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Costs Associated With Access Site and Same-Day Discharge Among Medicare Beneficiaries Undergoing Percutaneous Coronary Intervention

An Evaluation of the Current Percutaneous Coronary Intervention Care Pathways in the United States

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ABSTRACT

OBJECTIVES The aim of this study was to examine the independent impact of various care pathways, including those involving transradial intervention (TRI) and same-day discharge (SDD) after elective percutaneous coronary intervention (PCI), on hospital costs.

BACKGROUND PCI is associated with costs of $10 billion annually. Alternative payment models for PCI are being implemented, but few data exist on strategies to reduce costs. Various PCI care pathways, including TRI and SDD, exist, but their association with costs and outcomes is unknown.

METHODS In total, 279,987 PCI patients eligible for SDD in the National Cardiovascular Data Registry CathPCI Registry linked to Medicare claims files were analyzed. Hospital costs in 2014 U.S. dollars were estimated using cost-to-charge ratios. Propensity scores for TRI and SDD, with propensity adjustment via inverse probability weighting, was performed.

RESULTS Of the 279,987 PCI procedures, TRI was used in 9.0% (13.5% of which were SDD), and SDD was used in 5.3% of cases (23.1% of which were TRI). TRI (vs. transfemoral intervention) was associated with lower adjusted costs of $916 (95% confidence interval [CI]: $778 to $1,035), as was SDD ($3,502; 95% CI: $3,486 to $3,902). The adjusted cost associated with TRI and SDD was $13,389 (95% CI: $13,161 to $13,607), while the cost associated with transfemoral intervention and non-same-day discharge was $17,076 (95% CI: $16,999 to $17,147), a difference of $3,689 (95% CI: $3,486 to $3,902; $p < 0.0001$). Shifting current practice from transfemoral intervention non-same-day discharge to TRI SDD by 30% could potentially save a hospital performing 1,000 PCIs each year $1 million and the country $300 million annually.

CONCLUSIONS Among Medicare beneficiaries, TRI with SDD was independently associated with fewer complications and lower in-hospital costs. These findings have important implications for changing the current PCI care pathways to improve outcomes and reduce costs. (J Am Coll Cardiol Intv 2017;10:342–51)

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As the pressure on the U.S. health care system to reduce costs increases (1,2), hospitals are increasingly challenged to deliver higher quality care at lower costs (1–9). The Patient Protection and Affordable Care Act via the Bundled Payments for Care Improvement (BPCI) initiative applies direct pressure to hospitals to have both financial and performance accountability for care (3,4,10–15). These and future health care delivery models will provide strong incentives for hospitals to improve the efficiency of the care they provide. Percutaneous coronary intervention (PCI) is a prototypical example of shifting payment strategies. PCI was once primarily conducted, and paid for, as an inpatient procedure, until the Recovery Audit Contractor program began scrutinizing the clinical justification for paying for PCI as an inpatient, as opposed to an outpatient, procedure. Recently the Centers for Medicare and Medicaid Services (CMS) created and implemented the "2 midnight rule" to pay an inpatient fee only for PCI patients who spend at least 2 nights in the hospital, creating a strong incentive for hospitals to consider same-day discharge (SDD) to decrease their costs (13–19). In the face of decreasing reimbursements (1,2), existing care pathways need to be critically examined to define the safest and most efficient strategies.

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PCI procedures are an important contributor to hospital costs in the United States. PCI procedures are performed in 600,000 patients annually (20) and have the highest aggregate costs of all cardiovascular procedures (including cardiac surgery) and the third highest aggregate cost of any surgical procedure, estimated at approximately $10 billion annually (10–14,21–24). Recently both transradial intervention (TRI) and SDD after PCI have been introduced as approaches that can substantially reduce hospitals' cost to perform PCI. However, no study to date has examined the independent impact of various care pathways, including those involving TRI and SDD after PCI, on hospital costs. To address this gap in knowledge, we used data from Medicare claims files linked to the American College of Cardiology (ACC) National Cardiovascular Data Registry (NCDR) CathPCI Registry to examine the costs and outcomes associated with TRI and SDD from a hospital's perspective.

METHODS

POPULATION. The study population consisted of Medicare fee-for-service beneficiaries undergoing PCI between July 1, 2009, and December 31, 2012. Both inpatient and outpatient PCI procedures were included in this analysis. The inpatient PCI population was identified using the CMS Inpatient Research Identifiable Files (RIF) (International Classification of Diseases-Ninth Revision codes 00.66, 36.06, and 36.07). Outpatient procedures were identified using the CMS Outpatient RIF and the corresponding Current Procedural Terminology codes 92982, 92980, G0290, 92981, 92984, G0290, and G0291. A waiver of the requirement to obtain informed consent and Institutional Review Board approval was obtained from the Saint Luke's Hospital Institutional Review Board.

