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Novel Patient-Centered Approach to Facilitate Same-Day Discharge in Patients Undergoing Elective Percutaneous Coronary Intervention

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Background—Same-day discharge (SDD) after elective percutaneous coronary intervention is safe, less costly, and preferred by patients, but it is usually performed in low-risk patients, if at all. To increase the appropriate use of SDD in more complex patients, we implemented a “patient-centered” protocol based on risk of complications at Barnes-Jewish Hospital.

Methods and Results—Our objectives were as follows: (1) to evaluate time trends in SDD; (2) to compare (a) mortality, bleeding, and acute kidney injury, (b) patient satisfaction, and (c) hospital costs by SDD versus no SDD (NSDD); and (3) to compare SDD eligibility by our patient-centered approach versus Society for Cardiovascular Angiography and Interventions guidelines. Our patient-centered approach was based on prospectively identifying personalized bleeding, mortality, and acute kidney injury risks, with a personalized safe contrast limit and mitigating those risks. We analyzed Barnes-Jewish Hospital’s National Cardiovascular Data Registry CathPCI Registry data from July 1, 2009 to September 30, 2015 (N=1752). SDD increased rapidly from 0% to 77% ($P<0.001$), independent of radial access. Although SDD patients were comparable to NSDD patients, SDD was not associated with adverse outcomes (0% mortality, 0% bleeds, and 0.4% acute kidney injury). Patient satisfaction was high with SDD. Propensity score-adjusted costs were \$7331 lower/SDD patient ($P<0.001$), saving an estimated \$1.8 million annually. Only 16 patients (6.95%) met the eligibility for SDD by Society for Cardiovascular Angiography and Interventions guidelines, implying our patient-centered approach markedly increased SDD eligibility.

Conclusions—With a patient-centered approach, SDD rapidly increased and was safe in 75% of patients undergoing elective percutaneous coronary intervention, despite patient complexity. Patient satisfaction was high, and hospital costs were lower. Patient-centered decision making to facilitate SDD is an important opportunity to improve the value of percutaneous coronary intervention. (*J Am Heart Assoc.* 2018;7:e005733. DOI: 10.1161/JAHA.117.005733.)

Key Words: cost • elective percutaneous coronary intervention • hospital costs • percutaneous coronary intervention • same-day discharge • transradial • transradial approach

Percutaneous coronary intervention (PCI) is a common cardiovascular procedure, performed in >500 000 patients in the United States each year.¹ Historically, overnight observation after elective uncomplicated PCI was the standard of care to monitor for periprocedural complications. This practice of overnight observation has persisted despite marked improvements in PCI, including the use of improved stent design, uptake of radial access, reduction in bleeding complications, and newer and safer anticoagulation strategies.

Numerous single-center observational studies, small randomized controlled trials, and meta-analyses have demonstrated low complications, low cost, and higher patient satisfaction with same-day discharge (SDD) after PCI in carefully selected patients. However, what defines “carefully selected” elective PCI patients has been inconsistently applied, if defined at all.^{2–9} Some studies have cautiously explored the feasibility of SDD beyond the low-risk population,^{7,10–14} but they were evaluated in selected patients

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Clinical Perspective

What Is New?

- Same-day discharge is safe, less costly, and preferred by patients, but it is usually performed in low-risk patients, if at all.
- By implementing a patient-centered protocol based on risk of complications at Barnes-Jewish Hospital, we rapidly increased same-day discharge from 0% to 77%, even in more complex patients, with no increase in adverse outcomes, high patient satisfaction, and lower costs of \$7000/same-day discharge patient, reducing hospital costs by an estimated \$1.8 million annually.

What Are the Clinical Implications?

- When risks of complications were proactively identified and mitigated by a patient-centered approach at Barnes-Jewish Hospital, complications were avoided and same-day discharge became feasible in most patient undergoing elective percutaneous coronary intervention.
- This resulted in not only high patient satisfaction but a large reduction in hospital costs.
- We believe that our study has identified an important opportunity to improve the value of percutaneous coronary intervention for patients undergoing elective percutaneous coronary intervention in the United States.
- Our approach represents an important initial step towards achieving the triple aim of health care in percutaneous coronary intervention: improving the patient experience, achieving improved or equivalent outcomes, and lowering costs.
- Such strategies are essential as health care transitions from a volume-based reimbursement paradigm to one focused on value.

or required protocols or checklists. To the best of our knowledge, there are no studies that evaluate SDD in a broader and higher-risk elective PCI population using an explicit quantification of patient-specific risks.

Performing SDD in higher-risk, more complex patients requires a more explicit understanding and quantification of patients' individualized risks for PCI complications. Patient-centered decision making is defined as "the process of identifying clinically relevant, patient-specific circumstances and behaviors to formulate a contextually appropriate care plan."¹⁵ With patient-centered decision making, higher-risk and more complex patients could be considered for SDD provided that the risks are recognized upfront and successfully mitigated, which has never been reported. Although the SOCRATES (Study of Costs Realized After Percutaneous Coronary Intervention Employing Same Day Discharge) randomized trial, NCT02207270 was designed to apply a patient-centered approach to SDD, it was prematurely terminated because of lack of enrollment.¹⁶ Furthermore, the cost and

patient satisfaction of SDD via a patient-centered approach from a US hospital perspective have not been examined, which is a growing area of concern as bundled payments emerge.

To enable SDD in higher-risk patients, we devised a novel patient-centered protocol for SDD and implemented it at Barnes-Jewish Hospital (BJH); St Louis, MO. Our objectives were as follows: (1) to evaluate a trend in SDD over time; (2) to compare patients undergoing elective PCI who did or did not undergo SDD with respect to (a) patient and procedural characteristics, (b) outcomes of mortality, bleeding, and acute kidney injury (AKI), (c) patient satisfaction, and (d) costs of hospitalization (direct variable cost, direct fixed cost, and total cost); and (3) to compare eligibility for SDD by our patient-centered approach versus the established SDD recommendations by the Society for Cardiovascular Angiography and Interventions (SCAI) consensus statement.¹⁷

Methods

Patient-Centered SDD Protocol

Patient-centered care is the provision of care that is individualized and responsive to individual patient characteristics and needs.¹⁵ We developed and implemented a decision aid using a patient-centered care framework to facilitate SDD after PCI.^{15,18} The patient-centered SDD program at BJH required prospectively identifying risks of bleeding,¹⁹ mortality,²⁰ and AKI,²¹ with a patient-specific determination of a safe contrast limit²² at the point of care, before PCI. We used the American College of Cardiology's NCDR (National Cardiovascular Data Registry) CathPCI Registry models to identify the risks of bleeding, mortality, and AKI^{19–21} and developed a method for estimating the safe contrast limits.²² These were implemented using the ePRISM (Health Outcomes Sciences, Kansas City, KS) clinical decision aid that provided each patient's individual risks before the procedure (Figure 1).²³ Risks were prospectively reviewed by the interventional cardiologist performing the procedure (A.A., H.K., J.S., J.L., R.B., A.Z.) before the procedure in the catheterization laboratory holding area (Figure 2) to define the appropriate risk mitigation strategies, including both bleeding avoidance strategies²⁴ and contrast limits²² (Figure 2). After the procedure, the interventionalist and a catheterization laboratory holding area nurse ascertained procedural success, if the risks were successfully mitigated, and if the patient was stable after the procedure. The findings were reviewed with the patient and family members and, if everyone agreed, the patient was discharged the same day even if the patient had undergone a complex PCI or had numerous comorbidities (Figure 2). Thus, our protocol maximized patient centeredness at the point of care, and we structured the intervention so that it was reproducible and

