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Original Research

In-hospital Outcomes and Cost Associated With Treatments for Non–ST-elevation Myocardial Infarction

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ABSTRACT

Background: Although variation in the management of patients with non–ST-elevation myocardial infarction (NSTEMI) is well documented across US hospitals, few data exist characterizing variation in outcomes following specific management strategies.

Methods: Admissions for NSTEMI to hospitals performing coronary angiography, percutaneous coronary intervention (PCI), and coronary artery bypass graft (CABG) surgery between 2016 and 2018 were identified from the National Inpatient Sample. Patients were categorized according to treatment rendered (medical therapy alone, angiography without revascularization, PCI, or CABG). The primary end point was variation in the incidence of composite in-hospital death, postprocedure myocardial infarction, or stroke, stratified by treatment rendered. Secondary outcomes included variation in length of stay (LOS), cost, and use of each treatment modality. Variation was characterized by the median odds ratio.

Results: Among 140,194 hospitalizations for NSTEMI, 35,748 (25.5%) patients received medical therapy alone, 28,678 (20.5%) underwent angiography without revascularization, 58,383 (41.6%) underwent PCI, and 17,385 (12.4%) underwent CABG. Despite adjusting for patient- and hospital-related factors, 2 similar patients were 25% more likely to experience the composite primary outcome following PCI and 45% more likely following CABG at 1 randomly selected hospital than at another. Significant hospital-level variations in LOS and cost were also apparent following each treatment modality.

Conclusions: In a large national analysis of hospitalizations for NSTEMI, significant variation was observed in clinical outcome, LOS, and cost associated with each treatment modality, despite adjustment for patient- and hospital-related factors.

Introduction

Non–ST-elevation myocardial infarction (NSTEMI) is commonly encountered, and its associated morbidity and mortality approximate those of ST-segment elevation myocardial infarction during long-term follow-up.[1] Hospital variation in the treatments employed for and overall outcomes following acute myocardial infarction has been observed in the United States and elsewhere.[2–4] However, little is known about hospital variation in outcome following specific treatment strategies for NSTEMI. Using national claims data, we investigated hospital variation in outcomes among patients treated with coronary angiography without revascularization, percutaneous coronary intervention (PCI), and coronary artery bypass graft (CABG) surgery during admission for NSTEMI at US hospitals where each of these treatment modalities was available.

Materials and methods

Data source

Data were extracted from the publicly available Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project's (HCUP) 2016-2018 National Inpatient Sample (NIS). The NIS is the largest publicly available all-payer inpatient database and provides

Abbreviations: CABG, coronary artery bypass graft; HCUP, Healthcare Cost and Utilization Project; ICD 10-CM, International Classification of Diseases, 10th Edition, Clinical Modification; LOS, length of stay; MOR, median odds ratio; NIS, National Inpatient Sample; NSTEMI, non–ST-elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.

Keywords: coronary artery bypass graft surgery; non–ST-elevation myocardial infarction; percutaneous coronary intervention; variation.

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annual estimates on >7 million unweighted (35 million weighted) hospital discharges. The NIS approximates a 20% stratified sample of all US hospitalizations and includes states covering more than 97% of the US population.[5]

Study population

Patients aged 18 years or older with a primary diagnosis of NSTEMI (*International Classification of Diseases, 10th Edition, Clinical Modification* [ICD-10-CM] diagnosis code I21.4) were included. Clinical variables, including demographics and medical comorbidities, were extracted using Agency for Healthcare Research and Quality Elixhauser Comorbidity Software and ICD-10-CM codes.[6] A list of associated ICD-10-CM codes appears in Supplemental Table S1. A Charlson comorbidity score was calculated for each patient. Patients were excluded if they experienced ST-elevation myocardial infarction during the same encounter, were transferred to or from an outside hospital, or had missing discharge disposition. Only hospitals where coronary angiography, PCI, and CABG were available on-site were included. Hospitals were classified as PCI/CABG-capable if they performed ≥1 PCI and ≥1 CABG during a given calendar year. This study was deemed exempt by the Rhode Island Hospital Institutional Review Board.

Exposure

Patients were categorized according to the treatment modality rendered, which included medical therapy alone (neither coronary angiography nor coronary revascularization), coronary angiography without revascularization, PCI, or CABG.

Outcomes

The primary outcome of interest was variation in in-hospital outcomes, including composite death, postprocedure myocardial infarction, or stroke. Secondary outcomes included hospital variation in the length of stay (LOS), total in-hospital costs by treatment modality, and variation in treatment modality rendered. Costs were derived from the HCUP Cost-to-Charge Ratio Files, which are hospital-level files designed to supplement the data elements in the NIS. Costs in these files represent the actual expenses incurred in the production of hospital services, such as wages, supplies, and utility. In addition, HCUP total charges exclude professional (physician) fees. Costs were also inflation-adjusted to 2018 US dollars. More information regarding this can be found at https://www.hcup-us.ahrq.gov/db/ccr/ip-ccr/ip-ccr.jsp.

