40% of Medicare Part B spending on medical imaging, or over $17 billion annually.[5] Professional societies and policymakers have made several efforts to improve stress test utilization, including the development of appropriate use criteria and campaigns to reduce the use of "low-value" tests.[6,7] Despite these efforts, between 32% and 48% of stress tests performed in the United States are rated as "rarely appropriate" according to a recent meta-analysis.[8]

Recent scientific statements have championed the measurement of clinical outcomes after stress testing to better define their value.[9] Since healthcare value is generally defined as the outcome of a test or treatment divided by its cost, measuring relevant clinical outcomes after stress testing may provide new insights on the current value of stress testing. However, little is known about the incidence or predictors of clinical outcomes after stress testing in contemporary, nationally representative cohorts.

Accordingly, our objectives were to (1) determine the incidence of relevant clinical outcomes within 1 year after stress testing in a large cohort of commercially insured US individuals, and (2) identify and describe the characteristics of patients most and least likely to experience these outcomes. Relevant clinical outcomes were chosen consistent with

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recent scientific statements and clinical trials,[9,10] and included (1) hospitalization for acute myocardial infarction (AMI) with or without coronary revascularization, (2) elective coronary revascularization, and (3) coronary angiography without revascularization.

Methods

Study Data

This was an observational cohort study. Data were obtained from the Clinformatics™ Data Mart Database (OptumInsight, Eden Prairie, MN), which is a database of administrative health claims for members of a large national managed care company. Administrative claims submitted for payment by providers are verified, adjudicated, and de-identified before inclusion in Clinformatics™ Data Mart. The data are available for purchase by other researchers, but will not be made available by us for purposes of reproducing the results because our Data Use Agreement prohibits sharing these data with people outside of the research team who are not specifically authorized. The database consists of comprehensive medical claims for ≈15 million annual covered individuals. The population resides in all 50 US states. In addition to comprehensive medical claims, the database includes member eligibility, demographic data, and socioeconomic data including age, sex, self-reported race/ethnicity, and geographic region.

Study Population

We identified individuals without prevalent cardiovascular disease who underwent first-time stress testing from 2006 to 2011. We excluded the following individuals: (1) those under the age of 25 years because of the low expected likelihood of stress testing in this age group; (2) those over the age of 64 because of concurrent Medicare coverage, which would result in incomplete outcomes ascertainment; (3) those with

<365 days of coverage before the index test, so that relevant conditions present at the time of testing could be identified; (4) those with <365 days of coverage after testing in order to ensure complete ascertainment of subsequent clinical events; (5) patients with known cardiovascular disease at the time of testing, or who may have had stress testing performed for indications other than evaluation for obstructive coronary artery disease, as determined by the filing of a claim in the year before testing with a diagnosis code for coronary artery disease, heart failure, myocardial infarction, stroke, cardiomyopathy, or arrhythmia.

Identification of Stress Tests, Patient Characteristics, and Outcomes

Cardiac stress tests were identified using *Current Procedural Technology* (CPT) codes. Exercise electrocardiography stress tests were identified by CPT codes 93015 to 93018. Nuclear single photon emission computed tomography myocardial perfusion imaging tests were identified by CPT codes 78460, 78461, 78464, and 78465 until January 2010, and 78451 to 78454 thereafter. Stress echocardiography was identified by CPT codes 93350 to 93352. Exercise electrocardiography tests performed within 48 hours of a nuclear single photon emission computed tomography or stress echocardiogram test were considered to be a single imaging stress event. If a patient received >1 stress test, we used the index test for the purposes of this analysis. Cardiac computed tomography angiography, nuclear positron emission tomography myocardial perfusion imaging, and stress cardiac magnetic resonance imaging were not included because of low utilization rates (2% of total stress tests) during the study period.