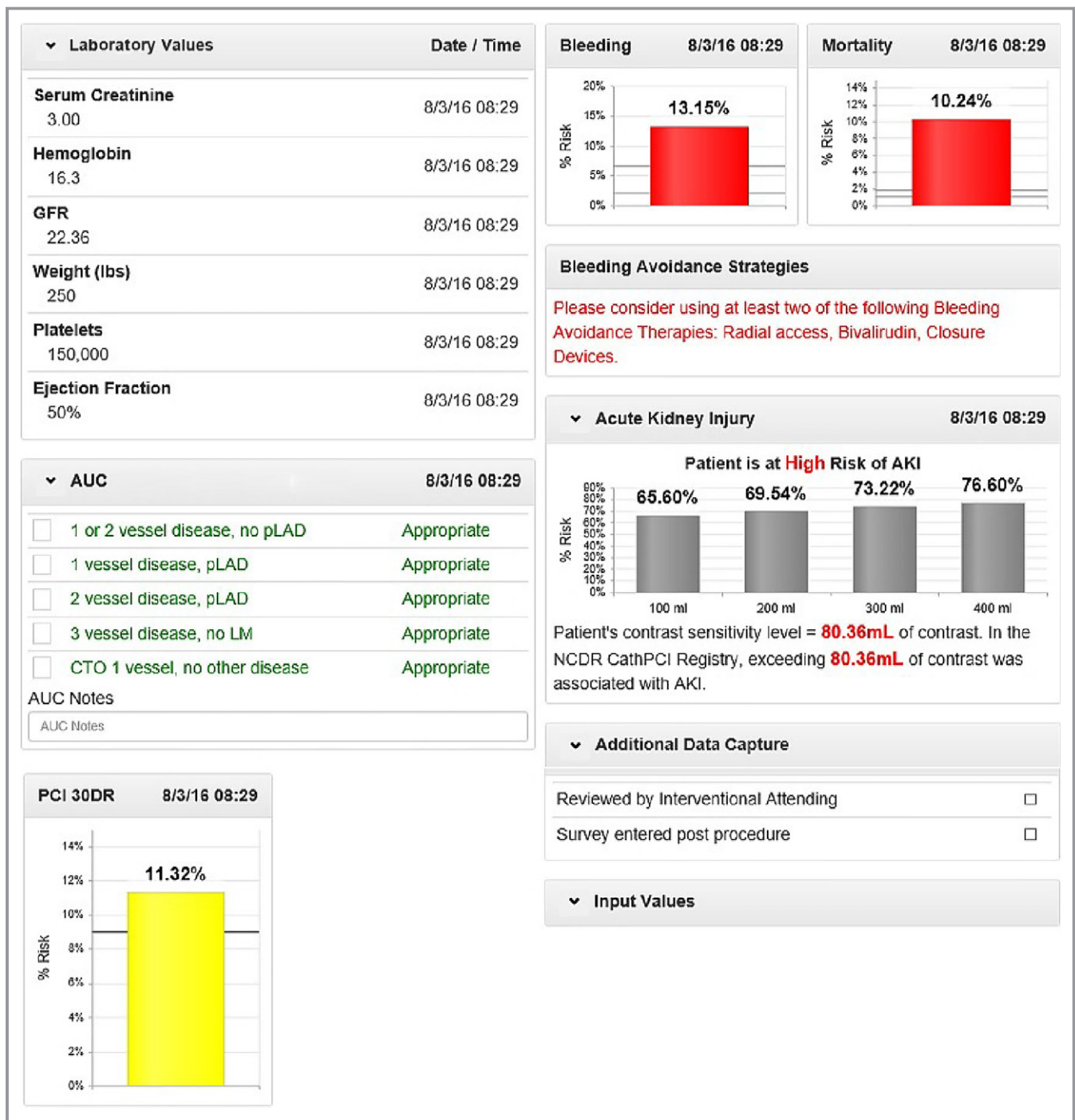


Figure 1. Decision aid for patient-centered PCI care, which is reviewed by the interventionalist before percutaneous coronary intervention. AKI indicates acute kidney injury; AUC, appropriate use criteria; GFR, glomerular filtration rate; NCDR, National Cardiovascular Data Registry; PCI, percutaneous coronary intervention; pLAD, proximal left anterior descending coronary artery; and 30DR, 30 day readmission.

scalable. The protocol was implemented at the beginning of quarter 4, 2013.

Study Population

For this study, we included elective PCIs performed at BJH from July 1, 2009 to September 30, 2015 (N=1752). Elective

PCI is defined in the NCDR CathPCI Registry as “the (PCI) procedure performed on an outpatient basis without significant risk of infarction or death.” Because the protocol was implemented in quarter 4 of 2013, we had ~3.5 years of pre-intervention control data and 2 years of post-implementation data. All variables in the data set were coded according to the American College of Cardiology’s NCDR CathPCI Registry

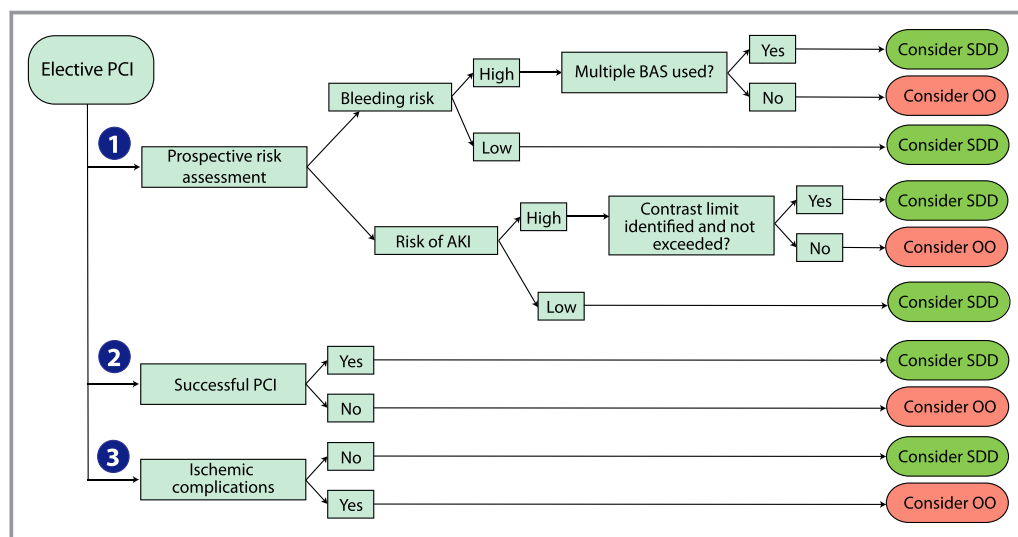


Figure 2. Overview of the patient-centered approach to same-day discharge (SDD) protocol. AKI indicates acute kidney injury; BAS, bleeding avoidance strategies; OO, overnight observation; and PCI, percutaneous coronary intervention.

standards (https://www.ncdr.com/WebNCDR/docs/public-data-collection-documents/cathpci_v4_codersdictionary_4-4.pdf).²⁵ The final cohort included for analyses was composed of 1752 patients who underwent PCIs at BJH during the study period. Of these patients, 230 (13%) underwent SDD during the entire time period.

