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Use of Stress Testing and Diagnostic Catheterization after Coronary Stenting: Association of Site-level Patterns with Patient Characteristics and Outcomes in 247,052 Medicare Beneficiaries

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Abstract

Objectives—To determine diagnostic testing patterns after percutaneous coronary intervention (PCI).

Background—Little is known about patterns of diagnostic testing after PCI in the U.S. or the relationship of these patterns with clinical outcomes.

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Methods—We linked Centers for Medicare & Medicaid Services inpatient and outpatient claims to the National Cardiovascular Data Registry® CathPCI Registry® data from 2005–2007. Hospital quartiles of the cumulative incidence of diagnostic testing use within 12 and 24 months post-PCI were compared for patient characteristics, repeat revascularization, acute myocardial infarction (AMI), and death.

Results—A total of 247,052 patients underwent PCI at 656 institutions. Patient and site characteristics were similar across testing use quartiles. There was a 9% and 20% higher adjusted risk of repeat revascularization in Quartile 3 and Quartile 4 (highest testing rate), respectively, when compared to Quartile 1 (lowest testing rate) (p=0.020 and <0.0001, respectively). The adjusted risk for death or AMI did not differ among quartiles.

Conclusions—While patient characteristics were largely independent of rates of post-PCI testing, higher testing rates was not associated with lower risks of myocardial infarction or death, but repeat revascularization was significantly higher at these sites. Additional studies should examine whether increased testing is a marker for improved quality of post-PCI care or simply increased healthcare utilization.

Keywords

stress testing; diagnostic catheterization; site-level patterns; patient outcomes

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Despite the utility of cardiac imaging technologies for guiding clinical decision making, increased utilization of testing in recent decades has raised concerns regarding possible over-use, particularly in light of rising overall U.S. health care costs (1). This increase in cardiac imaging has occurred as the incidence of coronary disease has remained stable, if not decreased slightly (2,3). Cardiac stress testing and diagnostic angiography are among the most commonly performed diagnostic tests, and are often used after revascularization—particularly percutaneous coronary intervention (PCI).

Previous studies have demonstrated significant regional variation in cardiac imaging and cardiac catheterization use (4–7) that does not appear to be entirely due to differences in patient characteristics. Cross-sectional and observational studies examining variation in testing have demonstrated that greater diagnostic testing results in increased invasive procedures and interventions (8,9). Nevertheless, it is unclear if these patterns represent increased use or overuse from routine surveillance testing (5). Together, these concerns prompted the American College of Cardiology Foundation (ACCF) to develop Appropriate Use Criteria for imaging stress testing in hopes of decreasing variation, and to target scenarios providing the most clinical benefit (10,11).

Prior studies have not examined the institutional variations in testing or the associated clinical outcomes after PCI. To address these gaps, we assessed the relationship between rates of diagnostic testing for coronary artery disease following PCI and the incidence of repeat revascularization, acute myocardial infarction (AMI), and death in a national patient cohort.

Methods

The Duke University Medical Center Institutional Review Board granted a waiver of informed consent and authorization for this study, and the Duke Clinical Research Institute conducted all analyses.

Data sources

The study population included all patients receiving PCI with stenting who were at least 65 years of age, were admitted and discharged between January 2004 and December 2008, and were enrolled in the National Cardiovascular Data Registry® (NCDR) CathPCI Registry®. The CathPCI Registry is a large, national, clinical registry of patients undergoing cardiac catheterization or PCI. For each patient, the first PCI with stent procedure captured in the CathPCI Registry was considered to be the index event and was treated as the initial unit of analysis. There were a total of 672,617 eligible index events of which 67% linked to a single record in the Centers for Medicare & Medicaid Services (CMS) inpatient claims data for patients >65 years old using an established probabilistic matching methodology (12,13). Index PCI events were matched to CMS claims data using three variables: sex, age, and date of service for the PCI procedure. Matching to the CMS data allowed identification of subsequent inpatient and outpatient claims. The patient was treated as the unit of analysis.