Relevant patient comorbidities were identified using *International Classification of Diseases, Ninth Revision* (*ICD-9*) diagnosis codes from claims filed within 1 year before the date of the stress test, and using algorithms from the Centers for Medicare and Medicaid Services' Chronic Conditions Warehouse.[11] Relevant clinical outcomes were identified using the following codes: (1) CPT codes 93454 to 93461, or *ICD-9* procedure codes 37.22 to 37.23 for coronary angiography; (2) CPT codes 92980 to 92982, 92984, or *ICD-9* procedure codes 36.01 to 36.09 for percutaneous coronary intervention; (3) *ICD-9* procedure codes 36.10 to 36.19 for coronary artery bypass surgery; and (4) primary *ICD-9* discharge diagnosis codes 410.0 to 410.9 for hospitalization for AMI.

Incidence of Clinical Outcomes and Risk Stratification

We calculated the rate of clinical outcomes that occurred within 1 year after stress testing. Separate event rates were

calculated for (1) hospitalization for AMI (with or without coronary revascularization), (2) elective coronary revascularization (percutaneous coronary intervention or coronary artery bypass grafting without concurrent hospitalization for AMI), and (3) coronary angiography without revascularization. Next, we determined the association of patient-level demographic and clinical characteristics with each of these outcomes. Variables included relevant demographics (age, sex, race, and geographic region), coexisting conditions that are known risk factors for cardiovascular disease (diabetes mellitus, hypertension, dyslipidemia, and chronic kidney disease), and a surrogate marker of chronic smoking (chronic obstructive pulmonary disease). Finally, we stratified the cohort into quintiles based on each patient's likelihood of coronary revascularization and/or AMI, in order to describe the profile of patients with high and low probability of experiencing this outcome.

Statistical Analysis

First, unadjusted cumulative event rates for (1) hospitalization for AMI, (2) elective coronary revascularization, and (3) coronary angiography without revascularization were calculated as a function of the time from performance of the stress test using Kaplan–Meier time-to-event analyses. Next, logistic regression models were estimated using occurrence of the outcome measure within 1 year of stress testing as the dependent variable, and patient-level demographic and clinical characteristics as the independent variables. Backwards stepwise regression was performed to identify a parsimonious prediction model for each outcome. Then, each patient's likelihood of experiencing a combined outcome of AMI and/or coronary revascularization was calculated in postestimation using the coefficients derived from the logistic regression model. Finally, the cohort was stratified into quintiles based on their likelihood of AMI and/or coronary revascularization. Standard summary statistics were used to compare patient-level characteristics between patients who experienced each clinical outcome, and patients at highest and lowest risk of subsequent AMI and/or revascularization. All statistical tests were 2-sided, with $P<0.05$ indicating statistical significance. Analyses were performed using Stata version 14 (Stata Corp, College Station, TX). The study protocol was granted exemption by the Institutional Review Board at the University of Pennsylvania since all data were de-identified. Drs Kini and Dayoub had full access to all the data in the study and take responsibility for its integrity and the data analysis.

Results

Study Cohort

We identified 553 027 unique patients aged 25 to 64 who had no known cardiovascular disease and underwent first-time
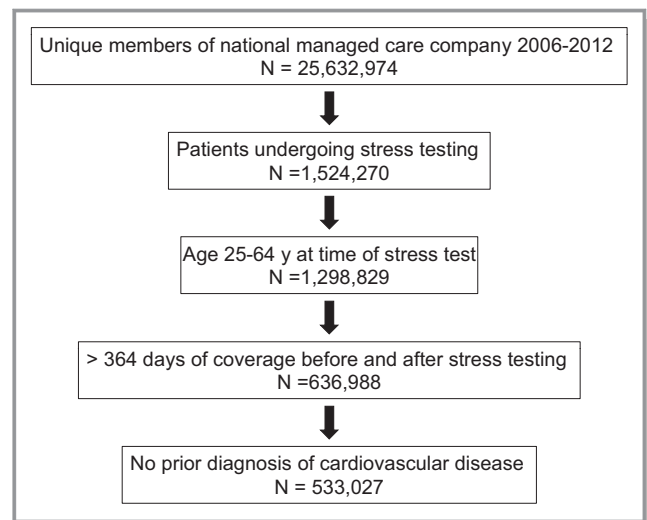

Figure 1. Study flow.

stress testing during the study period from 2006 to 2011 (Figure 1). Characteristics of the study cohort are provided in Table 1. The mean (SD) age was 50 (7) years, 49% were women, and 73% self-identified as white. Among these patients, 15% had diabetes mellitus, 37% had hypertension, and 42% had dyslipidemia.