Predictors and Outcomes

The predictor variable of interest we examined was SDD (versus NSDD, coded as 1 for patients who received an SDD and 0 otherwise). SDD was defined as discharge occurring on the same day of the PCI for elective PCI procedures performed on an outpatient basis or for stable low-risk inpatients when the date of hospital arrival and the date of PCI procedure was the same as the date of discharge. This variable was either singly or in combination with other covariates used in regression models that permitted a comparison on the SDD and NSDD groups.

The primary outcomes of interest were outcomes of bleeding, AKI, and death across the SDD groups. Bleeding was defined according to the NCDR CathPCI Registry definition as any one of the following: (1) bleeding event within 72 hours, (2) hemorrhagic stroke, (3) tamponade, (4) post-PCI transfusion for patients with a preprocedure hemoglobin level >8 g/dL and a preprocedure hemoglobin level not missing, or (5) an absolute hemoglobin decrease from pre-PCI to post-PCI of ≥ 3 g/dL, preprocedure hemoglobin level <16 g/dL, and preprocedure hemoglobin level not missing. AKI was defined, according to the Acute Kidney Injury Network criteria, as the change from preprocedure to peak serum creatinine levels ≥ 0.3 mg/dL absolute increase or ≥ 1.5 -fold relative increase

in serum creatinine. The secondary outcomes of interest were patient satisfaction and cost. A postdischarge telephone follow-up questionnaire was administered to patients by the catheterization laboratory nurse (BD, MP) within the 2 days of SDD to ascertain patient status, medication compliance, access site problems, and patient satisfaction. This patient satisfaction survey was available only in patients undergoing SDD after November 1, 2014 (N=145), when we started this assessment. The follow-up questionnaire consisted of the following 11 questions:

1. How did you feel about being discharged the same day?
2. Do you have any questions about your procedure?
3. Do you have any questions specific to your care?
4. Describe what your site looks like?
5. Were you able to obtain your prescriptions?
6. Were you able to take your medications?
7. Do you have a follow-up appointment with your cardiologist?
8. If no follow-up appointment, have you called to make an appointment?
9. Do you have any problems or concerns after the procedure?
10. Our goal is to provide you with the best care possible. How would you rate your overall care?
11. Is there anyone you would like to mention or thank about your care?

Of these 11 items, patient satisfaction with SDD was ascertained via 2 nonvalidated questions, developed at BJH, on a 5-point Likert scale:²⁶

1. How did you feel about being discharged the same day?
2. Our goal is to provide you with the best care possible. How would you rate your overall care?

Clinical variables were defined by the NCDR CathPCI Registry.²⁵ Chronic kidney disease was defined as a glomerular filtration rate of ≤ 60 mL/min per 1.73 m^2 . An indicator variable for complex PCI was created and defined by the presence of type C lesions, bifurcation lesions, bypass graft lesions, lesions requiring atherectomy and chronic total occlusion lesions. Atherectomy was defined as use of a Diamondback 360, or ELCA coronary LASER atherectomy catheter, or Rotablator rotational atherectomy system.

Costs

Costs, from a hospital perspective, were directly obtained from BJH's finance department and linked to each specific patient by his or her NCDR patient identifier. We compared mean values for 3 different hospital costs between SDD PCI groups: direct variable cost, direct fixed cost, and total cost. Cost data were available for 63.69% of PCIs ($n=1116$). The missing cost data were attributable to unavailability of cost data from the BJH finance division for 2 years (2009, $n=185$ [10.55%]; and 2010, $n=345$ [19.69%]). Cost data were also not available for the last few months of 2015 ($n=94$ [5.36%]). From the other 4 years (2011, 2012, 2013, and 2014), cost data were consecutively available and were missing only for 12 (0.68%) of patients. In aggregate, these accounted for missing cost data for 636 patients (36.31%).

Direct variable costs were defined as patient-specific laboratory tests, medications, medical and surgical supplies, and physician and nursing expenses. Direct variable costs were composed of all medications, blood, disposable medical and surgical supplies, devices, and implants obtained using a microcosting approach from BJH's finance department. Specifically, the catheterization laboratory supply costs were obtained from a registry of supply and costs and included detailed balloons, wires, stents, other ancillary devices, medications, and contrast costs. Physician and nursing services were also included in direct variable costs. Direct fixed costs were independent of patient activity (eg, salaries of other individuals involved in conducting PCI and equipment maintenance costs). Direct fixed costs were the departmental fixed staff salary and benefits and equipment costs (accounting for equipment depreciation). Indirect costs reflected the costs incurred by the departments that did not produce revenue (eg, information technology, plant maintenance, and hospital financial services) and were applied to all clinical departments that generate revenue by the BJH finance department. Fixed indirect costs were organizational administrative, housekeeping, and facilities costs, including fixed staff costs and information technology costs (and their depreciation). These

costs were spread by multiple methods, depending on the function of the department, including share of charges, square footage, and department headcount. Total cost was the sum of all direct variable, direct fixed, and indirect costs.

Statistical Analysis

We first described time trends in the proportion of patients with SDD in each quarter to assess the discharge pattern over time and tested the null hypothesis of no linear trend with a 1-sided Cochran-Armitage test. Differences in the patient and procedural characteristics between SDD groups were described by means and percentages and tested with t tests and the Pearson χ^2 , as appropriate. We used box-and-whisker plots and Mann-Whitney U tests to compare the estimated risks of adverse outcomes across SDD groups. The association of SDD with outcomes of bleeding, AKI, and mortality was examined using the Fisher exact test. To examine the association of the cost with SDD, we conducted propensity score analyses and propensity adjustment. A propensity score predicting SDD was generated (Figure 6). To ensure that the propensity score was normally distributed across the study groups, we used a logarithm-odds transformation of the raw propensity score. We assessed balance of covariates with respect to SDD versus NSDD (Figure 6). To estimate the adjusted cost associated with SDD, we used the total costs as the dependent variable and SDD (coded as 1 or 0) and quintiles of the logarithm-odds propensity score as the covariates in a least-squares linear regression model. Finally, we applied the SDD criteria recommended in the 2009 SCAI expert consensus statement¹⁷ to our "patient-centered" SDD population, to examine the proportion of patients not meeting SCAI criteria for SDD.