Statistical analysis

Continuous data are displayed as means with standard deviations or medians with interquartile ranges when nonnormally distributed; these were compared with *t* test/analysis of variance or Mann-Whitney/Kruskal-Wallis tests, respectively. Categorical data are displayed as frequencies and percentages and were compared using the χ^2 or Fisher exact test where appropriate. National estimates were obtained utilizing discharge weights provided by HCUP, using PROC Surveyfreq (SAS Institute Inc), and are provided in Figure 1. In all other summary tables, unweighted data are presented. The median odds ratio (MOR) was used to quantify variation across hospitals using hierarchical logistic regression models with a random effect for each site. The MOR is interpreted as the odds that 2 similar patients would experience an identical outcome at 1 vs another randomly selected hospital. The primary outcome, variation in the incidence of composite death or postprocedure myocardial infarction or

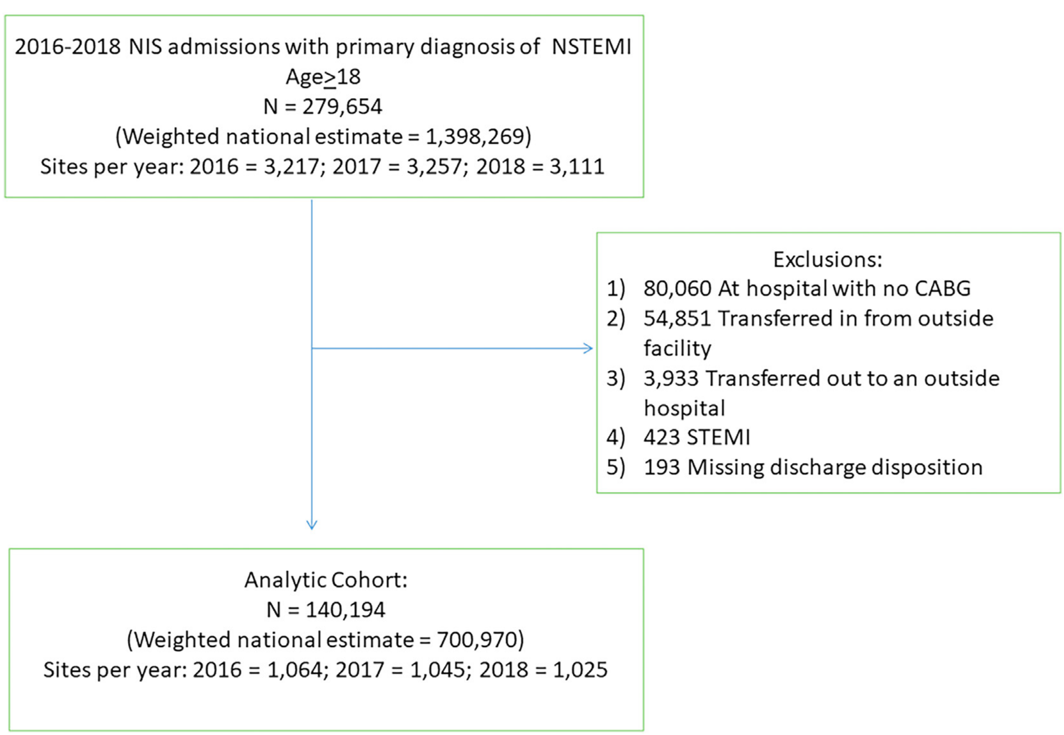


Figure 1.
Study flow diagram. Hospitalizations for non–ST-elevation myocardial infarction (NSTEMI) at sites capable of providing medical care, coronary angiography without revascularization, percutaneous coronary intervention (PCI), and coronary artery bypass graft (CABG) surgery. NIS, National Inpatient Sample; STEMI, ST-elevation myocardial infarction.

Table 1. Baseline characteristics according to treatment strategy (n = 140,194).

