

Economic and Clinical Impact of Routine Weekend Catheterization Services

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High operating costs can force hospitals to reduce staffing and the availability of elective services on weekends. This “weekend phenomenon” typically provides capacity for acute treatment and maintains staff satisfaction with traditional work-day hours, but can delay patient access to elective testing and procedures.^{1,2} For some conditions, weekend admissions have resulted in delayed hospital discharge, which, if not fully reimbursed, brings into question the overall economic efficiency of this staffing model.³⁻⁵

Weekend admissions may also correlate with an increased risk of adverse events compared with weekday admissions, although whether this is a result of unmeasured patient risk factors or hospital processes remains uncertain.⁶⁻¹⁵ Much of this research focused on clinical outcomes for higher-risk cardiovascular admissions; for example, acute myocardial infarction (MI) or ischemic stroke, where timeliness of therapy is critical.^{6,8,9,11-15} Research on whether “weekend effects” persist for elective admissions is limited for nonemergent cardiac patients, such as those presenting with chest pain, unstable angina, or non-ST segment elevation myocardial infarction (NSTEMI), where timely catheterization laboratory (cath lab) availability may impact patient care processes and outcomes.¹⁶

Mayo Clinic Rochester has a long history of providing emergency cath and revascularization services 24/7 for patients presenting with acute cardiac conditions, such as STEMI. In January 2009, cardiac catheterization service availability (CSA) was expanded to Saturdays for inpatients who previously would have waited until a weekday for a cath procedure. This clinical practice change had a goal of timely access with improved efficiency of care; no other cardiovascular services changed at this time. We assessed the economic and clinical impact of this increased weekend CSA for non-emergent inpatients.

ABSTRACT

Objectives: To assess the impact of weekend cardiac catheterization (cath) services for nonemergent inpatients.

Study Design: Retrospective cohort study of patients undergoing cath before and after Saturday cath service availability (CSA).

Methods: Cohorts included Friday and Saturday admissions with cath (with or without revascularization) on the subsequent Monday from January 1, 2007, to December 31, 2008 (pre-CSA events), and Friday or Saturday admissions undergoing cath the subsequent or same Saturday from January 1, 2009, to December 31, 2010 (post-CSA events). Administrative and registry data provided demographics, comorbidities, percutaneous coronary intervention (PCI) details, adverse events, hospital length of stay (LOS), and inpatient expenditures. We used generalized linear modeling to predict LOS and costs, and logistic regression to estimate the likelihood of adverse events during follow-up.

Results: We identified 331 pre-CSA cases (327 patients) and 244 post-CSA cases (243 patients). Cohorts were similar in age (66 years), sex (59% male), and level of comorbidity. PCI use was higher following CSA (42% vs 26%; $P < .001$), with procedural success accomplished in 95% and 94% of pre- and post-CSA patients, respectively. Adjusted clinical outcomes were similar (odds ratio [OR] for in-hospital mortality, 0.67 post-CSA vs pre-CSA; $P = .55$; OR for 30-day revascularization, 1.14; $P = .68$). Models predict an average LOS reduction of 1.7 days following CSA (5.7 vs 4.0 days; $P < .001$) yet inpatient costs were similar (\$24,817 vs \$24,753; 95% CI of difference, -\$3611 to \$3576).

Conclusions: Weekend CSA for routine inpatients was clinically safe and effective, and reduced hospital LOS. Similar inpatient costs likely reflect a shift in case mix in this nonrandomized study.

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Take-Away Points

We assessed the economic and clinical impact of increased weekend catheterization service availability (CSA) for nonemergent inpatients.

- Weekend CSA for inpatient use significantly reduced length of stay and maintained excellent clinical outcomes with no signal of an excess hazard for weekend cases, but total costs of care were similar due to offsetting utilization.
- These data suggest that weekend CSA for routine inpatients can improve patient access and efficiency of care, while maintaining clinical quality.

METHODS

Study Setting and Population

Mayo Clinic is a high-volume integrated healthcare delivery system. Physicians are salaried and, with administrative leaders, are accountable for both professional and technical costs. The Division of Cardiovascular Diseases has a long-standing tradition of physician-led continuous quality improvement focused on improving the value of service delivery through evidence-based clinical pathways and ongoing cost-containment strategies.¹⁷

The study population consisted of pre-CSA and post-CSA cohorts of hospitalized patients aged at least 18 years, undergoing diagnostic cath (with or without revascularization for a non-STEMI indication) between January 1, 2007, to December 31, 2008, and January 1, 2009, to December 31, 2010, respectively. Pre-CSA episodes included Friday and Saturday admissions with cath procedures on the subsequent Monday, whereas post-CSA episodes included Friday or Saturday admissions undergoing cath procedures the subsequent or same Saturday.