All results were tested for statistical significance at a type I error rate of 0.05. Analyses were performed using Stata 14.0 (Stat Corp, College Station, TX). The study was approved by the Washington University institutional review board, and no informed consent was required.

Results

Time Trends of SDD

SDD was rare in the 3.5 years before the personalized protocol, occurring in only 0% to 4% of cases each quarter. After implementation, there was a rapid increase in SDD from 14% in the first quarter to 78% in the last quarter (Figure 3). The Cochran-Armitage trend test yielded a statistically significant 1-sided $P<0.001$, demonstrating a significant increasing time trend in the proportion of PCIs with SDD. The rapidly increasing time trend in SDD occurred independent of radial access; in the patients with

femoral access, SDD increased from 1.06% in the third quarter of 2009 to 69.23% in the third quarter of 2015, implying that the patient-centered approach was perhaps associated with rapidly increasing SDD in radial and femoral patients alike.

Association of SDD With Patient and Procedural Characteristics

In general, characteristics of the patients undergoing PCIs who did or did not have SDD were largely comparable (Table 1). However, those who underwent SDD were younger ($P<0.001$) but had a significantly higher prevalence of heart failure ($P<0.001$), prior myocardial infarction ($P=0.004$), and prior PCI ($P<0.001$) compared with the NSDD group (Table 1). Procedural characteristics of the study groups are also shown in Table 1. Mean total lesion length, mean number of diseased vessels, and percentage of saphenous vein grafts were nearly identical between SDD groups. The percentage of PCIs with type C lesions ($P=0.015$), procedural access through the radial artery ($P<0.001$), and vascular closure devices among femoral PCIs ($P<0.001$) were higher in SDD PCIs. Conversely, mean number of lesions ($P<0.001$), mean number of stents ($P<0.001$), and percentage with atherectomy ($P<0.001$) were higher in the NSDD group compared with the SDD patients.

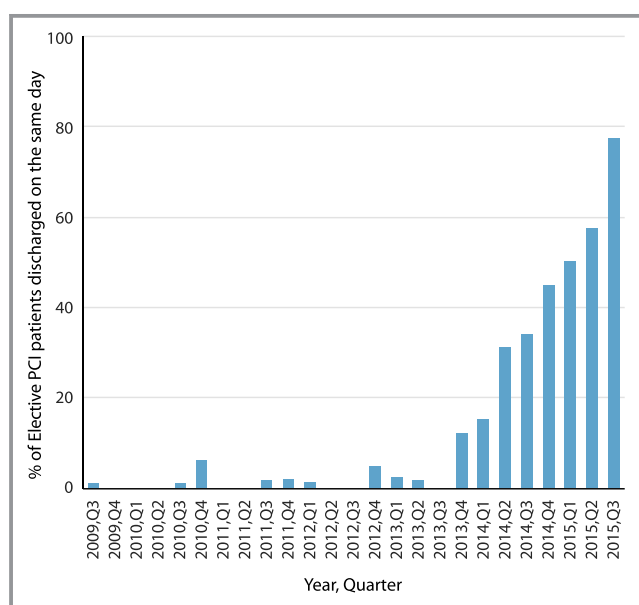


Figure 3. Percentage of percutaneous coronary interventions (PCIs) with same-day discharge (SDD) over time. The bar chart shows proportion of PCIs with SDD during each study quarter. The Cochran-Armitage test for trend yielded a 1-sided $P<0.001$, indicating a statistically significant trend.

Table 1. Patient and Procedural Characteristics by SDD

Characteristics	SDD Group (N=230)	NSDD Group (N=1522)	P Value
Patient characteristics			
Age, mean±SD, y	62.4±11.7	65.4±11.9	<0.001
Female sex, N (%)	47 (20)	395 (26)	0.073
Body mass index, mean±SD	30.4±6.0	30.1±6.0	0.502
Diabetes mellitus, N (%)	88 (38)	640 (42)	0.277
Dyslipidemia, N (%)	217 (94)	1380 (91)	0.067
Hypertension, N (%)	211 (92)	1386 (91)	0.737
Chronic lung disease, N (%)	54 (23)	290 (19)	0.115
Chronic kidney disease, glomerular filtration rate ≤60 mL/min per 1.73 m ² N (%)	58 (25)	403 (26)	0.686
Current dialysis, N (%)	10 (4)	77 (5)	0.643
Pre-PCI left ventricular ejection fraction, mean±SD	54.6±11.5	52.6±13.1	0.069
Prior coronary artery bypass graft surgery, N (%)	57 (25)	365 (24)	0.791
Prior cerebrovascular disease, N (%)	41 (18)	253 (17)	0.649
Prior heart failure, N (%)	108 (47)	411 (27)	<0.001
Prior myocardial infarction, N (%)	122 (53)	637 (42)	0.001
Prior peripheral vascular disease, N (%)	45 (20)	238 (16)	0.131
Prior PCI, N (%)	154 (67)	740 (49)	<0.001
Procedural characteristics			
No. of lesions, mean±SD	1.2±0.5	1.5±0.7	<0.001
Total lesion length, mean±SD	33.9±22.5	35.3±24.1	0.412
Type C lesion, N (%)	159 (69)	937 (62)	0.027
Bifurcation, N (%)	41 (18)	342 (22)	0.112
Chronic occlusion, N (%)	18 (8)	80 (5)	0.114
Atherectomy, N (%)	4 (2)	124 (8)	0.001
No. of diseased vessels, mean±SD	1.5±0.8	1.6±0.8	0.112
No. of stents, mean±SD	1.5±0.8	1.9±1.1	<0.001
Radial access, N (%)	100 (42)	69 (5)	<0.001
Closure proportion, N (%)*	111 (85)	887 (61)	<0.001

NSDD indicates no SDD; PCI, percutaneous coronary intervention; and SDD, same-day discharge.

*Closure devices proportion is assessed for PCI with femoral access only (N = 1583); of which SDD = 130; and NSDD = 1453.

Association of SDD With Predicted Probability of Mortality, Bleeding, and AKI

We prospectively performed preprocedural risk assessment for adverse events of mortality, bleeding, and AKI. These predicted probabilities of adverse outcomes are shown in Figure 4. When compared using the Mann-Whitney test, we observed that the median predicted probability of mortality and AKI was significantly higher in the SDD group, whereas the predicted probability of bleeding was comparable in both groups.

Association of SDD With Outcomes of Mortality, Bleeding, and AKI

From 2009 to 2015, a total of 4 deaths (0.2%), 16 bleeding events (0.9%), 44 transfusion events (2.5%), and 41 AKI events (2.3%) occurred (Table 2) in the study patients. Other adverse events, including vascular complications, new-onset dialysis, cerebrovascular attack, new-onset heart failure, and periprocedural myocardial infarction, are also shown in Table 2. Other than 1 AKI event, no other adverse outcomes occurred in the SDD groups (Table 2). By the Fisher exact test, there was no statistical difference in the outcomes of mortality, bleeding, and AKI (all $P=NS$).