	Medical therapy only (n = 35,748)	Angio, no revasc, (n = 28,678)	PCI (n = 58,383)	CABG (n = 17,385)	*P* value
Age, y	73.7 ± 14.0	65.9 ± 13.3	65.6 ± 12.5	65.4 ± 10.7	<.001
Male	18,676 (22.0%)	15,279 (18.0%)	38,420 (45.2%)	12,696 (14.9%)	<.001
Female	17,072 (31.0%)	13,399 (24.3%)	19,963 (36.2%)	4689 (8.5%)	
Race					<.001
White	23,662 (24.4%)	18,962 (19.6%)	41,756 (43.1%)	12,454 (12.9%)	
Black	5650 (31.0%)	4665 (25.6%)	6423 (35.3%)	1475 (8.1%)	
Hispanic	3430 (25.9%)	2906 (21.9%)	5115 (38.6%)	1791 (13.5%)	
Asian	1113 (29.4%)	655 (17.3%)	1444 (38.2%)	571 (15.1%)	
Native/indigenous	157 (25.1%)	115 (18.4%)	275 (44.0%)	78 (12.5%)	
Other	860 (22.8%)	705 (18.7%)	1700 (45.2%)	500 (13.3%)	
Missing	876 (23.5%)	670 (18.0%)	1670 (44.8%)	515 (13.8%)	
Hypertension	17,132 (21.3%)	16,324 (20.3%)	36,457 (45.4%)	10,426 (13.0%)	<.001
Hyperlipidemia	3053 (18.5%)	3175 (19.3%)	7813 (47.4%)	2441 (14.8%)	<.001
Diabetes without chronic complications	5427 (22.4%)	4970 (20.5%)	10,950 (45.2%)	2892 (11.9%)	<.001
Diabetes with chronic complications	10,616 (28.5%)	6798 (18.3%)	13,879 (37.3%)	5918 (15.9%)	<.001
Tobacco abuse	11,901 (20.0%)	12,437 (20.9%)	27,751 (46.7%)	7336 (12.3%)	<.001
Coronary artery disease	23,054 (20.1%)	22,614 (19.7%)	52,818 (46.1%)	16,208 (14.1%)	<.001
Prior MI	5951 (26.3%)	4740 (20.9%)	9822 (43.4%)	2117 (9.4%)	<.001
Prior PCI	5076 (23.0%)	4837 (21.9%)	10,447 (47.2%)	1756 (7.9%)	<.001
Prior CABG	5273 (33.8%)	3851 (24.7%)	6166 (39.6%)	296 (1.9%)	<.001
Prior TIA/stroke	4558 (35.0%)	2743 (21.1%)	4595 (35.3%)	1115 (8.6%)	<.001
Congestive heart failure	19,348 (37.7%)	10,044 (19.6%)	15,759 (30.7%)	6177 (12.0%)	<.001
Peripheral vascular disease	3429 (28.9%)	2412 (20.3%)	4470 (37.7%)	1543 (13.0%)	<.001
Atrial fibrillation	10,106 (34.7%)	5583 (19.2%)	8136 (27.9%)	5318 (18.2%)	<.001
Aortic stenosis	3051 (44.4%)	1081 (15.7%)	1916 (27.9%)	819 (11.9%)	<.001
Prior pacemaker	1708 (40.9%)	829 (19.8%)	1474 (35.3%)	167 (4.0%)	<.001
Prior defibrillator	1219 (38.8%)	776 (24.7%)	1068 (34.0%)	78 (2.5%)	<.001
Drug abuse	1291 (33.2%)	938 (24.1%)	1252 (32.2%)	404 (10.4%)	<.001
Chronic kidney disease	14,535 (39.3%)	6583 (17.8%)	12,016 (32.5%)	3846 (10.4%)	<.001
Obstructive sleep apnea	2315 (20.8%)	2342 (21.0%)	4825 (43.3%)	1658 (14.9%)	<.001
Chronic pulmonary disease	10,181 (30.9%)	7222 (21.9%)	11,442 (34.7%)	4098 (12.4%)	<.001
Alcohol abuse	1146 (25.7%)	959 (21.5%)	1595 (35.7%)	764 (17.1%)	<.001
Pulmonary hypertension	3684 (45.6%)	1323 (6.4%)	2247 (27.8%)	827 (10.2%)	<.001
Hypothyroidism	5881 (31.6%)	4011 (21.6%)	6934 (37.3%)	1761 (9.5%)	<.001
Liver disease	1124 (32.1%)	702 (20.1%)	1231 (35.2%)	444 (12.7%)	<.001
Fluid and electrolyte disorders	12,502 (33.7%)	6684 (18.0%)	10,916 (29.5%)	6946 (18.7%)	<.001
Peptic ulcer disease without bleeding	382 (33.2%)	230 (20.0%)	371 (32.3%)	166 (14.4%)	<.001
Metastatic cancer	757 (2.1%)	202 (0.7%)	289 (0.5%)	51 (0.3%)	<.001
Acquired immune deficiency syndrome	84 (29.8%)	49 (17.4%)	107 (37.9%)	42 (14.9%)	.127
Lymphoma	300 (41.8%)	119 (16.6%)	240 (33.5%)	58 (8.1%)	<.001
Rheumatoid arthritis/collagen vascular disease	1184 (29.6%)	867 (21.7%)	1555 (38.9%)	391 (9.8%)	<.001
Coagulopathy	2436 (26.0%)	1157 (12.3%)	2029 (21.6%)	3761 (40.1%)	<.001
Chronic blood loss anemia	379 (38.2%)	156 (15.7%)	231 (23.3%)	226 (22.8%)	<.001
Deficiency anemias	10,156 (38.2%)	4896 (18.4%)	8154 (30.7%)	3391 (12.7%)	<.001
Psychoses	1031 (34.2%)	681 (22.6%)	965 (32.0%)	337 (11.2%)	<.001
Depression	3792 (28.1%)	3002 (22.3%)	5151 (38.2%)	1536 (11.4%)	<.001
Paralysis	1457 (39.7%)	660 (18.0%)	1071 (29.2%)	484 (13.2%)	<.001
Other neurological disorders	4216 (42.1%)	1872 (18.7%)	2874 (28.7%)	1049 (10.5%)	<.001
Charlson comorbidity score	3.4 ± 1.4	2.7 ± 1.4	2.5 ± 1.4	2.9 ± 1.4	<.001
Hospital characteristics					
Bed size:					.002
Small	3994 (25.2%)	3407 (21.5%)	6494 (40.9%)	1969 (12.4%)	
Medium	10,687 (25.9%)	8478 (20.5%)	17,040 (41.3%)	5057 (12.3%)	
Large	21,067 (25.4%)	16,793 (20.2%)	34,849 (42.0%)	10,359 (12.5%)	
Location/teaching status of hospital:					.225
Rural	1209 (24.8%)	1034 (21.2%)	2046 (41.9%)	593 (12.1%)	
Urban nonteaching	7457 (25.7%)	6029 (20.7%)	11,942 (41.1%)	3639 (12.5%)	
Urban teaching	27,082 (25.5%)	21,615 (20.3%)	44,395 (41.8%)	13,153 (12.4%)	
Ownership:					<.001
Government	2699 (23.7%)	2419 (21.2%)	4795 (42.1%)	1477 (13.0%)	
Private, not-for-profit	26,612 (25.6%)	20,570 (19.8%)	43,876 (42.2%)	12,843 (12.4%)	
Private, for-profit	6437 (25.8%)	5689 (22.8%)	9712 (39.0%)	3065 (12.3%)	
Primary expected payer:					<.001
Medicare	27,033 (31.7%)	16,852 (19.8%)	32,048 (37.6%)	9260 (10.9%)	
Medicaid	3004 (23.4%)	2928 (22.8%)	5219 (40.7%)	1664 (13.0%)	
Private	3979 (12.3%)	6637 (20.5%)	16,720 (51.7%)	5019 (15.5%)	
Self-pay	974 (16.8%)	1336 (23.0%)	2654 (45.7%)	847 (14.6%)	
No charge	69 (13.4%)	128 (24.8%)	235 (45.5%)	84 (16.3%)	
Other	665 (19.9%)	765 (22.9%)	1438 (43.1%)	472 (14.1%)	
Median household income:					<.001
0-25th percentile	11,906 (27.1%)	9803 (22.3%)	17,212 (39.1%)	5068 (11.5%)	
26th-50th percentile	9182 (24.9%)	7590 (20.6%)	15,390 (41.8%)	4661 (12.7%)	
51st-75th percentile	8154 (24.5%)	6395 (19.2%)	14,393 (43.2%)	4393 (13.2%)	
76th-100th percentile	5857 (24.8%)	4376 (18.6%)	10,400 (44.1%)	2956 (12.5%)	