Stress Test Modalities

Of the 553 027 stress tests identified, 293 443 (53%) were nuclear single photon emission computed tomography myocardial perfusion imaging tests, 124 149 (22%) were stress echocardiography tests, and 135 435 (25%) were exercise electrocardiography tests (Figure 2). Characteristics of patients who underwent each type of test are provided in Table 2. Compared with patients who underwent exercise electrocardiography, patients who underwent nuclear single photon emission computed tomography myocardial perfusion imaging tended to be older (mean [SD] age 51.9 [7] versus 48.5 [8] years; $P<0.001$) and were more likely to have comorbid conditions (18.6% versus 10.7% with diabetes mellitus and 43.6% versus 30.2% with hypertension, both $P<0.001$).

Clinical Outcomes After Stress Testing

Within 1 year of testing, 0.8% (4202) of the cohort were hospitalized for AMI, 1.8% (9902) underwent elective coronary revascularization, and 2.5% (14 042) underwent coronary angiography without revascularization (Figure 3). The overall rate of invasive coronary angiography after testing was 5.0% (27 708). Event rates stratified by each stress testing modality are provided in Figure 4. The rate of subsequent invasive coronary angiography among patients who

Table 1. Characteristics of Patients Undergoing Stress Testing and Subsequent AMI (With or Without Revascularization), Elective Coronary Revascularization, or Coronary Angiography Without Revascularization

	Stress Testing Cohort n=553 027	Subsequent AMI (With/Without Revascularization) n=4204	Subsequent Elective Revascularization n=9902	Subsequent Angiography Without Revascularization n=14 042	P Value*
Age, mean (y)	50.4	53.6	55.5	52.5	<0.001
Age category, % (y)					<0.001
25 to 34	5.1	1.7	0.4	1.7	
35 to 44	20.0	10.4	6.2	14.7	
45 to 54	38.0	35.5	31.0	38.0	
55 to 64	36.9	52.4	62.3	45.5	
Women, %	48.6	31.8	21.1	47.2	<0.001
Race, %					
White	72.8	72.9	78.7	72.4	<0.001
Black	10.9	11.8	9.0	14.6	<0.001
Hispanic	8.5	8.3	6.0	7.6	0.002
Asian	3.0	2.4	2.2	1.6	<0.001
Unknown	4.8	4.6	4.1	3.8	0.053
Region, %					<0.001
Northeast	10.3	11.1	7.3	7.2	
Midwest	23.3	27.5	28.0	23.0	
South	53.4	49.0	53.8	61.1	
West	12.2	11.6	9.7	8.0	
Unknown	0.9	0.8	1.2	0.7	
Comorbidity, %					
COPD	5.0	7.6	6.7	7.1	0.600
CKD	15.4	25.4	29.5	23.4	<0.001
Diabetes mellitus	14.7	23.4	28.5	22.2	<0.001
Hypertension	37.1	46.4	51.4	48.2	0.005
Hyperlipidemia	41.9	45.9	52.7	45.8	<0.001

AMI indicates acute myocardial infarction; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease.
*P value for comparison of groups experiencing subsequent outcome.

underwent nuclear single photon emission computed tomography was significantly higher compared with the rate of angiography for patients undergoing exercise electrocardiography and stress echocardiography (7.0% versus 2.4% and 2.6%, respectively; *P* value for both <0.001).