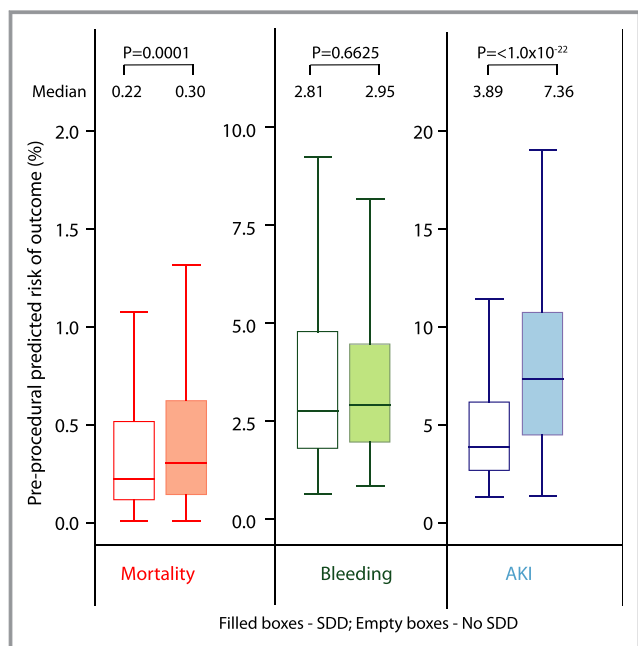


Figure 4. Box-and-whisker plots of preprocedural predicted risks of mortality, bleeding, and acute kidney injury (AKI) by same-day discharge (SDD) groups. A comparative diagram with 6 box-and-whisker plots grouped by risk type (mortality, bleeding, or AKI) and SDD status (filled boxes, SDD; empty boxes, no SDD [NSDD]). Predicted probability was a summary measure obtained using the National Cardiovascular Data Registry method.^{19–21} Shown at the top are the median values for each box plot and P value (obtained using Mann–Whitney test)

Patient Satisfaction

Although patient satisfaction was assessed in only 145 of the 230 SDD patients, they reported high satisfaction. We obtained 145 responses to the question: “How did you feel about being discharged the same day?”; of the patients, 144 (99.31%) reported feeling “extremely satisfied.” Among the 135 responses to the question: “Our goal is to provide you with the best care possible. How would you rate your overall care?”; of the patients, all 135 (100%) reported “excellent care.” These questionnaires were not administered to the NSDD group of patients.

Association of SDD With Hospital Costs

We first compared the discharge practice and outcomes based on whether cost data were available (cost data available group) or not (cost data not available group). We observed that the proportion who were discharged on the same day was 14% and 13% in the cost data available and cost data not available groups, respectively, which was statistically not significant ($P=0.548$). For the outcomes also, the proportions of patients with mortality (0.36% versus 0%; $P=0.303$), a bleeding event (1.25% versus 0.31%; $P=0.065$), and AKI (2.87% versus 2.00%; $P=0.286$) in the cost data available and cost data not available groups, respectively, were comparable.

We found (Figure 5A) that the median values for all the studied cost variables were significantly lower for the SDD group compared with the NSDD group, even when we used nonparametric methods for testing of statistical significance. The mean total cost of PCI was $\$10\,425.62\pm\2305.77 for the SDD group compared with $\$17\,135.91\pm\$16\,917.23$ for the NSDD group, a difference of $\$6710$ favoring SDD. This resulted in a cost savings of 39.15% (see the pie charts at the top of Figure 5A). The cost savings attributable to SDD were from 36.76% to 46.36%, indicating a substantial cost saving. The greatest relative savings occurred in the direct fixed costs (Figure 5A), perhaps because of a reduction in use of fixed hospitalization resources related to a reduced length of stay. Consistent with the temporal increase in the proportion of SDD PCIs over time (shown in Figure 3), we also observed that each percentage increase in a shift towards the SDD strategy was associated with a 0.77% improvement in total cost savings ($P=0.0145$; Figure 5B).

Propensity-Adjusted Cost Reduction Associated With SDD

We first developed a propensity score to account for confounding by patient and procedural characteristics to predict the likelihood of SDD. After adjusting the sequential logistic models to account for these interactions, the propensity score generating model contained all variables balanced across the

study groups (compare the red dots with the blue dots in Figure 6A). We observed that the raw propensity score was heavily skewed (Figure 6B, left panel) across study groups and, hence, we used the logarithm odds of this raw propensity score as the final propensity score (Figure 6B, right panel). This logarithm odds score was clearly higher in the SDD patients (mean, -0.49) compared with the NSDD patients (mean, -3.14 ; Figure 6C). After adjusting for quintiles of this propensity score, we found that the adjusted per-patient cost difference between the SDD and NSDD groups was \$7331 (95% confidence interval, \$4370–\$10 292). Using this adjusted estimate of the reduced per-patient costs, we estimate that even if the current rates of $\approx 75\%$ SDDs for an average of 250 elective PCIs every year continue, then the total annual saved costs for BJH will be \$1 843 233.

Comparison of SDD Eligibility by Patient-Centered Approach Versus SCAI Criteria

When we applied criteria for SDD recommended in 2009 by the SCAI expert consensus statement, we found that 1628 of 1752 patients (92.9%) at BJH were not eligible for SDD. These noneligible patients had the following characteristics: established congestive heart failure ($N=673$) or existing left ventricular systolic dysfunction ($N=158$), chronic kidney disease with an eGFR of ≤ 60 ml/min/ 1.73 m² ($N=187$), current dialysis ($N=2$), prior stroke, transient ischemic attack,

or cerebrovascular disease ($N=94$), peripheral vascular disease ($N=58$), chronic lung disease ($N=79$), use of glycoprotein IIb/IIIa inhibitors ($N=113$), stent length ≥ 28 mm ($N=204$), femoral access with no closure device ($N=47$), atherectomy device used ($N=4$), left main or chronic total occlusion PCI ($N=8$), and coronary perforation during PCI ($N=1$). No patients would have been disqualified for coagulopathy, contrast allergy, inadequate thienopyridine load, complications, and poor at-home support. Of the 230 patients undergoing SDD in our study, only 16 (6.96%) were eligible for SDD by the SCAI expert consensus guideline, implying that the other 214 (93.04%) patients' SDD was perhaps facilitated by our patient-centered approach.