The linked cohort was restricted to patients receiving only stent type (either bare metal or drug-eluting) allowing for comparisons by stent type. Multiple revascularization procedures within a single encounter were considered a single revascularization event. Patients were excluded if they did not have both Part A (inpatient hospital) and Part B (physician services and outpatient hospital) Medicare during their index admission. Also, patients were excluded who did not have physician claims for their index intervention or had a primary payer besides Medicare (Figure 1a).

Study population

Since Version 3 of the CathPCI Registry data collection form was implemented nationwide on January 1, 2005, we restricted our analysis to patients treated on or after this date; similarly, since we had follow-up data through December 31, 2008, only patients treated prior to December 31, 2007 were included to ensure a minimum one-year follow-up (Figure 1b). Patients who did not have fee-for-service Medicare coverage for the entire follow-up period were censored once they ceased to have such coverage.

A 60-day blackout period after PCI was defined for each patient since diagnostic tests during this early period may be performed for cardiac rehabilitation, staging of procedures, or functional capacity assessments. Patients were excluded if they did not survive this blackout period or did not retain both Part A and Part B Medicare coverage. Additionally, patients receiving stress positron emission tomography, coronary computed tomography angiography, or stress magnetic resonance imaging after the 60-day blackout period were excluded, because they were rarely performed in this study cohort. Finally, we limited the sample to those hospitals that performed at least 50 PCI procedures during analysis period to eliminate hospitals with low procedural volumes.

Data definitions

The use of cardiac stress testing with and without imaging after coronary stent implantation was assessed by examining testing patterns following the initial revascularization procedure overall and stratified by type of test, which were identified by Current Procedural Terminology (CPT) codes (see Appendix for codes). The type, number, and dates of any cardiac testing or imaging procedure 60 days after the index coronary stent placement were used to stratify patients based on type of first diagnostic test after stenting. Stress electrocardiogram (ECG) and imaging procedures performed within one day of each other were considered a single stress event.

The number and dates of repeat catheterizations and coronary revascularization (e.g., PCI or coronary artery bypass grafting [CABG] surgery) following the first diagnostic test were identified using CPT and International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. Lastly, acute myocardial infarction (AMI) was defined according to ICD-9-CM coding (see Appendix for codes).

Statistical analysis

Patient and hospital baseline characteristics of patients undergoing an index revascularization stent procedure were provided overall and by hospital quartiles of cumulative incidence rate stress testing at 12 months post-PCI using descriptive statistics (number of observations, mean, standard deviation, median, 25^{th} and 75^{th} percentiles, minimum, and maximum) for numerical (or continuous) variables and with frequency and percentage for categorical variables. Bivariate tests of association were based on either Pearson chi-square tests for categorical variables or Kruskal-Wallis tests for continuous or ordinal variables.

Time-to-first stress test occurring at least 60 days after the index revascularization episode were calculated using cumulative incidence functions that accounted for administrative censoring; death, AMI, and catheterization were considered competing risks. Cumulative incidence rates at 12 months were calculated separately for each institution. Institutions were categorized based on quartiles of cumulative incidence of stress testing. To examine trends of institutional cumulative incidence rates at 12 months over calendar time, we estimated an intraclass correlation from a linear random effects model with institution as a random effect.

Cause-specific Cox proportional hazards models were used to estimate hazard ratios associated with risk of death first, AMI first, and revascularization first, with adjustment for baseline variables that were selected a priori based on clinical expertise. A robust variance estimator was used to account for the possible within-cluster correlation (14). We adjusted for age, race, gender, body mass index (BMI), acute coronary syndrome (ACS) at time of index PCI, peripheral vascular disease, history of congestive heart failure (CHF), diabetes, hypertension, dyslipidemia, current smoking status, cerebrovascular disease, family history of coronary artery disease before age 55, previous MI more than seven days before index PCI, chronic lung disease, drug-eluting stent versus bare metal stent, glomerular filtration rate <30 ml/min or receiving dialysis, previous PCI, previous CABG, current CHF status, year of index PCI, hospital type (government, private and teaching, private and non-teaching, versus university), average annual PCI volume, number of CMS-certified beds, and region. In each model, patients were censored at the end of follow-up, or at 365 or 720 days. To describe whether clinical events rates (AMI, repeat revascularization, death) differed by quartile of testing, we calculated 12-month and 720-day institutional event rates per 100 person-years and calculated the median of the institutional event rates separately for each quartile. To examine outcomes up to 365 and 720 days, we plotted the cumulative incidence using the Kaplan-Meier method and tested for equality of survivor functions with the log-rank test.