LINKAGE OF MEDICARE CLAIMS DATA TO ACC NCDR CathPCI REGISTRY. The time period for this analysis was the third quarter of 2009 through the third quarter of 2012. To create a national dataset with detailed clinical and claims information, we linked the Medicare claims data to the ACC NCDR CathPCI Registry (25). Unique patient identifiers, such as Social Security number, were not available for use in the ACC NCDR CathPCI Registry to perform exact matching. We therefore performed a probabilistic match using the following identifiers: hospital National Provider

ABBREVIATIONS AND ACRONYMS

ACC = American College of Cardiology

BPCI = Bundled Payments for Care Improvement

CI = confidence interval

CMS = Centers for Medicare and Medicaid Services

IPW = inverse probability weighting

LOS = length of stay

NCDR = National Cardiovascular Data Registry

NSDD = non-same-day discharge

PCI = percutaneous coronary intervention

RIF = Research Identifiable Files

SDD = same-day discharge

TFI = transfemoral intervention

TRI = transradial intervention

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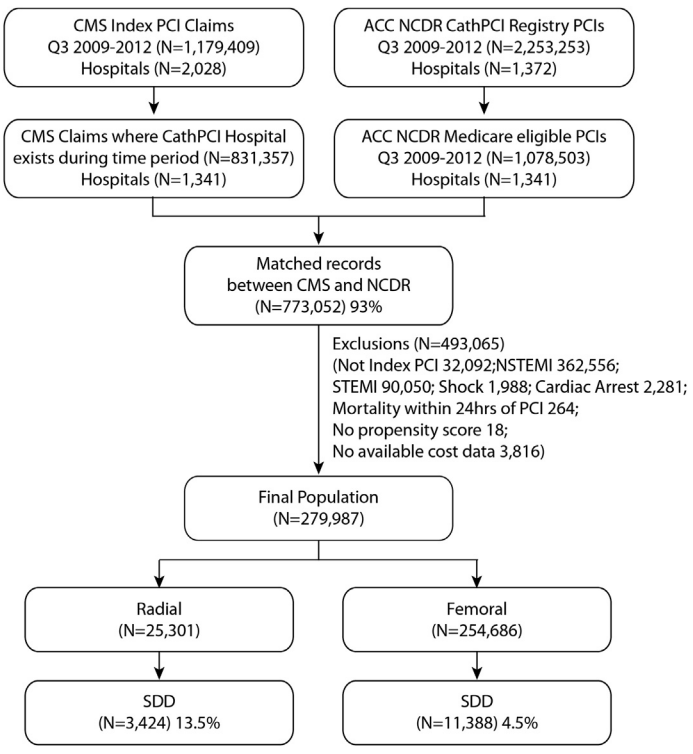
FIGURE 1 Inclusions, Exclusions, and Flow Diagram of Probabilistic Matching



ACC = American College of Cardiology; CMS = Centers for Medicare and Medicaid Services; NCDR = National Cardiovascular Data Registry; NSTEMI = non-ST-segment elevation myocardial infarction; PCI = percutaneous coronary intervention; Q3 = third quarter; SDD = same-day discharge; STEMI = ST-segment elevation myocardial infarction.

Identifier number, date of birth, sex, and admission date (25). We required exact matches for hospital National Provider Identifier number, date of birth, and sex. The date of admission could vary by ±1 day. There were 831,357 CMS claims available for matching. Using a deterministic matching strategy, 749,366 of the 831,357 possible CMS claims (93%) were matched to the CathPCI Registry procedures. Of these 749,366 PCI procedures, the following procedures were excluded: procedures clearly indicated for inpatient stay (ST-segment elevation myocardial infarction [n = 90,050, 12.02%], non-ST-segment elevation myocardial infarction [n = 380,051, 49.16%], chronic total occlusion [n = 7,565, 0.98%], intra-aortic balloon pump [n = 1,254, 0.16%], cardiogenic shock [n = 1,002, 0.08%], and cardiac arrest within 24 h [n = 590, 0.08%]), salvage PCI (n = 49 [0.01%]), patients who died in-hospital within 24 h of PCI (n = 53 [0.01%]), beneficiaries with missing variables for whom propensity scores could not be calculated (n = 10,380 [1.34%]), and procedures for which cost variables were missing (n = 2,071 [0.27%]) (Figure 1). The final cohort available for analysis comprised 279,987 procedures.

ASCERTAINMENT OF KEY DATA ELEMENTS. Determination of arterial access, transfemoral or transradial, was derived from the ACC NCDR Cath PCI Registry. When more than 1 access site was used, the primary access site for the PCI was classified as the access site used to perform the majority of the PCI. Determination of SDD was made from the ACC NCDR Cath PCI Registry when discharge occurred on the date of the PCI procedure.