(*continued on next page*)

Table 1. (*continued*)

	Medical therapy only (n = 35,748)	Angio, no revasc, (n = 28,678)	PCI (n = 58,383)	CABG (n = 17,385)	*P* value
Discharge disposition					<.001
Home (self-care)	17,494 (18.4%)	22,461 (23.6%)	48,921 (51.4%)	6254 (6.6%)	
Skilled nursing facility	7472 (42.0%)	2263 (12.7%)	3473 (19.5%)	4603 (25.8%)	
Home health care	6721 (33.0%)	2910 (14.3%)	4753 (23.3%)	5987 (29.4%)	

Values are mean ± SD or n (%).
Note: Row percentages are displayed (eg, among female patients, 31.0% received medical therapy, 24.3% underwent angiography without revascularization, 36.2% underwent PCI, and 8.5% underwent CABG).
Angio, no revasc, angiography without revascularization; CABG, coronary artery bypass graft surgery; MI, myocardial infarction; PCI, percutaneous coronary intervention; TIA, transient ischemic attack.

stroke, and the secondary outcomes, variation in hospital cost and LOS, were examined within each treatment modality in unadjusted models, adjusted for patient factors only, and adjusted for both patient- and hospital-related factors. At each site, the mean cost and LOS for survivors were derived after trimming values to the 99th percentile to minimize the impact of outliers; variance in cost and LOS was characterized using the F test. Furthermore, only sites performing >10 coronary revascularization procedures annually were included in the analyses of cost and LOS to minimize the skewing of the data by outliers. The secondary end point, variation in assigned treatment modality, was also assessed in 3 separate models: unadjusted, adjusted for patient factors only, and adjusted for the patient- and site-related factors. Patient- and site-level variables included in models appear in Supplemental Table S2. A *P* value of <.05 was considered statistically significant. All analyses were conducted using SAS version 9.4.

Results

Patient and hospital characteristics

A total of 279,654 patients presented with NSTEMI during the study period. After excluding patients who (1) presented to a hospital that did not perform CABG (n = 80,060); (2) were transferred from an outside hospital (n = 54,851); (3) were transferred to an outside hospital (n = 3933); (4) experienced ST-elevation myocardial infarction during the same encounter (n = 423); or (5) were missing discharge disposition (n = 193), the final analytical cohort included 140,194 patients (weighted national estimate = 700,970); there were 3217, 3257, and 3111 participating hospitals in 2016, 2017, and 2018, respectively (Figure 1). In the overall cohort, 64,426 (45.9%) were not revascularized; of these, 35,748 (25.5%) received medical therapy alone and 28,678 (20.5%) underwent coronary angiography without revascularization. The remaining 75,768 patients underwent revascularization (58,383 [41.6%] PCI and 17,385 [12.4%] CABG).

Patient and hospital characteristics according to the treatment modality employed appear in Table 1. A greater proportion of men than women underwent PCI or CABG. White patients were more likely than Black, Hispanic, or Asian patients to undergo PCI and more likely than Black patients to undergo CABG. Patients who received medical therapy alone or coronary angiography without revascularization were older and less likely to have most traditional cardiovascular risk factors but more likely to have other comorbidities when compared with those who underwent PCI or CABG. Nearly 60% of each treatment group presented to large hospitals.

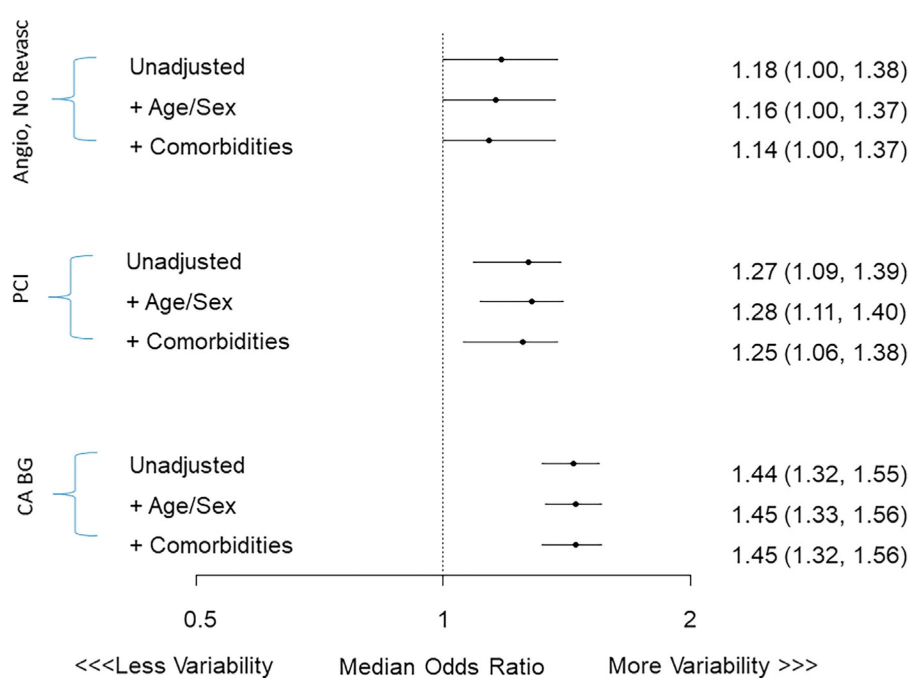


Figure 2.
Unadjusted and adjusted median odds ratios for the composite end point, in-hospital death, postprocedure myocardial infarction, or stroke by each treatment modality. Forrest plot of median odds ratios and corresponding 95% CIs for treatment with coronary angiography without revascularization, percutaneous coronary intervention (PCI), and coronary artery bypass graft (CABG). Angio, no revasc, angiography without revascularization.