Discussion

This is the first and only study, of which we are aware, to examine patient-centered decision making through an explicit risk-based protocol for facilitating SDD in patients undergoing elective PCI. Our approach represents an important initial step towards achieving the triple aim of health care in PCI: improving the patient experience, achieving improved or equivalent outcomes, and lowering costs.²⁷ A patient-centered framework explicitly uncovers a distinct cognitive aspect in clinical decision making: the ability to classify patient conditions into specific risk categories that then

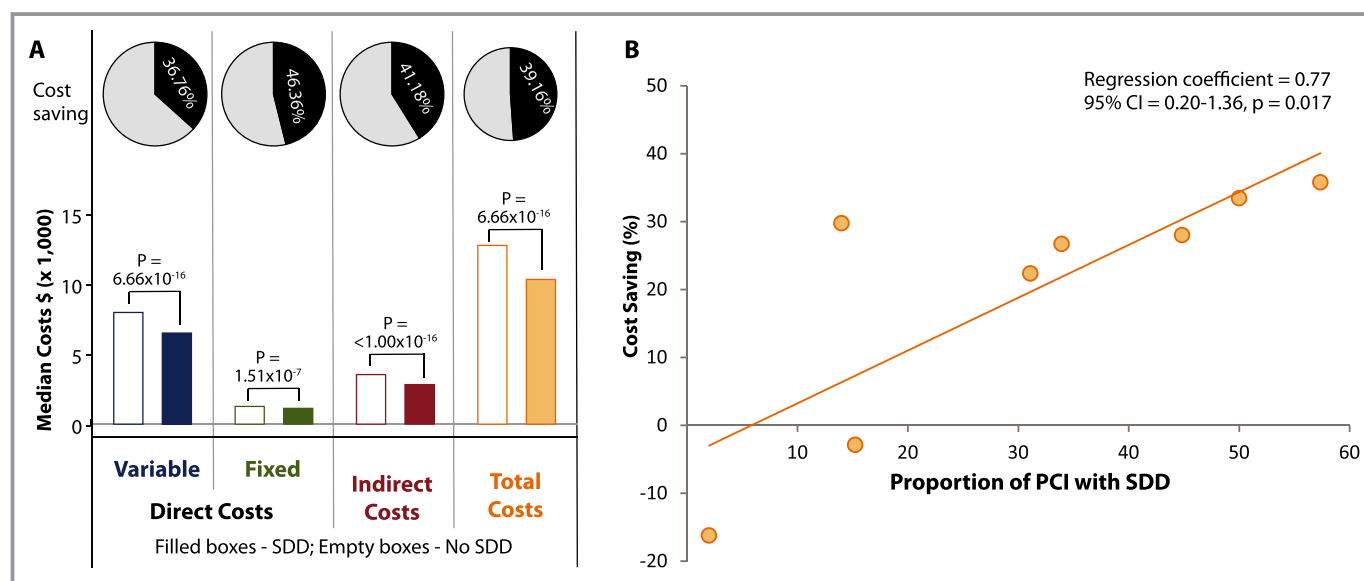


Figure 5. Costs associated with SDD in elective PCI. (A) Distribution of various costs across SDD groups. The box plots show the distribution of the color-coded buckets based on SDD status (filled boxes - SDD, empty boxes, NSDD). Significance values were obtained using the Mann-Whitney test. Pie charts at the top show the estimated cost saving (defined as $100 \times$ per-patient cost difference/per-patient cost in the no-SDD group). (B) Association of cost saving with proportion of SDD PCIs. These 2-year, quarterly data span from third quarter in 2013 up to 2nd quarter in 2015. Each dot represents a combination of the SDD rate (x axis) and estimated cost saving (y axis). Regression coefficient was obtained using ordinary least squares regression. Results of the regression analyses indicate that for every additional 10% SDD resorted to in a quarter the cost savings increased by an additional 7.7%. NSDD indicates No SDD; PCI, percutaneous coronary intervention; and SDD, Same-day discharge.

Table 2. Observed Outcomes Based on the SDD Status

Outcome	SDD Group	NSDD Group	Fisher Exact P Value
Mortality	0 (0)	4 (0.3)	1.000
Bleeding*	0 (0)	16 (1.1)	0.252
Acute kidney injury [†]	1 (0.5)	40 (2.8)	0.080
Transfusion [‡]	0 (0)	44 (2.9)	0.003
Other vascular complications [§]	0 (0)	17 (1.1)	0.151
Dialysis	0 (0)	0 (0)	1.000
Cerebrovascular attack [¶]	0 (0)	0 (0)	1.000
Heart failure [#]	0 (0)	1 (0.1)	1.000
Myocardial infarction**	0 (0)	54 (3.6)	0.001

NSDD indicates no SDD; and SDD, same-day discharge.

*Bleeding was defined according to the National Cardiovascular Data Registry CathPCI Registry definition as any one of the following: (1) bleeding event within 72 hours; (2) hemorrhagic stroke; (3) tamponade; (4) post-percutaneous coronary intervention (PCI) transfusion for patients with a preprocedure hemoglobin level >8 g/dL and preprocedure hemoglobin level not missing; or (5) an absolute hemoglobin decrease from pre-PCI to post-PCI of ≥ 3 g/dL, preprocedure hemoglobin level <16 g/dL, and preprocedure hemoglobin level not missing.

[†]Acute kidney injury was defined according to the Acute Kidney Injury Network criteria as the change from preprocedure to peak serum creatinine levels ≥ 0.3 mg/dL absolute increase or ≥ 1.5 -fold relative increase in serum creatinine.

[‡]Transfusions were defined as transfusion(s) of either whole blood or packed red blood cells.

[§]Vascular complications were defined as any other vascular complications (excluding external bleeding or hematomas) at the percutaneous entry site that required treatment or intervention, including, but not limited to, access site occlusions, peripheral embolizations, dissections, pseudoaneurysms, and/or AV fistulas. Any noted vascular complication must have had an intervention, such as a fibrin injection, angioplasty, or surgical repair, to qualify. Prolonged pressure did not qualify as an intervention, but ultrasonic-guided compression after making a diagnosis of pseudoaneurysm did qualify.

^{||}New onset of dialysis was defined as present if the patient experienced acute or worsening renal failure necessitating renal dialysis of all types, including continuous venovenous hemofiltration, between start of procedure and until next procedure or discharge.

[¶]A stroke or cerebrovascular accident was defined as loss of any neurological function caused by an ischemic or hemorrhagic event, with residual symptoms lasting at least 24 hours after onset or leading to death.

[#]New onset of heart failure was defined as new onset or acute recurrence of heart failure, which necessitated new or increased pharmacologic therapy.

**In patients with normal baseline (preprocedure) cardiac biomarker values, myocardial infarction within 24 hours after percutaneous coronary intervention was defined as follows: Elevations of cardiac biomarkers >3 times the upper limit of normal for your laboratory (ie, >3 times the 99th percentile upper reference limit for a normal population). ECG changes or symptoms were not required to qualify.

permits the application of evidence to individualize treatment to risk. Such strategies are essential as health care transitions from a volume-based reimbursement paradigm to one focused on value.