The association of patient characteristics with subsequent hospitalization for AMI, elective coronary revascularization, or coronary angiography without revascularization is shown in Table 3. Compared with patients aged 45 to 54, patients aged 25 to 34 were significantly less likely have subsequent AMI (odds ratio 0.36 [95% confidence interval [CI], 0.29, 0.46]; *P*<0.001) or elective coronary revascularization (odds ratio 0.10 [95% CI, 0.07, 0.13]; *P*<0.001), while patients aged 55 to 64 were more likely to have subsequent AMI (odds ratio 1.49

[95% CI, 1.40, 1.60]; *P*<0.001) or elective coronary revascularization (odds ratio 1.99 [95% CI, 1.90, 2.08]; *P*<0.001). Women were less likely to have subsequent AMI (odds ratio 0.47 [95% CI, 0.44, 0.50]; *P*<0.001) or elective coronary revascularization (odds ratio 0.26 [95% CI, 0.25, 0.28]; *P*<0.001) compared with men. Nonwhite patients were less likely to undergo elective coronary revascularization compared with whites (odds ratios for black and Hispanic patients 0.81 [95% CI, 0.76, 0.87] and 0.77 [95% CI, 0.71, 0.84], respectively, both *P*<0.001).

Characteristics associated with higher likelihood of undergoing coronary angiography without revascularization included age 55 to 64 (odds ratio compared with aged 45–54 1.17 [95% CI, 1.12, 1.21]; *P*<0.001), black race (odds
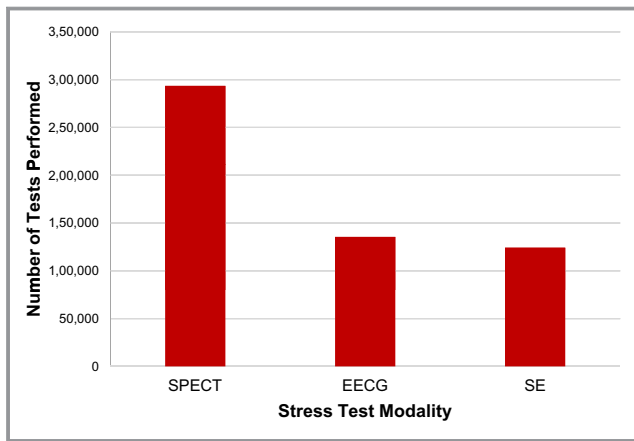
Figure 2. Stress testing modalities, 2006–2011. EECG indicates exercise electrocardiography; SE, stress echocardiography; SPECT, nuclear single photon emission computed tomography.

ratio compared with white race 1.18 [95% CI, 1.12, 1.24]; *P*<0.001), and residence in the Southern US region (odds ratios for residence in the Northeast and West regions 0.64 [95% CI, 0.60, 0.68] and 0.60 [95% CI, 0.57, 0.64], respectively, both *P*<0.001).

In the analysis stratified by likelihood of subsequent AMI or elective coronary revascularization, patients in the lowest likelihood quintile (n=109 008) had an event rate of 0.5% while patients in the highest likelihood quintile (n=112 983) had an event rate of 6.2% (*P*<0.001). Compared with the highest likelihood quintile, patients in the lowest likelihood quintile were younger (mean age 40 versus 58 years; *P*<0.001), more likely to be women (85% versus 0%; *P*<0.001), more likely to be nonwhite (36% versus 16%; *P*<0.001), and less likely to have comorbidities (Table 4).

Discussion

The proportion of commercially insured US patients who were hospitalized for AMI or underwent elective coronary revascularization within 1 year of stress testing was low. Characteristics of patients with low likelihood of subsequent AMI or coronary revascularization included younger age, nonwhite race/ethnicity, and female sex.