Three-quarters of the cohort were treated at teaching institutions in urban locations, and most presented to private, not-for-profit hospitals.

Clinical outcomes

Unadjusted and adjusted MORs for the composite end point, in-hospital death, postprocedure myocardial infarction, or stroke according to each treatment modality appear in Figure 2. After adjusting for patient- and hospital-related factors, there was no significant variation in the incidence of the composite outcome across hospitals among patients undergoing coronary angiography without revascularization. In contrast, there was significant variation following PCI, where the MOR was 1.25 (95% CI, 1.06-1.38), and even more so following CABG, where the MOR was 1.45 (95% CI, 1.32-1.56).

Cost and LOS

The distribution of cost across hospitals for each treatment modality is depicted in Figure 3. Mean costs were highest for CABG, followed by PCI, coronary angiography without revascularization, and medical therapy alone ($48,656 [± SD $11,363], $22,176 [± SD $5615], $12,582 [± SD $3236] and $11,043 [± SD $4033, respectively]; $P < .001$ for all between-group comparisons). The variance in cost differed significantly across treatment modalities and was greatest for CABG, followed by PCI, medical therapy, and coronary angiography without revascularization ($P < .001$ for all between-group comparisons). The distribution of LOS across hospitals for each treatment modality is shown in Figure 4. Mean LOS was longest for CABG, followed by medical therapy, coronary angiography without revascularization, and PCI (11.1 [± SD 1.8], 4.9 [± SD 1.1], 3.8 [± SD 0.8], and 3.7 [± SD 0.8] days, respectively; $P < .001$ for all comparisons except PCI vs angiography without coronary revascularization, for which $P = .008$). Variation in LOS also differed significantly across treatment modalities and was greatest for CABG, followed by medical therapy and then by PCI and coronary angiography without revascularization, which were similar ($P < .001$ for all comparisons except PCI vs coronary angiography without revascularization, for which $P = .37$).

Treatment modality

Across all hospitals, the median revascularization rate was 54.3% (IQR, 46.8%-62.1%). Unadjusted and adjusted MORs for medical therapy, coronary angiography without revascularization, any coronary revascularization, PCI, and CABG appear in Figure 5. There was significant variation across sites in the utilization of treatment modalities, which was greatest for medical therapy; the degree of variation across hospitals was similar for the remaining 3 treatment modalities. MOR estimates within each treatment modality were similar, whether unadjusted, adjusted for patient characteristics only, or adjusted for both patient and hospital characteristics. After adjustment for patient and hospital characteristics, 2 similar patients were 1.47 (95% CI, 1.44-1.50) times more likely to be treated with medical therapy alone, 1.28 (95% CI, 1.25-1.30) times more likely to undergo angiography without revascularization, 1.31 (95% CI, 1.28-1.33) times more likely to undergo PCI, and 1.37 (95% CI, 1.34-1.40) times more likely to undergo CABG at 1 randomly selected hospital than at another (Central Illustration).

Unadjusted and adjusted MORs for in-hospital death, postprocedure myocardial infarction, or stroke according to each treatment modality are listed in Supplemental Table S3. After adjusting for patient- and hospital-related factors, there was no significant variation in the incidence of in-hospital death across the treatment modalities. However, the incidence of postprocedure myocardial infarction and stroke significantly varied among those treated with CABG. Stroke incidence also varied significantly among those treated with PCI. Event rates by treatment modality are presented in Supplemental Table S4. The composite end point occurred most frequently among patients undergoing CABG and least frequently among those treated with PCI (16% vs 4.5%; $P < .001$, respectively). Similarly, postprocedure myocardial infarction and stroke occurred most frequently following CABG and least frequently among those who underwent PCI (8.4% vs 2.7%; $P < .001$, respectively). In-hospital mortality was highest among those treated by medical therapy only (11.3%).

Discussion

Using a contemporary, nationally representative US cohort, we observed no significant hospital-level variation in the incidence of clinical events among patients who underwent coronary angiography without revascularization but observed significant variation among

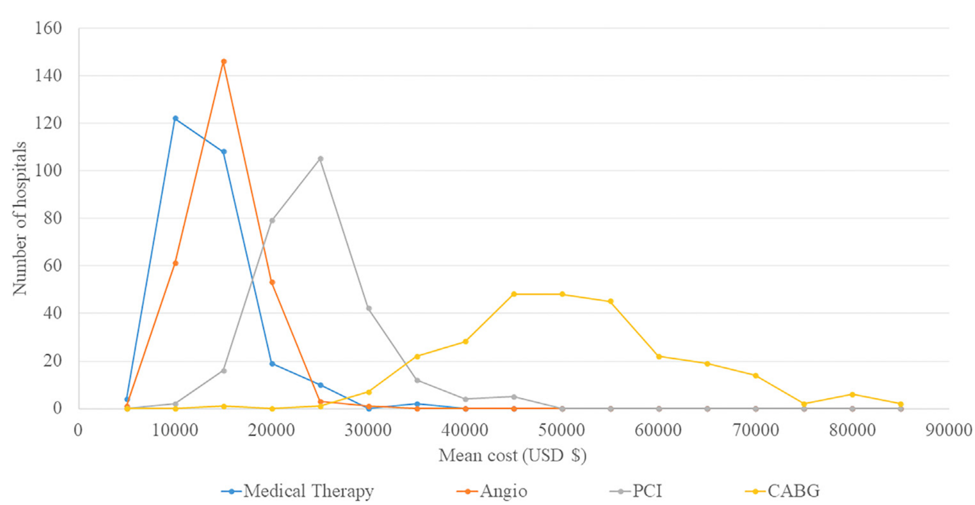


Figure 3.
Cost according to treatment modality. Mean costs and variance in costs across hospitals for medical therapy, coronary angiography without revascularization, any revascularization, PCI, and CABG. $P < .001$ for all between-group comparisons of mean cost and variability in costs. CABG, coronary artery bypass graft surgery; PCI, percutaneous coronary intervention.