All statistical analyses were conducted using SAS version 9.2 or higher (SAS Institute Inc., Cary, NC) and Stata Statistical Software: Release 11 (StataCorp, College Station, TX). All statistical tests were two-sided with a significance level of 0.05.

Results

The study population included 247,052 patients who underwent PCI with stenting between 2005–2007 at 656 hospitals (Figures 1a and 1b). Mean duration of follow-up was 756 days (25^{th}–75^{th} percentile, 512–1047 days). Overall, 79,741 (32.3%) patients had a stress ECG, stress echocardiography, or stress nuclear as the first test in the interval from 60–365 days after coronary stenting, 18,455 (7.5%) patients had invasive diagnostic coronary angiography as the first test, and 148,856 (60.3%) patients had no testing in the 60–365 day interval after coronary stenting.

Institutional quartiles of testing incidence

We examined the site-level 12-month cumulative incidence rate of stress testing used as the first test within 60–365 days after PCI, with either stress testing or cardiac catheterization used as the first test after PCI. The institutional 12-month cumulative incidence rates of any stress testing varied from 8.6% to 66.0% (median 31.6%, 25^{th}–75^{th} percentile, 24.7%–38.9%). The intraclass correlation of cumulative incidence of non-invasive testing between sites over study years was 0.702 (95% CI: 0.668–0.735).

Patient and hospital characteristics

After sites were stratified into quartiles based on their 12-month testing cumulative incidence during the study period, we compared baseline characteristics and demographics of patients at the time of index PCI. This comparison was done first for quartiles of hospitals based on rates of patients undergoing stress testing as the first test after PCI (Table).

Stress test first—Patient characteristics were largely similar across hospital quartiles for cumulative incidence of testing. Compared to the lowest testing rate quartiles, patients receiving PCI at the highest testing rate quartile were less likely to be Caucasian, or to have BMI ≥30, previous CHF, or ACS at index presentation. There was some also variability of site characteristics across the quartiles in use of drug-eluting stents, annual PCI volumes, and geography, but there were no clear trends in these differences across quartiles.

Unadjusted outcomes—Clinical outcomes at least 60 days after index PCI and up to 12 months after index PCI were examined overall and by hospital testing quartile (Figure 2). Overall, the incidence rates of repeat revascularization (CABG or PCI), AMI, or death within 12 months were 4.1, 2.3, and 5.2, respectively, per 100 person-years.

Adjusted outcomes for patients after PCI

Among hospital quartiles of stress testing use as the first test after PCI, no statistical difference in the cumulative incidence of death (p=0.187) or hospitalization for AMI (p=0.51) at 12 months after PCI was found when the higher three quartiles were jointly compared to the lowest quartile of testing (Quartile 1). In contrast, there was a highly significant difference in the incidence of repeat revascularization at 12 months after PCI (p<0.001). In pairwise comparisons, there were statistically significant 9% and 20% increases in repeat revascularization among sites in Quartile 3 and Quartile 4, respectively, compared to Quartile 1 (p=0.020 and <0.001, respectively; Figure 3).

When examining outcomes at least 60 days and up to 720 days after PCI, we found that the cumulative incidence rate of death for the lowest tested quartile (Quartile 1) compared to the other three quartiles was similar, although statistically significant (10.5%, 10.8%, 10.1% and 10.1%, respectively [p=0.011]). No significant clinical differences at 720 days were found when comparing Quartile 1 to the other three quartiles for the cumulative incidence of hospitalization for AMI (4.5%, 4.8%, 4.6%, 4.3% for Quartile 1–4, respectively [p=0.041]). Finally, a significant difference in the rates of repeat revascularization was found across the four groups with increasing rates of revascularization as testing quartile increased (13.8%, 13.8%, 14.7%, 15.4% for Quartiles 1–4, respectively; [p<0.001]). When examined by repeat revascularization type (PCI or CABG), there was no difference in the use of CABG across the 4 testing quartiles (1.93%, 1.92%, 2.04%, 1.94% for Quartiles 1–4, respectively; p = 0.567), whereas increased for PCI as testing quartile increased (12.3%, 12.3%, 13.2%, 14.0% for Quartiles 1–4, respectively; p<0.001) at 720 days.