Incidence of Clinical Events

Because of widely divergent trends in use of stress testing between health systems and significant rates of "rarely appropriate" testing, there is a growing emphasis on measuring clinical outcomes to determine the value of noninvasive cardiac tests.[1–4,8,9] However, few modern studies have reported on the rate of relevant clinical outcomes after

Table 2. Characteristics of Patients Undergoing Stress Testing by Modality

	Exercise Electrocardiography n=135 435	Stress Echocardiography n=124 149	Nuclear Single Photon Emission Computed Tomography n=293 443	P Value*
Age, mean (y)	48.5	49.3	51.9	<0.001
Age category, % (y)				<0.001
25 to 34	8.3	6.8	2.8	
35 to 44	24.5	23.0	16.2	
45 to 54	37.5	37.9	38.2	
55 to 64	29.7	32.3	42.7	
Women, %	42.2	52.1	50.2	<0.001
Race, %				<0.001
White	71.5	76.0	71.9	
Black	10.4	8.2	12.6	
Hispanic	9.3	7.1	8.9	
Asian	4.0	3.5	2.3	
Unknown	4.8	5.2	4.3	
Region, %				<0.001
Northeast	12.0	11.7	8.9	
Midwest	14.3	32.7	23.0	
South	57.0	38.9	58.5	
West	16.1	14.8	9.0	
Unknown	0.5	1.8	0.6	
Comorbidity, %				
COPD	4.0	4.2	6.0	<0.001
CKD	11.0	11.4	19.5	<0.001
Diabetes mellitus	10.7	11.1	18.6	<0.001
Hypertension	30.2	31.1	43.6	<0.001
Hyperlipidemia	37.5	37.6	46.2	<0.001

CKD indicates chronic kidney disease; COPD, chronic obstructive pulmonary disease.
*P value for comparison of groups undergoing each testing modality.

stress testing among large, real-world cohorts. Mudrick et al reported low rates of AMI (0.3%) and coronary revascularization (3.3%) within 1 year after stress testing among a smaller cohort of patients (n=80 676) aged 40 to 64 from 2004 to 2007.[12] In the PROMISE (Prospective Multicenter Imaging Study for Evaluation of Chest Pain) clinical trial evaluating the comparative effectiveness of anatomic versus functional testing, the rate of subsequent clinical events at 1 year was ≈2% at 1 year.[10] In our study of 564 313 patients undergoing stress testing, 0.8% of the cohort were hospitalized for AMI, 1.8% underwent elective coronary revascularization, and 2.5%
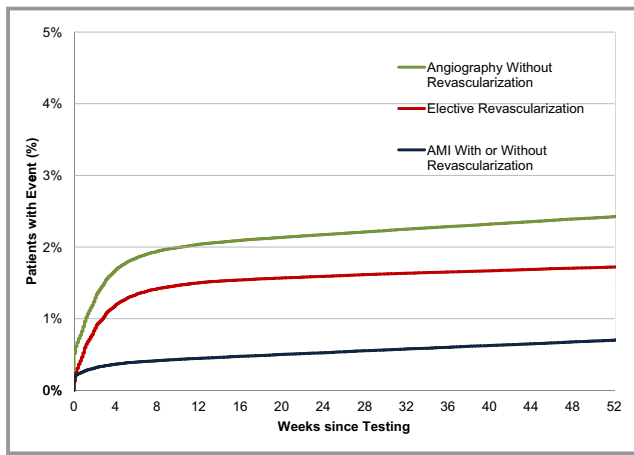
Figure 3. Rates of acute myocardial infarction (with or without revascularization), elective coronary revascularization, and coronary angiography without revascularization within 1 year after stress testing. AMI indicates acute myocardial infarction.

underwent coronary angiography without revascularization. While our study was not able to measure cardiac death as an outcome, prior studies have shown that the rate of cardiac death among patients under the age of 65, including those who receive stress tests, is <0.5% per year.[10,12,13] While the "correct" number of patients who should receive stress testing per subsequent clinical event is not known, the low incidence of clinical outcomes measured in this study suggests that there may be room for improvement in patient selection for testing.