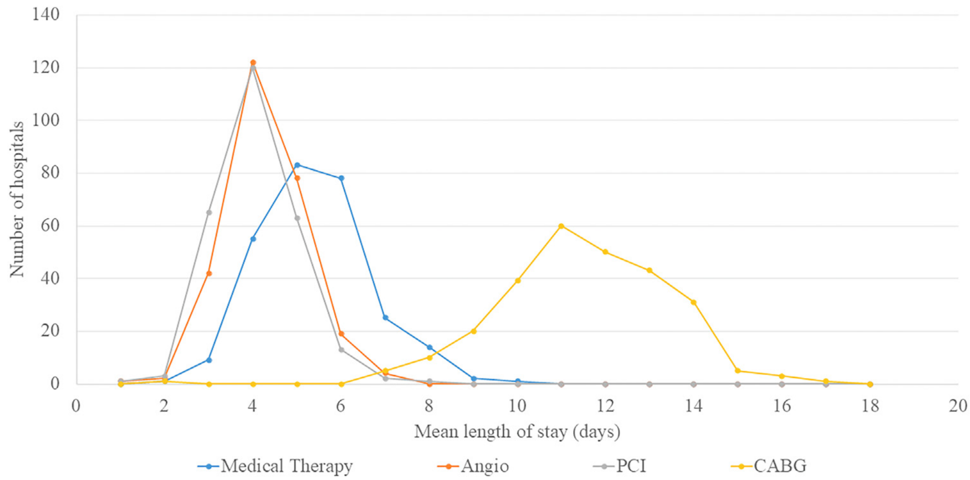


Figure 4.
Length of stay according to treatment modality. Mean length of stay and variance in length of stay across US hospitals for medical therapy, coronary angiography without revascularization, any revascularization, PCI, and CABG. *P* values for comparisons of means and variance are displayed in the footnote. Footnote: $P < .001$ for all comparisons of mean length of stay, except PCI vs coronary angiography without revascularization, where $P = .008$; $P < .001$ for all comparisons of variability in length of stay, except PCI vs angiography without revascularization, where $P = .37$. CABG, coronary artery bypass graft; PCI, percutaneous coronary intervention.

those treated with PCI or CABG, even after adjusting for hospital- and patient-level factors. Specifically, we found that 2 similar patients were 25% more likely to experience death, postprocedure myocardial infarction, or stroke following PCI and 45% more likely following CABG if they received care at 1 randomly selected hospital than at another. Significant hospital-level variation was also observed for cost and LOS following each treatment modality.

To our knowledge, no US studies have assessed hospital-level variation in patient outcomes after PCI or CABG among patients presenting with NSTEMI. Heterogeneity in outcomes following PCI and CABG has been demonstrated across countries and hospitals in Europe, Asia, and Oceania. In a cross-sectional cohort study of short-term outcomes after revascularization with PCI or CABG for NSTEMI at hospitals in 6 high-income countries, 30-day mortality ranged from 7.6% in the Netherlands to 14% in Taiwan.[2] Likewise, in a representative sampling of CABG-performing hospitals in Australia and New Zealand that controlled for patient-level characteristics, post-CABG mortality varied by approximately 4-fold.[7] In the present study, we found significant variation in outcomes across US hospitals following PCI and CABG for patients presenting with NSTEMI, albeit less so than that reported outside of the US. US News and World Reports, HealthGrades, LeapFrog, and Consumer Reports hospital rating systems frequently lack correlation with established quality metrics.[8–10] Furthermore, there is tremendous inconsistency across these ratings; in comprehensive,