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Discussion

In this national cohort undergoing PCI, there was marked variation in the use of subsequent cardiovascular testing that is not fully explained by differences in patient and hospital characteristics. Furthermore, increased use of testing after PCI is associated with a clear increase in repeat revascularization; however, the variation of testing and downstream revascularization did not result in decreased AMI or mortality.

In the current study, we found significant variation in non-invasive stress testing after PCI across Medicare fee-for-service sites with a range of 17% to 73% and a mean of 40% at 12 months. These rates parallel previous reports of cumulative incidence of 36% for either stress echocardiography or stress nuclear testing at 12 months in a non-Medicare population (5). Relative to previous reports in other PCI analyses, these rates are high, where less than 15% patients develop symptoms requiring reevaluation within 12 months post-PCI (15,16).

In our study, there were no significant differences in patient characteristics among sites stratified by quartile of testing use demonstrating that increased patient risk was not associated with increased testing use and vice versa. Specifically, patient characteristics, such as diabetes or a history of silent ischemia (i.e., no chest pain prior to index PCI) or bare metal stent use (versus drug-eluting stent), were not more common at sites with more frequent testing. This finding is similar to our prior observations in non-Medicare patients (5) suggesting significant opportunities exist to improve guidance on appropriate indications for testing.

We used the naturally occurring variation in testing rates across institutions to explore whether variation in the specified outcomes might be associated with different testing intensities. In particular, the variation in testing rates may be interpreted as a surrogate for the different post-PCI management strategies of ischemic symptom-driven testing (lower rates of use) versus surveillance testing (higher rates of use). The lack of association between stress testing use and clinical outcomes of death or AMI, suggests that the more intensive testing use (implying a surveillance testing strategy) did not prevent or reduce post-PCI events in the short- to medium-term. This lack of difference in death related to testing use after PCI parallels findings from prior studies examining the association of testing intensity and outcomes after AMI when controlling for patient characteristics (17). Nevertheless, our data only infer the presence of different diagnostic strategies and the associated outcomes.

In contrast to AMI and death, when examining the physician-guided outcome of repeat revascularization, a significantly higher utilization (up to 37% more) was found among sites that tested more frequently after PCI. Additionally, we found that the use of repeat revascularization with CABG was constant across testing quartiles, but repeat PCI increased with increased site testing. This clinical cascade mirrors previous studies demonstrating that increased imaging use leads to increased invasive procedures and interventions (8,9). To our knowledge, our findings are the first to use observational data to demonstrate that increased testing after PCI is not associated with lower rates of death or AMI, and is consistent with multiple randomized clinical trials that have found no reduction in events after PCI (18,19,20).

Despite the large number of sites and patient data available, our study had several limitations. First, data are limited to fee-for-service Medicare and CathPCI Registry patients. As a result, data on symptoms, clinical presentation, and findings at the time of retesting are unavailable and may differ between groups. It is unknown if higher rates of testing and revascularization result in better symptomatic outcomes, which are also important indicators to patients. Second, we have limited follow-up for patients and could not observe longerterm (greater than 24 months) outcomes. Despite similar patients across the utilization quartiles, we could not exclude clinicians who may have correctly identified higher clinical risk and may have acted appropriately upon abnormal test results by repeat coronary intervention. However, given the very low rates of subsequent repeat revascularization in this population, it is unlikely that repeat revascularization would be a significant driver of AMI reduction or death in our population. Also, follow-up events following PCI relied on ICD-9 codes as opposed to clinically adjudicated events which could understate the occurrence of events in our analysis cohort. Finally, we do not have information regarding other valid reasons to test, such as patient or provider preferences or need for patient reassurance.

In conclusion, our findings suggest that linking clinically rich patient registries with administrative data can create a platform to examine use of testing after PCI. It is unknown whether increased testing after PCI with increased subsequent repeat revascularization is a marker of higher quality post-PCI care, or simply an indication of increased health care utilization. Future studies should examine the indications for and results of post-PCI testing to further assess their use for patients to better understand the associated clinical outcomes.