The most compelling finding of this study is that our patient-centered approach, with prospective risk stratification, led to a deliberate and planned risk mitigation strategy, one that facilitated SDD in almost all patients in the last quarter despite complex PCI and patient comorbidities. Indeed, in this

large, observational, single-center study, we found the patient and procedural characteristics and the risk profile from a procedural perspective were largely similar between SDD and NSDD groups. We found that the SDD approach was safe, and adverse outcomes were not statistically different between SDD and NSDD groups, although they were numerically lower in the SDD group. The cost savings from SDD to the hospital were large, ranging from 36% to 46% for various cost categories. Most important, almost all the patients who were sent home the same day reported excellent patient satisfaction. From a physician perspective, it is noteworthy that when we implemented the protocol in quarter 4 of 2013, PCI operators did not feel comfortable discharging patients with SDD immediately, but the personalized approach facilitated a rapid increase in SDD over time. Finally, our patient-centered approach facilitated SDD in >10 -fold as many patients as defined by the SCAI expert consensus guideline.

There is an emerging body of literature^{7,12,14,28} suggesting that SDD may be performed in more complex and elderly patients undergoing PCI, in whom complex characteristics alone are not sufficient indicators for necessitating overnight admission. Unfortunately, the existing SDD “criteria,”¹⁷ which are applicable to a lower-risk population, are potentially too conservative to be applied in an increasingly complex elective PCI population treated in contemporary practice. As elective PCI complexity and patient comorbidity further increase, a risk-based approach is likely to be the best strategy for safely guiding SDD decisions. Our approach allowed 3 of 4 patients undergoing elective PCI to be discharged the same day, despite having similar risk profiles to those who had previously been in the NSDD group.

We observed that the median predicted probability of mortality and AKI was significantly higher in the SDD group than in the NSDD group. When the patient-centered approach to SDD was implemented prospectively, there was a careful review of comorbidities and improved understanding of patient-specific risks that, in turn, led to risk mitigation strategies. We hypothesize that perhaps a careful assessment of patient-specific risks led to a slightly numerically higher predicted probability of mortality and AKI in the SDD groups versus the NSDD group. This also partly explains why the SDD group showed a younger age but a paradoxically more complex pattern of cardiac comorbidities (Table 1). Notably, these results do not imply that higher-risk patients were being discharged irresponsibly; conversely, the results show that these patients were probed carefully for all factors before SDD. In aggregate, our findings indicate that the intuitive clinical logic of withholding SDD in complex PCIs may be overcome by using a patient-centered approach to SDD.

Because PCI is the most common cardiovascular procedure in the United States,^{1,29,30} it is also a major driver of

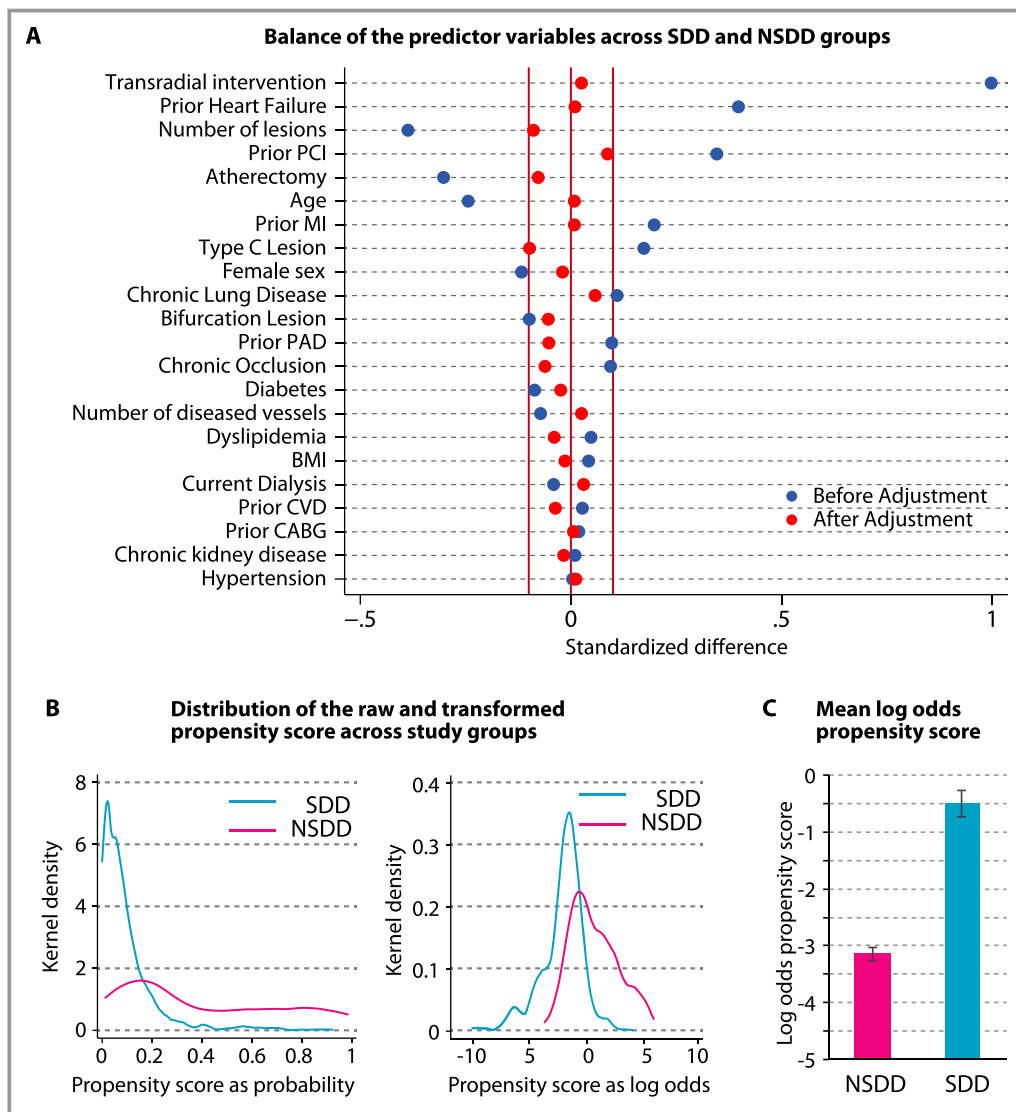


Figure 6. Propensity score analyses to estimate adjusted cost reductions associated with same-day discharge (SDD). A, Development of the propensity score using a sequential variable, balancing strategy implemented in the *prop_spl* package. The residual imbalance after adjustment is shown using red dots, and the corresponding imbalance before adjustment is shown using blue dots. All variables had acceptable levels of imbalance. B, Kernel density plots for the raw propensity score (left panel) and the logarithm (log)-odds transformed propensity score (right panel) for the SDD and no SDD (NSDD) groups. C, Average log-odds transformed propensity score across the study groups. The error bars represent 95% confidence intervals. BMI indicates body mass index; CABG, coronary artery bypass grafting; CVD, cardiovascular disease; MI, myocardial infarction; PAD, peripheral artery disease; and PCI, percutaneous coronary intervention.