To gain the best perspective on the impact of this expanded model of care on the overall nonemergent practice, no additional patient subsets (other than STEMI indications) were excluded. We included multiple qualifying procedures per patient; however, for procedures with percutaneous coronary intervention (PCI), target vessel revascularization was considered a complication of initial PCI and not an index event. We obtained institutional review board approval and excluded all patients who did not authorize use of their records for research.

Data Sources

Clinical, administrative, and research databases were accessed to obtain the data needed to complete study aims. A clinical scheduling tool was used to identify relevant cath cases and service days, associated demographic and clinical characteristics, and whether adjunctive revascularization was performed. We cross-referenced the pre- and post-CSA cohorts with the local STEMI database to

exclude patients undergoing procedure for a suspected or acute STEMI indication.¹⁸ For PCI-treated patients, we linked to the institutional PCI Registry for more detailed clinical, procedural, angiographic, and outcome data.

Since 1979, all PCI patients have been followed prospectively according to a well-established and validated protocol.¹⁹ Angiographic and procedural characteristics are determined and documented by the PCI operator. A blinded team of registered nurses and data coordinators collects and enters all pre- and postprocedural data, including any adverse clinical events; patients are interviewed in person or by telephone at 6 and 12 months after PCI and yearly thereafter. Medical records for local care and at other institutions are obtained for review with the patient's written informed release.

Administrative data provided additional information on comorbid conditions, discharge disposition, and adverse events (revascularization and MI) during follow-up. Claims also tracked medical resource utilization, related expenditures, and length of stay (LOS) measured in days for these inpatient cath episodes. Same-day patient admission and discharges were considered a 1-day hospital LOS. Further, because of well-known discrepancies between billed charges and true resource use, utilization was valued using the Medicare Part A and Part B classification. Part A billed charges (hospital-billed services and procedures) were adjusted using hospital cost-to-charge ratios at the departmental level and wage indexes and Medicare Part B items (primarily physician-billed services) were valued using national average Medicare reimbursement rates by Current Procedural Terminology (CPT-4) code.

Although the services provided represent local clinical practice patterns, the value of each unit of service has been adjusted to national norms by use of widely accepted valuation techniques providing an estimated economic cost for each line item in the billing record.²⁰ All costs presented here were adjusted to reflect 2010 constant dollars, and economic results are reported in accordance with guidelines for health economic evaluations: the ISPOR Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement.²¹

Outcomes

Economic analyses are from the provider perspective and focused on direct medical costs for hospital and physician services associated with the inpatient episode and total hospital LOS. Clinical outcomes included in-hospital

tal mortality and use of revascularization services (PCI and coronary artery bypass graft [CABG] procedures) in the 30 days following diagnostic cath. Revascularization during follow-up was identified in claims based on *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* procedural codes, CPT-4 codes, and Diagnosis-Related Group (DRG) billing codes.

We identified the occurrence of incident MI in the 30 days following discharge in claims based on ICD-9-CM diagnosis codes (initial MI episodes of care: 410.x1). Although likely a cath complication, MIs occurring after cath (without PCI) during the remaining hospital stay were not assessed because we lacked patient data on when an MI occurred within the identified hospitalization. For the patient subset undergoing adjunctive PCI, however, all MIs from cath onwards were assessed and considered adverse events, as captured by the PCI Registry. Procedural success (defined as $\leq 20\%$ residual stenosis and without in-hospital death, Q-wave MI, or CABG), as well as composite rates of death, MI, and any revascularization during long-term follow-up, were also assessed for this patient subset.

To account for possible differences in comorbidity burden by CSA cohort, we used the validated systematic method of classifying comorbidity utilizing administrative data (Deyo adaption of the Charlson Comorbidity Index) based on secondary diagnoses assigned as present on hospital admission.²²⁻²⁴ Similarly, validated in-hospital and follow-up Mayo Clinic Risk Scores were assessed using patient and clinical characteristics (recorded in the PCI Registry) to adjust clinical outcomes within the PCI subset.^{25,26}