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Role of the Sponsor

The funding organization had no role in the design and conduct of the study; in the collection, analysis, and interpretation of the data; or in the preparation, review, or approval of the manuscript.

Abbreviations and Acronyms

ACCF	American College of Cardiology Foundation
ACS	acute coronary syndrome
AMI	acute myocardial infarction
BMI	body mass index
CABG	coronary artery bypass grafting
CHF	congestive heart failure
CMS	Centers for Medicare & Medicaid Services
CPT	Current Procedural Terminology
DES	drug-eluting stent

ECG	electrocardiogram
ICD-9-CM	International Classification of Diseases, Ninth Revision, Clinical Modification
NCDR	National Cardiovascular Data Registry
PCI	percutaneous coronary intervention

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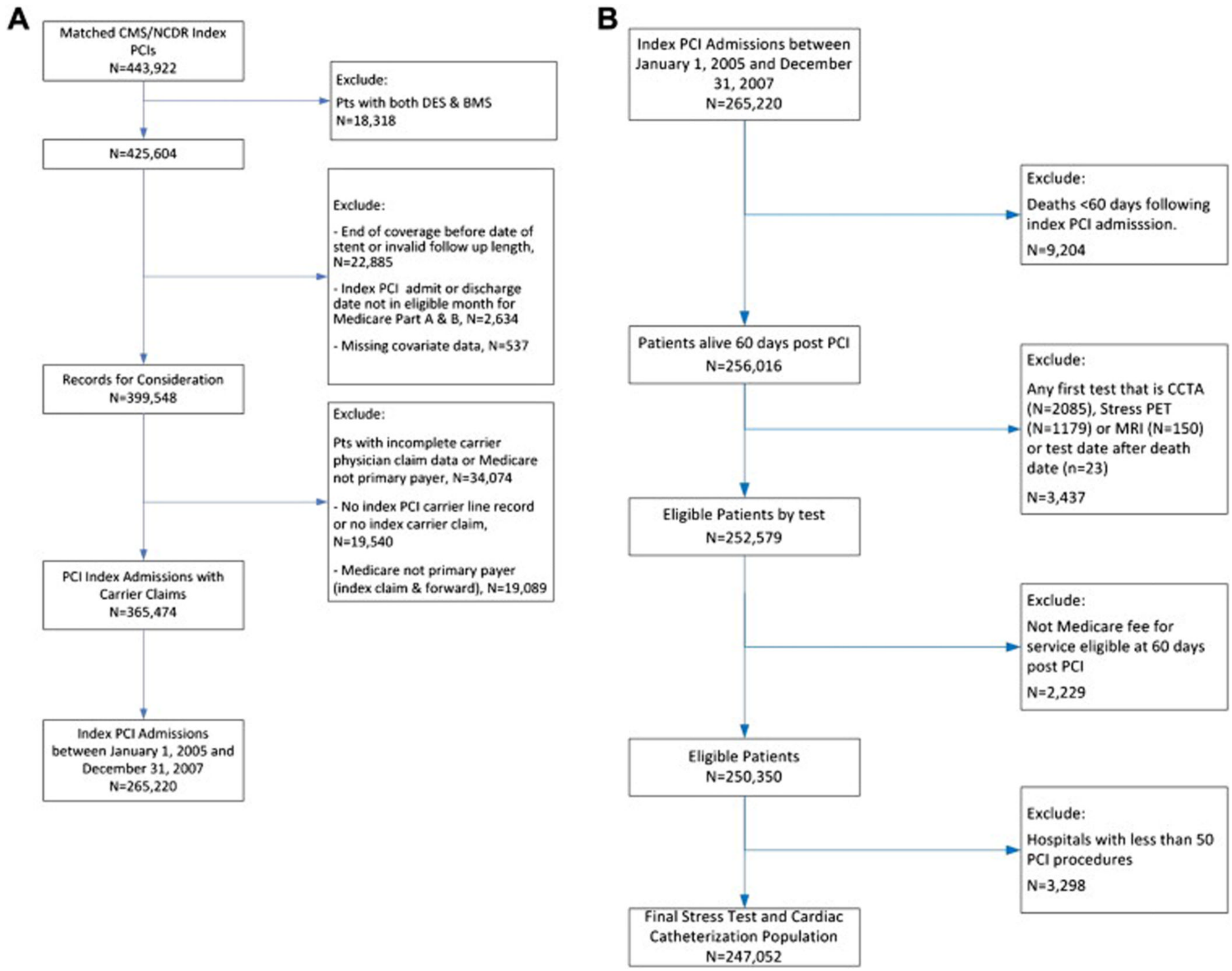