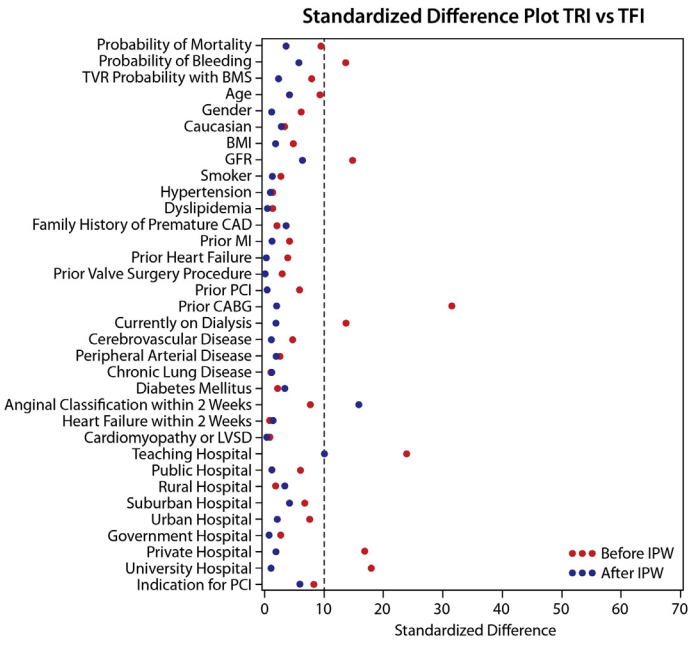
ESTIMATION OF COST. The primary outcome was hospital costs associated with PCI. When possible, we used hospital-level, cost center-specific cost-to-charge ratios to estimate the costs associated with PCI episodes of care. Cost was estimated using data from RIF using standard methodology described in detail previously (26). Briefly, using inpatient and outpatient RIF, beneficiary claims were collapsed into single PCI episodes of care. Charges were derived from hospital revenue codes as reported to Medicare. Cost-to-charge ratios for each revenue code are not publicly available for each hospital. However, cost-to-charge ratios are publically available by cost center using forms 2552-96 and 2552-10, worksheet C. "Cost centers" are groupings of similar resources used for services during an episode of care (https://www.cms.gov/Research-Statistics-Data-and-Systems/Downloadable-Public-Use-Files/Cost-Reports/Hospital-2010-form.html). When hospital revenue codes were mapped to specific cost centers, those overall cost-to-charge ratios were used to estimate costs. A crosswalk of revenue codes to cost centers was obtained from the 2009-2012 documents (http://www.dartmouthatlas.org/tools/downloads.aspx?tab=39). When revenue codes could not be mapped to cost centers, the overall hospital cost-to-charge ratio was used to estimate costs. Once the appropriate cost-to-charge ratio was determined, the charges for an episode of care for each cost center were multiplied by the cost-to-charge ratio. These hospital costs were summed over the admission and normalized across hospitals to the national average by applying the Dartmouth Atlas of Health Care 2012 Hospital Referral Region level price, age, sex, and race adjustment (http://www.dartmouthatlas.org/tools/downloads.aspx). Costs were inflated to 2014 dollars by using the medical consumer price index. To remove extreme outliers, individual hospital costs were Winsorized by trimming to the 99th percentile (27,28).

CLINICAL OUTCOMES. Secondary outcomes of interest included post-PCI bleeding, vascular complications, blood transfusions, and length of stay (LOS).

Post-PCI bleeding was defined according to the CathPCI Registry bleeding definition and consisted of: 1) suspected bleeding with transfusion; 2) a decrease in hemoglobin of >3.0 g/dl; or 3) a procedural intervention to correct the bleeding event. Vascular complications collected by the CathPCI Registry included access-site occlusion, peripheral embolization, dissection, pseudoaneurysm formation, arteriovenous fistula, or other vascular access-site complications requiring intervention.