Statistical Analysis

Continuous data are summarized as mean \pm standard deviation. Discrete data are presented as frequency (percentage). Patient characteristics and observed in-hospital clinical outcomes were compared using the *t* test for continuous data, the Mann-Whitney rank sum test for ordinal data, and Pearson's χ^2 test for categorical data, as appropriate. Kaplan-Meier estimated adverse-event rates during follow-up were compared using the log-rank test for the subset of PCI-treated patients (for whom we had outcomes data in continuous time). For these analyses, only the first PCI per unique patient was included, and follow-up started at index PCI such that in-hospital events were included. Observed costs and LOS were compared using *t* tests and the 95% CIs for the difference of means calculated using the percentile method for bootstrapping.^{27,28}

Logistic regression modeling estimated the impact of CSA on in-hospital mortality and 30-day MI and revascularization rates. Models adjusted for age, creatinine level,

troponin elevation, and use of adjunctive PCI. We employed Cox Proportional Hazard models to estimate the adjusted hazard for adverse events (death or MI) during longer-term follow-up for the PCI patient subset. These follow-up models adjusted risk before discharge with the calculated in-hospital risk score and used the long-term risk score to adjust risk for events after discharge.

We used generalized linear modeling to assess costs and LOS, accounting for the nonnegative and typically skewed nature of these economic end points.²⁹ Cost models assumed a logarithmic link function and a gamma distribution, whereas we assumed a negative binomial distribution function with log link in the model assessing LOS. All economic models adjusted for age, gender, Charlson Comorbidity Index, and adjunctive PCI. All statistical tests were 2-sided, and *P* values $< .05$ were considered significant. SAS version 9.3 (SAS Institute, Cary, North Carolina) was used in analyses.

RESULTS

We identified 331 pre-CSA cases (327 patients) and 244 post-CSA cases (243 patients) undergoing diagnostic cath (with or without revascularization) in the years of interest. Baseline clinical and procedural characteristics are shown in **Table 1**. The 2 cohorts were similar in terms of age (mean = 66 years), sex (59% male), body mass index (30.4), and comorbidity burden. However, a greater proportion of patients treated post-CSA underwent PCI (42% vs 26%; $P < .001$). Within this PCI subset, clinical characteristics were similar between cohorts, with the exception of a higher proportion of PCI patients having experienced an MI less than 24 hours before procedure post-CSA (32% vs 2%; $P < .001$).

Clinical Outcomes After CSA

Observed clinical outcomes by CSA era for the entire cohort and the PCI subset are shown in **Table 2**. In-hospital mortality rates were similar between groups, with death occurring in fewer than 2% of cases. New MI in the 30 days after discharge was rare, occurring in 0.3% and 0.4% of the pre- and post-CSA cohorts, respectively ($P = .83$). The incidence of revascularization (PCI or CABG) in the 30 days following catheterization was approximately 9% of patients in both cohorts, although patients were more likely to undergo CABG compared with PCI (30-day rates for entire cohort: approximately 8% CABG vs 1% PCI).

Among cases undergoing PCI, procedural success was attained in 95% and 94% of pre- and post-CSA patients, respectively ($P = .71$). Follow-up at 1 year was complete in 91% of patients (96% of controls and 87% of cases). Those with

Table 1. Baseline and Procedural Characteristics of Catheterization Patient Episodes Pre-CSA and Post-CSA