Figure 1. Population Description

This figure displays a description of: (a) the linked dataset population; and (b) the study population.

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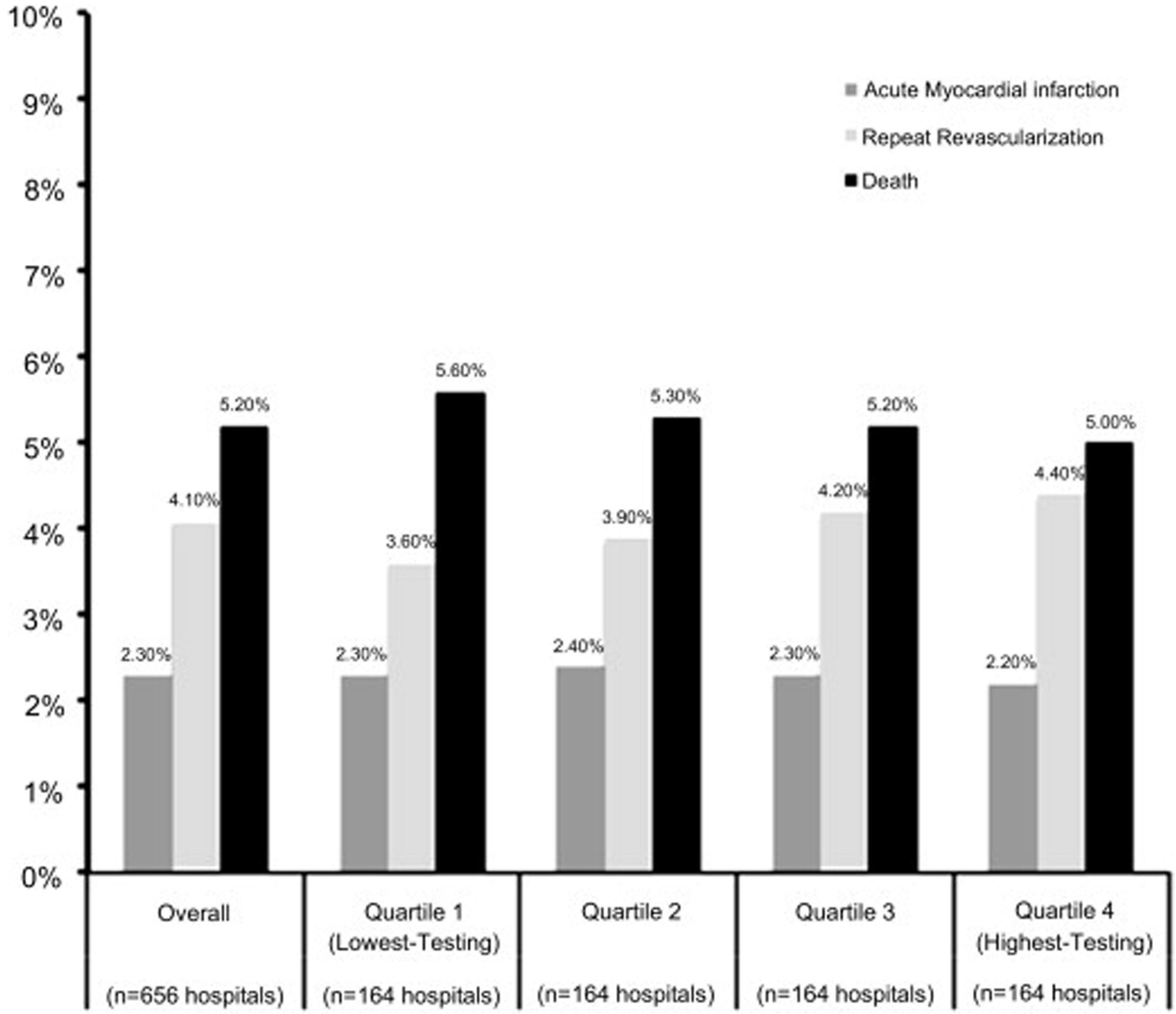

Figure 2. Observed 12-month Median Outcomes per 100 Person-Years by Hospital Quartile
This figure displays the observed 12-month median outcomes per 100 person-years by hospital quartile of stress testing 60–365 days after index PCI.