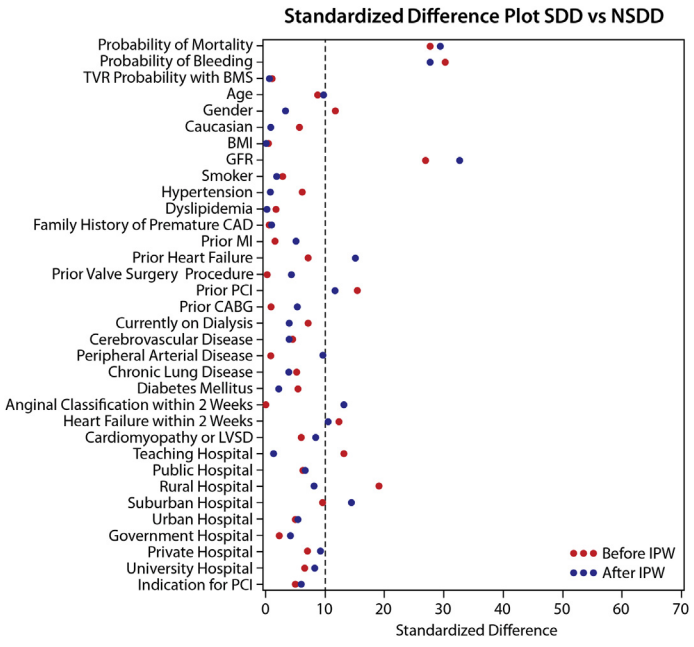
STATISTICAL ANALYSIS. Demographic data are described as mean ± SD for continuous variables and as numbers for categorical variables. To obtain independent costs for each arterial access site and SDD, and to mitigate selection bias and confounding, we developed 3 separate propensity score models as follows: 1) a logistic regression model to predict use of TRI (vs. transfemoral intervention [TFI]); 2) a logistic regression model to predict SDD (vs. non-same-day discharge [NSDD]); and 3) a multinomial logistic regression model to obtain predicted probabilities of TRI SDD, TFI SDD, and TRI NSDD, with TFI NSDD as the comparator for all (29-34). All 3 propensity score models included the following patient-level variables: age, sex, race, smoking status, diabetes, hypertension, dyslipidemia, a family history of coronary artery disease, prior myocardial infarction, prior congestive heart failure, estimated glomerular filtration rate, prior valve surgery, prior PCI, prior coronary artery bypass graft surgery, current dialysis, prior cerebrovascular disease, prior peripheral vascular disease, chronic lung disease, PCI indication (elective or unstable angina), procedure status (urgent or elective), severity of angina (angina class), current heart failure (heart failure symptoms in the prior 2 weeks), left ventricular dysfunction, perioperative evaluation, prior cardiac arrest, number of diseased vessels, probability of bleeding according to the NCDR bleeding risk model (a composite of several variables), probability of mortality according to the NCDR mortality risk model (which includes several additional variables), probability of restenosis according to the NCDR target vessel revascularization risk prediction model (which also includes several additional variables), hospital type (teaching hospital, public hospital, urban vs. suburban vs. rural hospital, government hospital, private vs. community hospital, university hospital), and regional census divisions. Variables such as use of anticoagulant agents and LOS were not included in the propensity model, because they are directly related to access site and in the causal pathway of costs. To estimate the independent costs of access site (TRI vs. TFI), a generalized linear cost model was developed using inverse probability weighting (IPW) (13), with total hospital cost as the dependent variable and TRI (vs. TFI) as the independent variable. To estimate the independent costs of SDD versus NSDD, a second, separate generalized linear cost model was developed using IPW (13), with total hospital cost as the dependent variable and SDD (vs. NSDD) as the independent variable. These 2 models yielded the adjusted costs of TRI versus TFI and SDD versus NSDD. To estimate the independent costs of the various combinations of PCI care pathways, we developed a third generalized linear cost model, with total hospital cost as the dependent variable and the various combination of PCI care pathways as the independent variables, with predicted probabilities of these care pathway variables (obtained from the multinomial propensity model) included as adjustment covariates. This modeling approach allowed us to obtain independent costs associated with the various care pathways while adjusting for factors that influence access-site selection and SDD status selection.

FIGURE 2 Standardized Differences After Inverse Probability Weighting Adjustment for Transradial Intervention



The x axis represents the standardized differences on a scale ranging from 0% to 100%. BMI = body mass index; BMS = bare-metal stent(s); CABG = coronary artery bypass grafting; CAD = coronary artery disease; GFR = glomerular filtration rate; IPW = inverse probability weighting; LVSD = left ventricular systolic dysfunction; MI = myocardial infarction; PCI = percutaneous coronary intervention; TFI = transfemoral intervention; TRI = transradial intervention.

FIGURE 3 Standardized Differences After Inverse Probability Weighting Adjustment for Same-Day Discharge



The x axis represents the standardized differences on a scale ranging from 0% to 100%. BMI = body mass index; BMS = bare-metal stent(s); CABG = coronary artery bypass grafting; CAD = coronary artery disease; GFR = glomerular filtration rate; IPW = inverse probability weighting; LVSD = left ventricular systolic dysfunction; MI = myocardial infarction; NSDD = non-same-day discharge; PCI = percutaneous coronary intervention; SDD = same-day discharge; TVR = target vessel revascularization.

In the IPW models, individual weights were stabilized to account for the effect of extreme weights in the model (13). To ascertain the adequacy of the model with IPW, standardized differences in covariate imbalances with and without the IPW were calculated for the first 2 models (**Figures 2 and 3**, **Table 1**) (14–16). The following variables remained unbalanced after IPW adjustment, as defined by a maximal standard difference of >10%: PCI indication, census division, and mortality risk; these were included as additional covariates in the final cost and outcome models. Costs were trimmed back to the 99th percentile to remove extreme outliers (27,28). Then bootstrapping using 1,000 replicates with replacement was applied to the models to account for skewness in the data (35) as follows: we sampled from 1 group, calculated that group's mean and its 95% confidence interval [CI], sampled from a comparator group, calculated that group's mean and its 95% CI, then calculated the difference between those means. This was repeated 1,000 times. The differences obtained themselves had a distribution and a variance, from which we estimated the 95% CI. We report the mean and 95% CI for costs of various care pathways and the cost differences between the means of various care pathways.

Secondary outcomes. Other outcomes of interest included post-PCI bleeding, vascular complications, blood transfusion, and LOS. Adjusted differences were estimated using an IPW generalized linear regression model for LOS and an IPW logistic regression model for bleeding.

Budget impact analysis. We used the mean costs of the various care pathways to estimate the impact of converting from TFI NSDD (the current most common care pathway) to TRI SDD, TRI NSDD, and TFI SDD pathways for a hypothetical hospital performing 1,000 elective PCI procedures annually and for the country, performing 600,000 PCI procedures annually (36).

Statistical significance for all analyses was defined as $p < 0.05$. All analyses were performed at Saint Luke's Mid America Heart Institute using SAS version 9.3 (SAS Institute, Cary, North Carolina).