healthcare costs. PCI costs are expected to cost the United States \$918 million by 2030.³¹ Consequently, approaches that reduce costs are urgently needed. Our study builds on and extends an accumulating body of evidence showing that SDD is safe and associated with lower costs of care. Two recent meta-analyses of randomized controlled trials of SDD have confirmed the safety of SDD in terms of adverse events, such as mortality, myocardial infarction, major bleeding, blood transfusion, repeated revascularization, and rehospitalization;

these adverse events were not significantly different between SDD and overnight stay groups, up to 30 days after PCI.^{3,32} In the current climate of healthcare reform, lower costs of care offer a tremendous competitive advantage to hospitals. There is a constant and increasing pressure on the US healthcare system to reduce costs of care, and hospitals are increasingly challenged to deliver higher-quality care at lower costs.^{27,33} Alternative payment models require that hospitals assume both financial and performance accountability for the care of

their patients undergoing PCI. Current and future healthcare delivery models, such as bundled payments, will provide even stronger incentives for hospitals to improve the efficiency of the care they provide. In a large national study of >250 000 patients undergoing elective PCI who are eligible for SDD from Medicare data, we previously found that the adjusted cost associated with transradial access for PCI combined with SDD was \$13 389, whereas the cost associated with the traditional transfemoral access and overnight observation was \$17 076, a difference of \$3689 (95% confidence interval, \$3486–\$3902; $P<0.0001$).³⁴ A Canadian study by Rinfret et al that compared SDD after transradial PCI with overnight hospitalization realized a 50% reduction, or \approx \$1100 per patient, in medical costs in Canada.³⁵ Muthusamy et al, from Spectrum Health (Grand Rapids, MI), found similar cost savings when analyzing Spectrum Health's first 200 SDD patients undergoing PCI.⁶ Our cost savings are higher in magnitude than prior studies reporting cost savings in the range of \$1500 to \$3600.^{34,36} However, these studies involved a carefully selected and a lower-risk population, and we hypothesize that when SDD is applied to a less selective, “all-comer,” higher-risk population, then cost savings increase in magnitude.

We observed that the radial artery was accessed in 42% of PCIs with SDD, compared with only 4.5% of PCIs without SDD (Table 1). Previous studies have shown radial access to be associated with many benefits, such as reductions in bleeding rates and major vascular complications.^{37–43} It is also the patient-preferred arterial access site^{44,45} and associated with lower cost.^{34,36} Concurrent with the increase in proportion of SDD rates over time, we also observed a temporal increase in the proportion of radially accessed PCIs (data not shown). For example, in the first quarter of 2013, the proportion of radial PCIs was \approx 7%, which increased to 30% in the third quarter of 2015. In concert, these observations imply a paradigmatic shift from the past practice of femoral artery as the predominant access site for PCI. Our findings support this shift, showing that transradial PCIs may provide more opportunities for SDD than the more prevalent transfemoral access.

Despite the success of radial access, there are cases in which the femoral artery remains the ideal procedural access. It is important to recognize that, in our study, more than half of the patients discharged the same day actually underwent femoral access. We had a total of 1590 PCIs with femoral access, 137 of which had SDD. SDD increased equally rapidly in patients undergoing femoral PCI as in patients undergoing radial PCI, implying that the patient-centered decision making was perhaps instrumental in SDD, independent of radial access. A significant difference in the use of vascular closure devices (VCDs) was present between SDD groups; almost all PCIs with SDD had closure devices used (85%). The observed

reduced hospitalization of PCIs with VCDs is not particularly surprising when considering its influence on shorter hemostasis compared with manual compression.²⁴ Our findings agree with several prior studies that examined the safety of SDD with femoral access and closure devices.^{46,47} Our study builds on prior studies that a patient-centered approach and careful preprocedural risk assessment enable a better informed and cognizant approach to SDD despite femoral access. In our observation, the explicit recognition and mitigation of procedural risks facilitate SDD despite a femoral approach. In addition, patient centered decision making engages patients in a more clear understanding of risks and benefits and improves patient satisfaction.⁴⁸

Limitations

Our findings need to be interpreted in the context of several potential limitations, primarily imposed by the data. First, this is a single-center study with a limited sample size and the data included in this article may not be generalizable to other hospitals in the United States that are not explicitly estimating patients' periprocedural risks and implementing tailored risk reduction strategies. Second, we did not have longitudinal follow-up data for our PCI population, thus precluding longer-term assessments of potential complications. Third, it is possible that there are other procedural decisions being made on the basis of characteristics not captured in this study. Fourth, costs were obtained from a hospital perspective and do not capture a broader patient and societal perspective. Fifth, patient satisfaction was not ascertained formally via validated scales nor was it available in all the patients given the limitations of implementation research; it cannot be concluded that patient satisfaction differed by SDD groups. Nonetheless, the fact that nearly all the patients reported excellent patient satisfaction is indicative of the overall signal in the SDD population and is worth reporting. Sixth, although a pattern of reduced adverse outcomes in the SDD group compared with the NSDD group was consistently observed (Table 2), the rarity of the adverse events limits our statistical power to investigate the direct impact of SDD on these outcomes. Larger studies focused primarily on improved outcomes are needed before the results of this study can be generalized. Last, it is conceivable that the higher predicted probabilities of mortality and AKI in the SDD group are reflective of a more cautious and proactive probing during the latter part of the study (after SDD implementation began). However, these seemingly paradoxical findings imply that when appropriate risk-mitigating measures are undertaken, SDD can be successfully advised even in the face of a higher estimated preprocedural risk of a potential negative outcome. However, when patients were being prepared for SDD after successful risk mitigation and were doing well clinically after

PCI, in the absence of symptoms postprocedure, laboratory tests were not drawn to a greater degree than in NSDD patients. These missed laboratory tests may have led to an ascertainment bias favoring SDD for outcomes, such as AKI and post-PCI myocardial infarction.

Conclusions

We used a novel patient-centered approach to estimate and mitigate risk as a foundation for facilitating SDD in an elective, all-comer, PCI population. We observed that SDD rapidly increased and allowed the discharge of nearly 3 of 4 patients undergoing elective PCI on the same day, despite complex lesions and comorbid conditions and including radial or femoral arterial access. Using this approach, we found that adjusted hospital costs were lower by \$7331/case, favoring SDD. Our study identifies an important opportunity to improve PCI outcomes and lower hospital costs with patient-centered decision making. Further well-controlled observational and interventional studies are needed to confirm our findings.

Data Access and Responsibility

Amin, Caruso, Kulkarni, and Sorensen had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Disclosures

Amin is a consultant to the Medicines Company, Terumo, and AstraZeneca. The Lasala is a consultant to Abiomed, BSCI, St. Jude/Abbott. Singh is a consultant to Philips/ Volcano/ Spectranetics, Boston Scientific, Abbott, Medtronic, TriReme. Bach has received Institutional Research Grants from Gilead, MyoKardia, Novartis, Volcano (with no personal compensation). Bach is a consultant/ received honoraria from: Amgen (Modest), Novo Nordisk (Significant), Pharmacosmos (Significant).

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