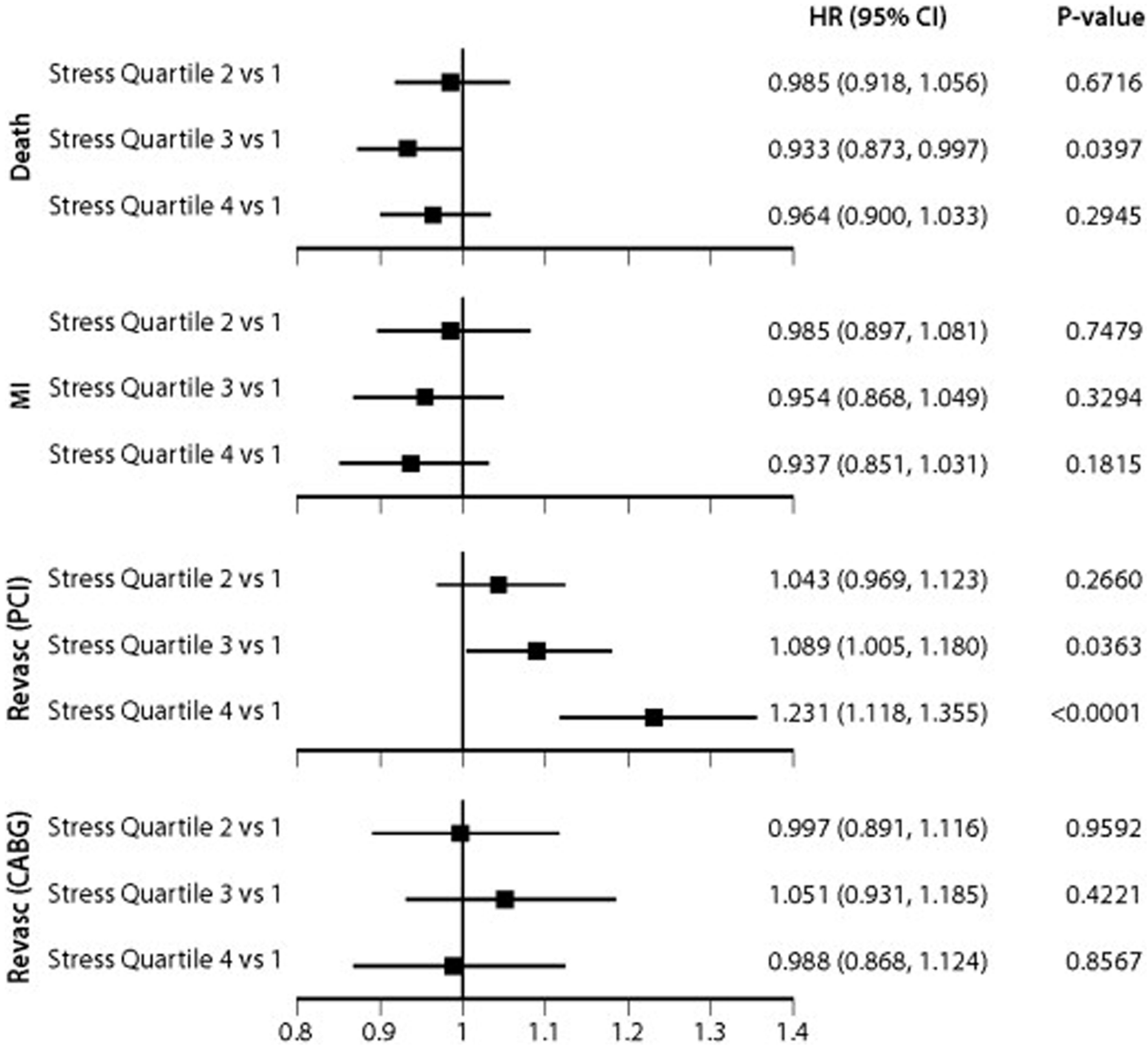

Figure 3. Adjusted Outcomes by Non-invasive Testing Quartiles

This figure displays the adjusted outcomes of non-invasive testing quartiles for death, myocardial infarction, and revascularization.