Optimizing the utilization of noninvasive cardiac tests has proved challenging. Stress tests may be particularly prone to overuse because they are readily available as a result of technology proliferation, potentially lucrative to providers and health systems, and can be used in a number of clinical situations to provide reassurance to both patients and providers.[14,15] Growing concerns about high healthcare costs, radiation exposure from medical imaging, and unnecessary invasive testing have spurred efforts to use stress tests more effectively.[16–19] However, the success of efforts such as dissemination of appropriate use criteria and "low-value" lists has been mixed.[8,20] Furthermore, even though most patients who receive elective coronary angiography undergo prior stress testing, only 38% of patients are found to have obstructive coronary artery disease according to a prior study.[21] Routine measurement of clinical outcomes after stress testing, rather than stress test appropriateness or stress test performance, could potentially serve as a novel measure to improve use of stress testing.

Risk of Subsequent Clinical Outcomes

In the lowest likelihood quintile for AMI and/or coronary revascularization after stress testing, the rate of subsequent
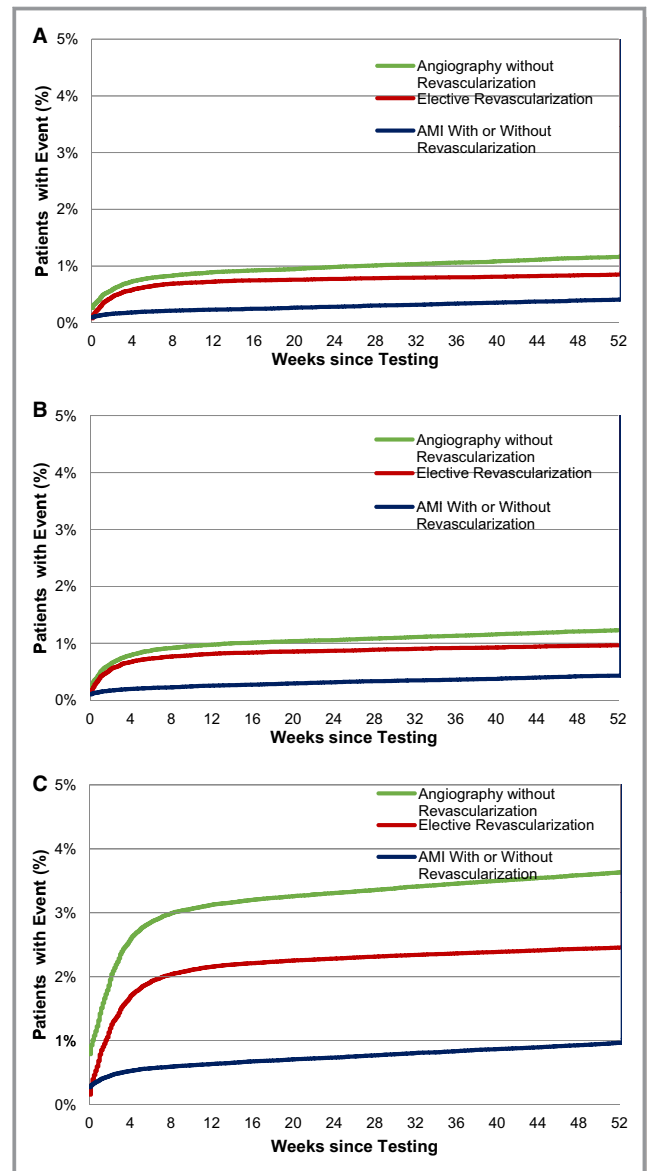

Figure 4. Rates of acute myocardial infarction (with or without revascularization), elective coronary revascularization, and coronary angiography without revascularization within 1 year after stress testing, stratified by testing modality. (A) represents exercise electrocardiography, (B) represents stress echocardiography, and (C) represents nuclear single photon emission computed tomography. AMI indicates acute myocardial infarction.