RESULTS

DEMOGRAPHIC AND DESCRIPTIVE STATISTICS. Of the 279,987 PCI procedures, TRI was performed in 25,301 (9.0%), and SDD occurred in 14,812 (5.3%). TRI and SDD occurred in 3,424 (1.2%), TFI and SDD occurred in 11,388 (4.1%), TRI and NSDD occurred in 21,877 (7.8%), and TFI and NSDD was the most common post-PCI care pathway, occurring in 243,298 (86.9%). The study population is depicted in **Figure 1**. Clinical demographics and hospital and procedural characteristics of the cohort are described in **Table 1**. In general, TRI and SDD patients were younger, were more often white men, and had a lower prevalence of cardiovascular risk factors and comorbidities. Unfractionated heparin was more frequently used in TRI and SDD patients, and bivalirudin was used less often. Procedural and fluoroscopy times were slightly longer with TRI, while the contrast volume used was lower with TRI.

PROPENSITY SCORE MODEL AND IPW ADJUSTMENT. **Figures 2 and 3** depict the standardized differences in all variables included in the propensity score model after IPW adjustment for both TRI and SDD.

HOSPITAL COSTS. The total unadjusted PCI costs associated with TRI were \$14,316 ± 9,089 versus \$15,866 ± 10,140 for TFI, which is a difference of \$1,550 favoring TRI ($p < 0.001$). After risk adjustment, the difference was \$916 (95% CI: \$778 to \$1,035; $p < 0.001$) favoring TRI.

The total unadjusted PCI costs for SDD were \$12,449 ± 8,028 versus \$15,909 ± 10,129 for NSDD, a difference of \$3,460 favoring SDD ($p < 0.001$). After

TABLE 1 Baseline Clinical, Demographic, and Procedural Characteristics

	Total (n = 279,987)	TRI SDD (n = 3,424)	TRI NSDD (n = 21,877)	TFI SDD (n = 11,388)	TFI NSDD (n = 243,298)	p Value
Demographics						
Age (yrs)	71.8 ± 8.8	70.7 ± 8.2	71.1 ± 8.6	71.2 ± 8.7	71.9 ± 8.8	<0.001
Sex						<0.001
Male	178,703 (63.8)	2,453 (71.6)	14,377 (65.7)	7,774 (68.3)	154,099 (63.3)	
Female	101,284 (36.2)	971 (28.4)	7,500 (34.3)	3,614 (31.7)	89,199 (36.7)	
Race (white)	253,126 (90.4)	3,191 (93.2)	19,911 (91.0)	10,421 (91.5)	219,603 (90.3)	<0.001
BMI	29.8 ± 19.0	30.3 ± 7.2	30.7 ± 23.8	29.6 ± 8.3	29.7 ± 19.0	<0.001
History						
Current/recent smoker (≤1 yr)	42,042 (15.0)	562 (16.4)	3,467 (15.8)	1,803 (15.8)	36,210 (14.9)	<0.001
Hypertension	249,234 (89.0)	3,008 (87.9)	19,426 (88.8)	9,899 (86.9)	216,901 (89.2)	<0.001
Dyslipidemia	241,681 (86.3)	3,042 (88.8)	18,689 (85.4)	9,824 (86.3)	210,126 (86.4)	<0.001
Family history of premature CAD	61,042 (21.8)	816 (23.8)	4,901 (22.4)	2,444 (21.5)	52,881 (21.7)	0.003
Prior MI	87,047 (31.1)	1,088 (31.8)	6,328 (28.9)	3,618 (31.8)	76,013 (31.2)	<0.001
Prior heart failure	43,763 (15.6)	474 (13.8)	3,159 (14.4)	1,491 (13.1)	38,639 (15.9)	<0.001
Prior valve surgery/procedure	6,189 (2.2)	74 (2.2)	388 (1.8)	258 (2.3)	5,469 (2.2)	<0.001
Prior PCI	136,403 (48.7)	1,845 (53.9)	9,805 (44.8)	6,447 (56.6)	118,306 (48.6)	<0.001
Prior CABG	69,372 (24.8)	488 (14.3)	2,929 (13.4)	3,237 (28.4)	62,718 (25.8)	<0.001
Currently on dialysis	9,619 (3.4)	35 (1.0)	337 (1.5)	306 (2.7)	8,941 (3.7)	<0.001
Cerebrovascular disease	46,471 (16.6)	500 (14.6)	3,302 (15.1)	1,732 (15.2)	40,937 (16.8)	<0.001
Peripheral arterial disease	49,626 (17.7)	545 (15.9)	3,711 (17.0)	2,037 (17.9)	43,333 (17.8)	<0.001
Chronic lung disease	49,868 (17.8)	536 (15.7)	3,873 (17.7)	1,830 (16.1)	43,629 (17.9)	<0.001
Diabetes mellitus	113,772 (40.6)	1,271 (37.1)	8,762 (40.1)	4,376 (38.4)	99,363 (40.8)	<0.001
Catheterization laboratory visit						
PCI indication						<0.001
Staged elective PCI	46,281 (16.5)	641 (18.7)	2,849 (13.0)	2,073 (18.2)	40,718 (16.7)	
Other	233,706 (83.5)	2,783 (81.3)	19,028 (87.0)	9,315 (81.8)	202,580 (83.3)	
PCI status						<0.001
Elective	231,030 (82.5)	3,239 (94.6)	18,049 (82.5)	10,596 (93.0)	199,146 (81.9)	
Urgent	48,243 (17.2)	185 (5.4)	3,788 (17.3)	777 (6.8)	43,493 (17.9)	
Emergent	714 (0.3)	0 (0.0)	40 (0.2)	15 (0.1)	659 (0.3)	
CAD presentation						<0.001
No symptoms, no angina	59,476 (21.2)	669 (19.5)	4,026 (18.4)	2,359 (20.7)	52,422 (21.5)	
Symptoms unlikely to be ischemic	19,964 (7.1)	234 (6.8)	1,541 (7.0)	682 (6.0)	17,507 (7.2)	
Stable angina	123,179 (44.0)	1,574 (46.0)	10,726 (49.0)	5,621 (49.4)	105,258 (43.3)	
Unstable angina	77,368 (27.6)	947 (27.7)	5,584 (25.5)	2,726 (23.9)	68,111 (28.0)	
Cardiomyopathy or left ventricular systolic dysfunction	32,919 (11.8)	352 (10.3)	2,564 (11.7)	1,128 (9.9)	28,875 (11.9)	<0.001
Procedure information						
Contrast volume	186.1 ± 89.8	159.5 ± 77.6	180.2 ± 85.2	168.5 ± 83.8	187.8 ± 90.5	<0.001
Fluoroscopy time (min)	14.5 ± 11.5	13.7 ± 10.4	17.0 ± 12.6	11.8 ± 9.3	14.4 ± 11.5	<0.001
LMW heparin	13,149 (4.7)	219 (6.4)	1,515 (6.9)	782 (6.9)	10,633 (4.4)	<0.001
Unfractionated heparin	107,146 (38.3)	2,255 (65.9)	14,930 (68.2)	4,354 (38.2)	85,607 (35.2)	<0.001
Bivalirudin	182,555 (65.2)	1,685 (49.2)	10,954 (50.1)	6,548 (57.5)	163,368 (67.1)	<0.001
Clopidogrel	222,272 (79.4)	2,574 (75.2)	17,010 (77.8)	8,721 (76.6)	193,967 (79.7)	<0.001
Prasugrel	23,813 (8.5)	470 (13.7)	2,466 (11.3)	1,073 (9.4)	19,804 (8.1)	<0.001
Ticagrelor	2,331 (0.8)	82 (2.4)	339 (1.5)	87 (0.8)	1,823 (0.7)	<0.001
Number of stents	1.5 ± 0.8	1.4 ± 0.7	1.5 ± 0.8	1.4 ± 0.7	1.5 ± 0.8	<0.001