Table

Baseline and Descriptive Characteristics at Time of Index Coronary Stenting by Quartiles of Site Cumulative Incidence of Stress Test Use at 365 days after Index PCI

	Overall (n=656 hospitals)	Lowest-testing Quartile 1 (n=164 hospitals)	Quartile 2 (n=164 hospitals)	Quartile 3 (n=164 hospitals)	Highest-testing Quartile 4 (n=164 hospitals)	p-value
Total patients	247,052	55,138	62,980	67,405	61,529	
Age (years; median, Q1, Q3)	75 (74, 75)	75 (74, 75)	75 (74,75)	75 (74,76)	75 (74,76)	0.0119
≥75,%	44	39	44	48	45	
Male, %	57	57	57	57	58	0.0584
Caucasian,% (median, Q1, Q3)	93 (85, 97)	95 (90, 98)	92 (85,97)	90 (82, 96)	93 (85, 97)	<0.0001
BMI (median, Q1, Q3)	28 (28, 29)	29 (28, 29)	28 (28, 29)	27 (24, 31)	28 (28, 29)	0.0054
≥30, %	2	3	1	0	4	
Previous MI (>7 days), %	25	25	25	24	24	0.4666
Previous CHF, %	13	13	14	12	12	0.0839
Family history CAD: age<55, %	16	16	15	18	17	0.9704
Hypertension, %	81	81	81	82	80	0.4761
Diabetes, %	32	32	32	32	32	0.4418
Renal failure, %						0.9999
30 ≤ GFR < 60	37	37	37	36	37	
GFR ≥ 60	59	59	59	59	59	
Cerebrovascular disease, %	15	16	15	15	15	0.2880
Peripheral vascular disease, %	14	14	14	14	14	0.9597
Chronic lung disease, %	18	19	19	17	18	0.0122
Dyslipidemia, %	74	73	74	75	74	0.9252
Current smoker, %	12	13	13	11	11	<0.0001
Previous PCI, %	26	25	26	27	27	0.1035
Previous CABG, %	21	21	22	21	21	0.4203
ACS, %	62	68	63	59	58	<0.0001
CHF on presentation, %	11	12	12	11	10	0.0174
DES used, %	79	80	80	77	79	0.0569

	Overall (n=656 hospitals)	Lowest-testing Quartile 1 (n=164 hospitals)	Quartile 2 (n=164 hospitals)	Quartile 3 (n=164 hospitals)	Highest-testing Quartile 4 (n=164 hospitals)	p-value
# of CMS-certified beds (median, Q1, Q3)	362 (260, 511)	374 (252, 477)	387 (285, 536)	364 (263, 521)	339 (252, 490)	0.1939
Region, %						<0.0001
Northeast	12	7	18	12	13	
Midwest	34	46	25	34	32	
South	33	35	40	29	27	
West	21	12	20	24	29	
Hospital profit type						0.0021
Private, teaching site %	37	37	40	34	37	
Private, non-teaching site, %	52	46	47	56	60	
Hospital type						
Government, %	1	3	0.6	0	1	0.0695
University, %	9	13	12	10	2	0.0015
Annual PCI volume (median, Q1, Q3)	594 (354, 907)	550 (329, 842)	601 (350, 928)	877 (556, 1455)	564 (356, 832)	0.2221

ACS = acute coronary syndrome; BMS = body mass index; CABG = coronary artery bypass grafting; CAD = coronary artery disease; CHF = congestive heart failure; CMS = Center for Medicare & Medicaid Services; DES = drug-eluting stent; GFR = glomerular filtration rate; MI = myocardial infarction; PCI = percutaneous coronary intervention