clinical events was low (0.5%, or a number needed to test of 200 patients). This group was largely comprised women under the age of 45 with a low prevalence of identifiable cardiovascular disease risk factors. While it is well established that young age and female sex are associated with lower risk for coronary artery disease,[22,23] symptoms of concern for obstructive coronary artery disease or other risk factors such as family history of early cardiovascular disease may still have prompted testing among these patients. Similarly, some patients were more likely to undergo angiography without

Table 3. Association of Patient Characteristics With Outcomes After Stress Testing

	Subsequent AMI (With/Without Revascularization)		Subsequent Elective Revascularization		Subsequent Angiography Without Revascularization	
	Odds Ratio (95% CI)	P Value	Odds Ratio (95% CI)	P Value	Odds Ratio (95% CI)	P Value
Age category (%) (y)						
25 to 34	0.36 (0.29, 0.46)	<0.001	0.10 (0.07, 0.13)	<0.001	0.35 (0.31, 0.40)	<0.001
35 to 44	0.56 (0.50, 0.62)	<0.001	0.39 (0.36, 0.43)	<0.001	0.76 (0.72, 0.80)	<0.001
45 to 54	REF		REF		REF	
55 to 64	1.49 (1.40, 1.60)	<0.001	1.99 (1.90, 2.08)	<0.001	1.17 (1.12, 1.21)	<0.001
Women (%)	0.47 (0.44, 0.50)	<0.001	0.26 (0.25, 0.28)	<0.001	0.90 (0.87, 0.93)	<0.001
Race, %						
White	REF		REF		REF	
Black	1.19 (1.08, 1.31)	<0.001	0.81 (0.76, 0.87)	<0.001	1.18 (1.12, 1.24)	<0.001
Hispanic	1.11 (0.99, 1.24)	0.069	0.77 (0.71, 0.84)	<0.001	0.94 (0.88, 1.00)	0.059
Asian	0.88 (0.72, 1.07)	0.219	0.80 (0.69, 0.92)	0.001	0.60 (0.53, 0.69)	<0.001
Region, %						
Northeast	1.21 (1.09, 1.34)	<0.001	0.69 (0.64, 0.75)	<0.001	0.64 (0.60, 0.68)	<0.001
Midwest	1.30 (1.20, 1.40)	<0.001	1.15 (1.09, 1.20)	<0.001	0.88 (0.84, 0.92)	<0.001
South	REF		REF		REF	
West	1.04 (0.94, 1.15)	0.403	0.75 (0.70, 0.81)	<0.001	0.60 (0.57, 0.64)	<0.001
Comorbidity, %						
COPD	1.35 (1.20, 1.53)	<0.001	1.18 (1.09, 1.29)	<0.001	1.33 (1.24, 1.42)	<0.001
CKD	1.58 (1.36, 1.84)	<0.001	1.35 (1.22, 1.49)	<0.001	1.23 (1.13, 1.34)	<0.001
Diabetes mellitus	1.02 (0.88, 1.19)	0.755	1.41 (1.27, 1.56)	<0.001	1.19 (1.09, 1.30)	<0.001
Hypertension	1.19 (1.11, 1.27)	<0.001	1.25 (1.20, 1.31)	<0.001	1.34 (1.29, 1.39)	<0.001
Hyperlipidemia	0.82 (0.77, 0.88)	<0.001	0.95 (0.90, 0.99)	0.013	0.89 (0.85, 0.92)	<0.001

AMI indicates acute myocardial infarction; CI, confidence interval; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease.

revascularization after stress testing, including patients aged 55 to 64, of black race, and located in the Southern United States. The clinical reasons for referral to coronary angiography are not known, but may include changes in symptoms after stress testing, a "true positive" stress test prompting angiography and subsequent medical treatment for obstructive coronary artery disease, or a "false positive" stress test result prompting angiography but not revascularization. Our results underscore the need for accurate assessment of pretest probability of disease and the likelihood of future clinical events to guide referrals for stress testing.