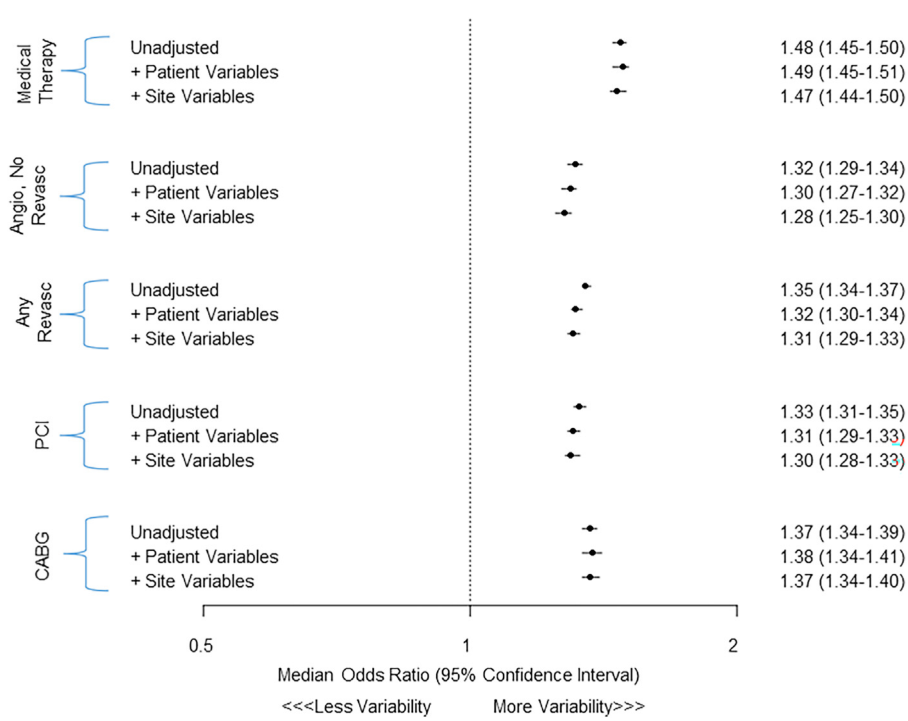
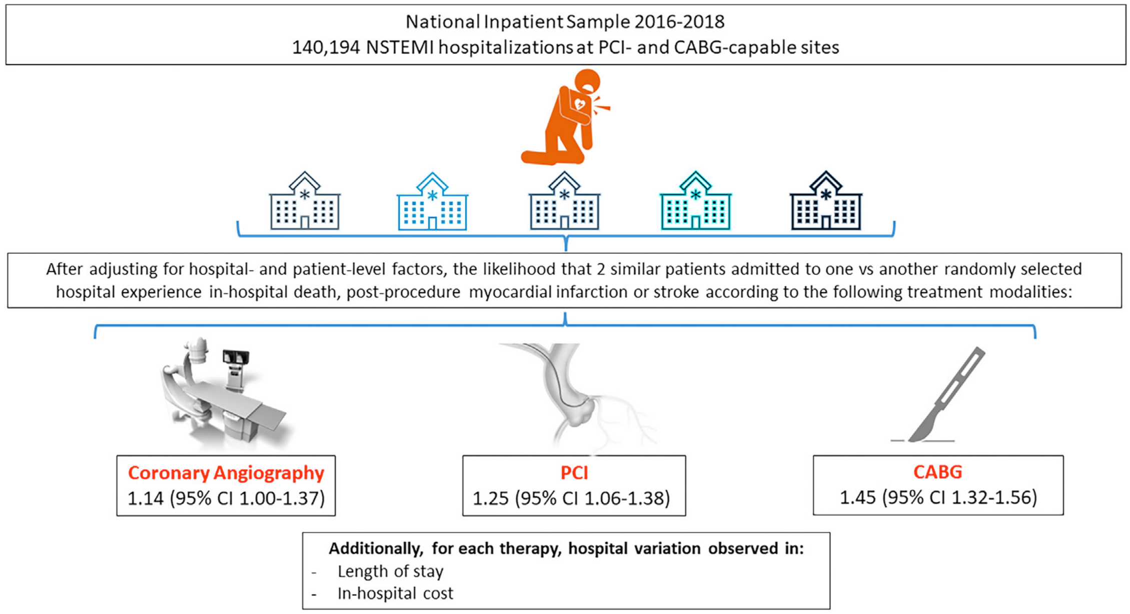


Figure 5.
Unadjusted and adjusted median odds ratios for treatment rendered by medical therapy, coronary angiography without revascularization, any coronary revascularization, PCI, and CABG. Forest plot of median odds ratios and corresponding 95% CIs for treatment with medical therapy, coronary angiography without revascularization, any revascularization, percutaneous coronary intervention (PCI), and coronary artery bypass graft (CABG) surgery. Any Revasc is either PCI or CABG. Angio, no revasc, angiography without revascularization.



Central Illustration.
Variation in clinical outcomes, length of stay, and cost during hospitalizations for non–ST-elevation at US sites with percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG) surgery capability.

all-specialty rankings, no institution was rated as high-performing across all 4 ranking systems, and only 10% of hospitals that were ranked as high-performing by 1 organization were also ranked as high-performing by another.[8,10] More consistent and accurate methods for objectively assessing variation in quality are needed. Risk-adjusted claims data from studies like ours will play an important role in this regard.

An array of factors might explain the variation observed in PCI and CABG outcomes in our study. Several prior analyses have found that operator volume is strongly associated with in-hospital mortality after PCI and varies across hospitals.[11–13] Utilization of intracoronary imaging has also been linked to variation in PCI outcomes, and patients receiving image-guided PCI have lower short-term mortality and lower target vessel revascularization compared with those treated with angiography-guided PCI.[14] Differential rates of bleeding complications might have also contributed to variations in the incidence of in-hospital mortality.[15] Ongoing quality assessment and improvement efforts are critical to optimizing outcomes at all centers, some of which are focused on factors such as those noted above. Benchmarking, using data from the National Cardiovascular Data Registry's CathPCI database and the Society of Thoracic Surgeons National Database, might also reduce interhospital variation in postprocedural outcomes.

Although it was not unexpected that the costs for PCI or CABG were 2- and 5-fold higher when compared with medical therapy or coronary angiography without revascularization, the significant hospital-level variation in cost within each treatment modality was of concern. This was most apparent for CABG, where the mean hospitalization cost ranged from ~$25,000 to ~$85,000. Whether this variation was driven by differential reimbursement, expenses, or both, requires further investigation. Finally, while the median LOS observed for CABG was similar to that reported by other investigators,[16] hospital variation in LOS following CABG was substantial. While it remains possible that the degree of variation observed in clinical outcome, costs, and LOS resulted from unmeasured patient characteristics for which we could not adjust in our multivariable models; it is more plausible that true differences in care at these hospitals may have translated into differential outcomes. Were there residual imbalances in patient- or hospital-level factors, one might have expected variation in outcome following diagnostic coronary angiography, but this was not observed. Public reporting of outcomes and greater price transparency in the marketplace may be necessary first steps toward narrowing some of these gaps through robust quality improvement initiatives.[17] Furthermore, future research using datasets that include more granular detail about procedural and medical therapy strategies, as well as disease severity, is needed to address these issues.

Limitations

There are noteworthy limitations to this study. First, because it was a retrospective observational analysis, we cannot rule out residual unmeasured confounding and selection bias; information on factors such as operator or hospital volume and adherence to quality measures was not available. Second, risk stratification was not possible without angiographic and other procedural data, laboratory results, and imaging findings required for calculating clinical risk scores. Third, only in-hospital outcomes are available in the NIS; consequently, it was not possible to characterize variation in longer-term clinical outcomes or costs associated with each treatment strategy. Fourth, provider identifiers were not available to enable the evaluation of individual vs hospital influences on outcomes. Fifth, our cohort may not represent all institutions in the United States that care for patients with NSTEMI as many do not offer all 3 of the treatment modalities studied herein. Because we included hospitals simultaneously offering all 3 treatment modalities, our sample comprised a greater proportion of urban teaching hospitals. It is possible that if all institutions were included, we might have observed higher or lower degrees of variability. Finally, the NIS randomly sampled 20% of admissions from participating hospitals, and it remains possible that observed treatment patterns or associated outcomes would differ were all consecutive admissions included.