Values are mean ± SD or n (%). Continuous variables were compared using one-way analysis of variance. Categorical variables were compared using chi-square or Fisher exact tests.

BMI = body mass index; CABG = coronary artery bypass grafting; CAD = coronary artery disease; LMW = low-molecular weight; MI = myocardial infarction; NSDD = non-same-day discharge; PCI = percutaneous coronary intervention; SDD = same-day discharge; TFI = transfemoral intervention; TRI = transradial intervention.

risk adjustment, the difference was $3,502 (95% CI: $3,347 to $3,648; $p < 0.001$) favoring SDD.

Adjusted costs of PCI by various care pathway groups are presented in Table 2. The differences in the adjusted PCI costs across these care pathways are presented in Table 3. A TRI SDD pathway was consistently associated with cost savings when compared with any other pathway (Table 3). The largest

TABLE 2 Adjusted Costs of Percutaneous Coronary Intervention by Care Pathway Groups

Care Pathway Group	Adjusted PCI Cost ($)	95% CI ($)
SDD	13,256	13,091–13,406
NSDD	16,753	16,673–16,833
TRI	15,786	15,642–15,928
TFI	16,701	16,620–16,787
TRI SDD	13,389	13,161–13,607
TRI NSDD	16,420	16,298–16,553
TFI SDD	13,913	13,772–14,060
TFI NSDD	17,076	16,999–17,147

CI = confidence interval; other abbreviations as in Table 1.

difference in adjusted costs was observed between a TRI SDD pathway, which was the least frequently used pathway, and a TFI NSDD pathway (the current most common pathway), which resulted in $3,689 in cost savings to hospitals favoring TRI SDD (Table 3).

BLEEDING AND LOS OUTCOMES. In-hospital bleeding occurred overall in 2.8% of patients, 1.4% in TRI and 3.0% in TFI procedures ($p < 0.001$). Similarly, the rates of transfusion and other vascular complications were also lower in the TRI versus TFI groups. After propensity adjustment, these differences remained statistically significant (Table 4).

LOS was 2.2 ± 4.4 days in the TRI group compared with 2.4 ± 3.5 days in the TFI group, a difference of 0.2 days favoring TRI ($p < 0.001$), and persisted after risk adjustment.