Patient-Centered Stress Testing

Although clinical outcomes represent an important component of value, few studies have explored the use of patient-centered outcomes after stress testing. There is some evidence that patients may still choose to undergo testing despite counseling that (1) they have a low pretest probability of disease and (2) testing in low-risk individuals increases the likelihood of false-positive tests that may prompt an invasive procedure with concurrent risks.[24,25] As the healthcare system shifts away from a fee-for-service model to one that emphasizes patient satisfaction and achievement of good clinical outcomes at lower cost,[26,27] novel means of measuring and improving stress test value from patient-centered perspectives could be considered.

Limitations

An important limitation is the lack of indication for stress testing in our data, and therefore the proportion of stress tests performed for indications other than evaluation for obstructive coronary artery disease was unknown. However, we excluded patients with a prior diagnosis of arrhythmia or cardiomyopathy to minimize this effect. Symptoms prompting performance of stress testing were not available to us, and therefore the pretest probability of obstructive coronary artery

Table 4. Characteristics of Patients by Risk Quintile of AMI and/or Elective Coronary Revascularization After Stress Testing

	Lowest Risk (First) Quintile n=109 008	Second Quintile n=110 113	Third Quintile n=110 327	Fourth Quintile n=110 596	Highest Risk (Fifth) Quintile n=112 983	*P* Value*
Age, mean (y)	40.4	46.3	51.4	55.5	58.0	<0.001
Age category, % (y)						<0.001
25 to 34	26.1	0.4	0	0	0	
35 to 44	46.9	40.2	11.4	2.3	0	
45 to 54	27.0	54.3	68.3	25.4	12.6	
55 to 64	0	5.1	20.3	72.3	87.4	
Women, %	84.7	83.7	59.8	17.3	0	<0.001
Race, %						<0.001
White	57.5	74.7	76.1	75.6	79.5	
Black	15.7	9.2	11.2	10.0	8.8	
Hispanic	14.7	9.2	5.3	7.5	6.1	
Asian	5.6	2.9	3.0	2.1	1.5	
Unknown	6.4	4.0	4.3	4.8	4.0	
Region, %						<0.001
Northeast	11.0	10.4	9.7	10.7	9.8	
Midwest	21.0	24.2	23.3	23.7	24.0	
South	55.8	52.5	53.8	52.6	52.3	
West	11.5	12.1	12.3	12.1	12.9	
Unknown	0.7	0.9	0.9	0.9	0.9	
Comorbidity, %						<0.001
COPD	4.1	4.0	5.1	6.0	5.9	
CKD	2.6	5.7	15.1	20.8	32.4	
Diabetes mellitus	2.7	5.2	15.3	19.3	30.9	
Hypertension	17.0	24.3	49.9	40.3	53.8	
Hyperlipidemia	23.5	32.8	45.0	52.1	56.4	

AMI indicates acute myocardial infarction; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease.

*P value for comparison of groups in lowest and highest quintile.

disease or the appropriateness of referrals for testing was not known. Certain risk factors for cardiovascular disease such as family history of early coronary artery disease or tobacco use, as well as medication use before testing, were not available in our data. Death was not used as an outcome because it was not available in our data set. Stress test results, parameters, and patient preferences for treatment were not available in our data, and therefore patients who may have been medically treated for coronary artery disease after stress testing were not captured in our cohort. Only patients who had at least 1 year of membership in the managed care company after stress testing were included in the study. Thus, disenrollment of sicker patients over time could have had the effect of underestimating true event rates after stress testing. Finally, given that our population only included commercially insured patients from a single managed care company, our results may not be fully generalizable to other health systems or insurance providers.

Conclusions

The proportion of commercially insured US patients younger than 65 who experienced an AMI or underwent coronary revascularization within 1 year of stress testing was small. Patient characteristics associated with low likelihood of subsequent revascularization and/or AMI included younger age, female sex, and nonwhite race/ethnicity. Assessing risk of experiencing subsequent outcomes may be useful in refining patient referrals for stress testing.

Disclosures

None.

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