Conclusion

In a nationwide analysis of US hospitalizations for NSTEMI, we observed significant hospital-level variation in outcome following PCI and CABG, despite accounting for patient- and hospital-level factors. Further investigation into clinical and hospital factors that drive such variation is needed.

Declaration of competing interests

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Ethics statement and patient consent

This study has adhered to the relevant ethical guidelines.

Supplementary material

To access the supplementary material accompanying this article, visit the online version of the Journal of the Society for Cardiovascular Angiography & Interventions at 10.1016/j.jscai.2022.100532.

References

1. Windecker S, Kolh P, Alfonso F, et al. 2014 ESC/EACTS guidelines on myocardial revascularization: the Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) Developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI). *Eur Heart J*. 2014;35(37):2541–2619. https://doi.org/10.1093/EURHEARTJ/EHU278
2. Cram P, Hatfield LA, Bakx P, et al. Variation in revascularisation use and outcomes of patients in hospital with acute myocardial infarction across six high income countries: cross sectional cohort study. *BMJ*. 2022;377:e069164–e069165. https://doi.org/10.1136/bmj-2021-069164
3. Chung SC, Sundström J, Gale CP, et al. Comparison of hospital variation in acute myocardial infarction care and outcome between Sweden and United Kingdom: population based cohort study using nationwide clinical registries. *BMJ*. 2015; 351:h3913–h3914. https://doi.org/10.1136/bmj.h3913
4. Krumholz HM, Chen J, Rathore SS, Wang Y, Radford MJ. Regional variation in the treatment and outcomes of myocardial infarction: investigating New England's advantage. *Am Heart J*. 2003;146(2):242–249. https://doi.org/10.1016/S0002-8703(03)00237-0
5. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project. Overview of the national (nationwide) inpatient sample (NIS). Accessed June 17, 2022. https://www.hcup-us.ahrq.gov/nisoverview.jsp
6. Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project. Elixhauser comorbidity software refined for ICD-10-CM. Accessed June 17, 2022. https://www.hcup-us.ahrq.gov/toolssoftware/comorbidityicd10/comorbidity_icd10.jsp
7. Patel A, Ngo L, Woodman RJ, et al. Institutional variation in early mortality following isolated coronary artery bypass graft surgery. *Int J Cardiol*. 2022;362:35–41. https://doi.org/10.1016/J.IJCARD.2022.04.080
8. Shah RF, Manning DW, Butler BA, Bilimoria KY. Do hospital rankings mislead patients? Variability among national rating systems for orthopaedic surgery. *J Am Acad Orthop Surg*. 2020;28(17):e766–e773. https://doi.org/10.5435/JAAOS-D-19-00165
9. Austin JM, Jha AK, Romano PS, et al. National hospital ratings systems share few common scores and may generate confusion instead of clarity. *Health Aff (Millwood)*. 2015;34(3):423–430. https://doi.org/10.1377/HLTHAFF.2014.0201/SUPPL_FILE/2014-0201_AUSTIN_APPENDIX.PDF.
10. Bhattacharyya T, Freiberg AA, Mehta P, Katz JN, Ferris T. Measuring The report card: the validity of pay-for-performance metrics in orthopedic surgery. *Health Aff (Millwood)*. 2009;28(2):526–532. https://doi.org/10.1377/hlthaff.28.2.526
11. Badheka AO, Patel NJ, Grover P, et al. Impact of annual operator and institutional volume on percutaneous coronary intervention outcomes: A 5-year United States experience (2005-2009). *Circulation*. 2014;130(16):1392–1406. https://doi.org/10.1161/CIRCULATIONAHA.114.009281
12. Post PN, Kuijpers M, Ebels T, Zijlstra F. The relation between volume and outcome of coronary interventions: a systematic review and meta-analysis. *Eur Heart J*. 2010; 31(16):1985–1992. https://doi.org/10.1093/EURHEARTJ/EHQ151
13. Inohara T, Kohsaka S, Yamaji K, et al. Impact of institutional and operator volume on short-term outcomes of percutaneous coronary intervention: A report from the Japanese nationwide registry. *JACC Cardiovasc Interv*. 2017;10(9):918–927. https://doi.org/10.1016/J.JCIN.2017.02.015
14. Hannan EL, Zhong Y, Reddy P, et al. Percutaneous coronary intervention with and without intravascular ultrasound for patients with complex lesions: utilization, mortality, and target vessel revascularization. *Circ Cardiovasc Interv*. 2022;15(6):e011687–e011688. https://doi.org/10.1161/CIRCINTERVENTIONS.121.011687
15. Sawayama Y, Yamaji K, Kohsaka S, et al. Variation in-hospital mortality and its association with percutaneous coronary intervention-related bleeding complications: A report from nationwide registry in Japan. *PLOS ONE*. 2021; 16(12):e0261371–e0261372. https://doi.org/10.1371/JOURNAL.PONE.0261371
16. Elbaz-Greener G, Rozen G, Kusniec F, et al. Trends in utilization and safety of in-hospital coronary artery bypass grafting during a non-ST-segment elevation myocardial infarction. *Am J Cardiol*. 2020;134:32–40. https://doi.org/10.1016/J.AMJCARD.2020.08.019
17. Westert GP, Groenewoud S, Wennberg JE, et al. Medical practice variation: public reporting a first necessary step to spark change. *Int J Qual Health Care*. 2018;30(9): 731–735. https://doi.org/10.1093/INTQHC/MZY092