BUDGET IMPACT ANALYSIS. For a hypothetical hospital performing 1,000 elective PCI procedures annually, the impact of converting from TFI NSDD (the current most common pathway of care) to TRI SDD, TRI NSDD, and TFI SDD pathways is shown in Figure 4. A relatively small 30% conversion from the current pathway of TFI NSDD to TRI SDD could potentially save $1 million annually. Hospitals shifting practice by even 100 cases every year may save up to $350,000 (Figure 4). Approximately 600,000 PCI procedures are performed in the United States annually (20,36), one-half of which are elective PCI procedures, eligible for SDD. A 30% conversion from the current pathway of TFI NSDD to TRI SDD could potentially save U.S. hospitals approximately $332 million annually.

TABLE 3 Adjusted Cost Differences Between Various Care Pathways

Care Pathway	Cost Difference ($)	95% CI	p Value
TRI vs. TFI	−916	−778 to −1,035	<0.001
SDD vs. NSDD	−3,502	−3,347 to −3,648	<0.001
TRI SDD vs. TRI NSDD	−3,035	−3,273 to −2,825	<0.001
TRI SDD vs. TFI SDD	−527	−776 to −295	<0.001
TRI SDD vs. TFI NSDD	−3,689	−3,902 to −3,486	<0.001
TRI NSDD vs. TFI SDD	2,508	2,324 to 2,680	<0.001
TRI NSDD vs. TFI NSDD	−652	−765 to −534	<0.001
TFI SDD vs. TFI NSDD	−3,160	−3,299 to −3,027	<0.001

Abbreviations as in in Tables 1 and 2.

DISCUSSION

SUMMARY OF FINDINGS. In this linked analysis from the CMS and ACC NCDR CathPCI Registry, we have identified the hospital costs of PCI associated with alternative clinical care pathways in a nationally representative population. We found that: 1) TRI costs were $916 lower compared with TFI; 2) SDD costs were $3,500 lower than NSDD costs; 3) a strategy of TRI access coupled with SDD cost nearly $3,700 less than the current, most frequently used pathway of TFI NSDD; 4) TRI access was associated with less bleeding, fewer vascular complications, and less transfusions than TFI; and 5) conversion from the existing most common care pathway of TFI NSDD to TRI SDD could potentially yield large cost savings to U.S. hospitals.

CLINICAL IMPLICATIONS. Our results have important cost implications for hospitals and the U.S. health system. Hospitalization costs for Medicare beneficiaries are on the rise. The hospitalization cost for Medicare beneficiaries is higher ($12,200) than that of privately insured patients ($9,700) (23), and the number of hospitalizations billed to Medicare has been increasing at a greater rate than that of privately insured patients (22). For PCI hospitalization specifically, increasing intensity of services (resources and cost per day) and increasing LOS were major drivers for growth in the aggregate cost (21). Recent data from 2012 demonstrate that Medicare paid $5.9 billion for short inpatient stays, an average of $5,142 per stay, while it paid only $2.6 billion for observation stays, an average of $1,741 per stay (13). A PCI procedure was ranked as the second most common reason contributing to the high costs of short inpatient stays, the first being chest pain (13). The average payment difference between a short inpatient and an observation stay for PCI was $2,267, which was among the highest differences in cost for any diagnosis between a short inpatient stay and an observation stay (13). CMS has created time-based rules for determining inpatient status, and the final rule was published in August 2013 (15,19). Under this "2-midnight rule," inpatient admission is appropriate only if a physician expects a patient's stay to span at least 2 midnights (13–15,19). With the implementation of the 2-midnight rule (13–15,19), more PCI patients will be reclassified as outpatients (13) and billed under outpatient observation

rather than inpatient status (13,15–19). The current practice of classifying a PCI patient as an outpatient but not discharging the patient on the same hospital day is anticipated to result in higher cost in the range of $2,000 to $4,000 per PCI to hospitals (13,15–19). By providing a detailed analyses of hospital costs across various care pathways for PCI, we have identified a mechanism to reduce hospital losses with the implementation of new rules. Our findings show that TRI combined with SDD may offer a tremendous potential for hospitals across the country to reduce PCI costs.

Similarly, the BPCI initiative, begun in January 2013 by CMS through its Innovation Center authority, which was created by the Patient Protection and Affordable Care Act (37–40), seeks to improve health care delivery and ultimately to reduce costs by allowing providers to enter into pre-negotiated payment arrangements that include financial and performance accountability for a clinical episode in which a risk-and-reward calculus must be determined. As participation of hospitals and practices under these alternative payment models increases, providers will need to embrace these changes and identify areas of opportunity to maintain a competitive advantage. This study of index PCI hospitalization cost across various PCI care pathways should guide hospitals in reducing costs of index PCI care and conserve resources that could be reallocated more efficiently for downstream costs of care in the era of bundled payments. For U.S. hospitals, our budget impact analysis showed that even a relatively small 30% conversion from the current pathway of TFI NSDD to TRI SDD could result in large savings. These potential savings are meaningful and offer insight to hospitals to help them modify staffing patterns or initiate SDD protocols.

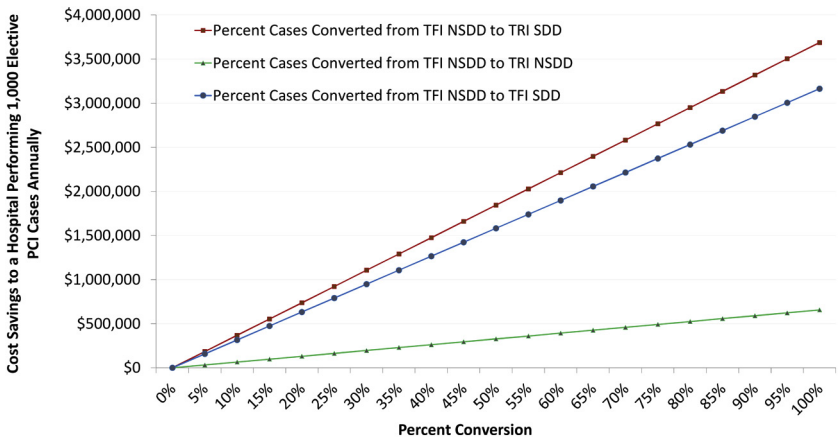
TABLE 4 In-Hospital Bleeding, Transfusion, and Vascular Complications by Transradial and Transfemoral Access

	Unadjusted			Adjusted	
	TRI	TFI	p Value	Odds Ratio (95% CI)	p Value
Bleeding	353 (1.4%)	7,544 (3.0%)	<0.0001	0.488 (0.470–0.508)	<0.0001
Transfusion	117 (0.5%)	3,062 (1.2%)	<0.0001	0.461 (0.434–0.491)	<0.0001
Vascular complications	41 (0.2%)	945 (0.4%)	<0.0001	0.377 (0.334–0.424)	<0.0001

Abbreviations as in Tables 1 and 2.

The association of TRI with fewer complications is consistent with previously published studies. Our study notes fewer bleeding complications associated with TRI compared with TFI. Both the direction and magnitude of reduced bleeding in this study are also consistent with prior randomized and observational studies comparing TRI with TFI (41–44). Particularly noteworthy, the observed bleeding reduction in the TRI group was achieved despite frequent use of other bleeding avoidance strategies (e.g., 51% bivalirudin use, 58% closure devices) in the TFI group. Although the feasibility of TRI in older patients has been challenged, several studies have established the success of TRI in older patients and those with complex coronary anatomy, including bifurcations, bypass grafts,

FIGURE 4 Cost Savings to a Hospital Performing 1,000 Elective PCIs Annually When Converting From TFI NSDD to Either TRI SDD, TFI SDD, or TRI NSDD



NSDD = non-same-day discharge; PCI = percutaneous coronary intervention; SDD = same-day discharge; TFI = transfemoral intervention; TRI = transradial intervention.

left main disease, long lesions, and calcified vessels. Our findings confirm lower complication rates in a large national population and establish that better outcomes may be achieved at a lower cost.

STUDY LIMITATIONS. First, the observational nature of these data may be subject to selection bias and unmeasured confounding, despite rigorous exclusions and propensity score methods with IPW to adjust for confounding associated with TRI use and SDD. Propensity score methods do not account for unmeasured confounding or selection bias (45-47).

Second, the costs demonstrated here are from the hospital perspective. A broader societal-level perspective may be preferable, as downstream costs or savings associated with TRI are possible.

Third, costs were obtained from claims data by applying hospital and cost center-specific cost-to-charge ratios. No detailed costing of actual resources, direct and indirect costs of care have been obtained.

Fourth, CMS claims were linked to the CathPCI Registry via matching techniques, which was not a perfect match. However, we were able to match 95% of the observations. It should be noted that the CathPCI Registry only captures data on the percutaneous entry site used for the majority of the procedure. Therefore, some variation may exist in reported rates of TRI and TFI when an operator switched entry sites during a given procedure, although we believe this occurred infrequently.

CONCLUSIONS

In this nationally representative dataset of Medicare beneficiaries, both TRI and SDD were associated with significantly lower costs compared with TFI and NSDD when examined from a hospital perspective. The magnitude of cost savings, exceeding $900 for TRI PCI and $3,500 for TRI PCI with SDD, may be appealing to hospitals that consider adopting TRI and SDD programs for PCI.

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PERSPECTIVES

WHAT IS KNOWN? PCI is a costly procedure, but few data exist on strategies to reduce hospital costs of PCI.

WHAT IS NEW? For the first time, in a nationally representative dataset of Medicare beneficiaries linked to the NCDR CathPCI Registry, we found that PCI care pathways of TRI and SDD were associated with significantly lower costs compared with TFI with NSDD when examined from a hospital perspective. Furthermore, the magnitude of cost savings was large, exceeding $900 for TRI PCI and $3,500 for TRI PCI with SDD, implying that even small shifts in the current practice of TFI NSDD to TRI SDD by 30% could save a hospital performing 1,000 elective PCIs each year $1 million and the country $300 million annually.

WHAT IS NEXT? Further studies are needed to evaluate the impact of changing the current PCI care pathways to improve outcomes and reduce PCI costs for hospitals.

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