| Variable | Pre-CSA (n = 331) | Post-CSA (n = 244) | P |
|-----------------------------------|---------------------|--------------------|-------|
| Age, years: mean ± SD | 66.6 ± 13.4 | 66.61 ± 13.4 | .63 |
| Male sex, n (%) | 194 (58.6) | 145 (59.4) | .84 |
| BMI, mean ± SD | 30.4 ± 6.5 | 30.4 ± 6.1 | .90 |
| Creatinine, median (Q1, Q3) | 1.0 (0.9, 1.2) | 1.0 (0.8, 1.2) | .05 |
| Troponin, median (Q1, Q3) | <0.01 (<0.01, 0.08) | 0.02 (<0.01, 0.18) | .007 |
| Charlson Comorbidity Index, n (%) | | | .24 |
| 0 | 92 (27.8) | 75 (30.7) | |
| 1 | 84 (25.4) | 66 (27.0) | |
| 2 | 67 (20.2) | 45 (18.4) | |
| 3 | 35 (10.6) | 29 (11.9) | |
| 4 | 21 (6.3) | 12 (4.9) | |
| 5 or more | 21 (6.3) | 12 (4.9) | |
| PCI | 86 (26.0) | 102 (41.8) | <.001 |
| Age, mean ± SD, years | 68.2 ± 12.4 | 66.7 ± 13.3 | .42 |
| Male sex, n (%) | 56 (65) | 75 (74) | .21 |
| BMI, mean ± SD | 30.8 ± 6.2 | 30.5 ± 5.5 | .69 |
| Most recent MI, n (%) | | | <.001 |
| <24 hours | 2 (2) | 32 (32) | |
| 1-7 days | 29 (35) | 26 (26) | |
| >7 days | 20 (24) | 16 (16) | |
| Never | 32 (39) | 27 (27) | |
| Pre-procedural shock, n (%) | 1 (1) | 6 (6) | .09 |
| Definite/probable angina, n (%) | 66 (77) | 65 (64) | .05 |
| Troponin, median (Q1, Q3) | 0.02 (<0.01, 0.10) | 0.06 (<0.01, 0.24) | .25 |
| Charlson Comorbidity Index, n (%) | | | .85 |
| 0 | 31 (36) | 32 (31) | |
| 1 | 17 (20) | 26 (25) | |
| 2 | 16 (19) | 19 (19) | |
| 3 | 9 (10) | 10 (10) | |
| 4 | 8 (9) | 11 (11) | |
| 5 or more | 5 (6) | 4 (4) | |
| No family history of CHD, n (%) | 35 (41) | 48 (47) | .60 |
| Prior PTCA, n (%) | 35 (41) | 35 (34) | .37 |
| Prior CABG, n (%) | 22 (26) | 24 (24) | .74 |

BMI indicates body mass index; CABG, coronary artery bypass graft; cath, cardiac catheterization; CHD, coronary heart disease; CSA, catheterization service availability; MI, myocardial infarction; PCI, percutaneous coronary intervention; PTCA, percutaneous transluminal coronary angioplasty; SD, standard deviation.

incomplete follow-up were treated as censored at the time of last contact. The median duration of follow-up for adverse clinical events was 4.2 years and 2.2 years for the pre- and post-CSA PCI cohorts, respectively. Two PCI episodes were excluded in long-term clinical analyses given multiple procedures per patient, resulting in 85 pre-CSA and 101

post-CSA PCI-treated patients. The Kaplan-Meier estimated all-cause mortality at 12 months following PCI was 6% and 9% in the pre- and post-CSA PCI groups, respectively ($P = .39$). Overall, Kaplan-Meier adverse event rates (composite of death, MI, CABG, or target lesion revascularization) in the year following procedure were similar between groups, estimated at 11% and 17% of PCI-treated patients in the pre- and post-CSA cohorts, respectively ($P = .25$).

Clinical outcomes remained similar between CSA groups, with adjustment for patient baseline and time-dependent characteristics (Table 3). Logistic model results for in-hospital death, 30-day post-discharge MI, and 30-day revascularization suggest that CSA implementation did not adversely affect clinical event rates. Within the PCI patient subset, CSA implementation was also not associated with an increased hazard for death or with the composite end point of death or MI during long-term follow-up.

Economic Outcomes After CSA

Table 4 summarizes observed costs of care and LOS associated with these hospitalizations with cath. Total costs were, on average, approximately \$1571 less for post-CSA patients compared with pre-CSA treated patients, although this difference was not of statistical significance (\$23,289 vs \$25,400; 95% CI of difference = -\$5405 to \$2428). Similarly, hospital (\$1317; $P = .46$) and physician costs (\$189; $P = .46$) were nonsignificantly reduced after CSA, comprising 87% and 13% of total inpatient costs, respectively. On the other hand, LOS was significantly reduced by 2.09 days, on average, following CSA (5.91 days pre-CSA vs 3.82 days post-CSA; $P < .001$).

With adjustment for patient characteristics and PCI use, increased CSA was not associated with total, hospital, or physician costs of care (Table 5). Predicted costs were, in fact, nearly identical between cohorts, estimated at \$24,817, on average, for pre-CSA hospital episodes and at \$24,752 following CSA implementation (95% CI of mean cost difference, -\$3611 to \$3576). Substantial reductions in LOS following CSA

Table 2. Observed Clinical Outcomes by CSA Era

| Variable | Pre-CSA (n = 331) | Post-CSA (n = 244) | P |
|---------------------------------------------------------------------------|---------------------------------|-----------------------------------|-----|
| In-hospital death | 6 (1.8%) | 3 (1.2%) | .58 |
| 30-day postdischarge MI | 1 (0.3%) | 1 (0.4%) | .83 |
| 30-day PCI | 5 (1.5%) | 1 (0.4%) | .20 |
| 30-day CABG | 26 (7.9%) | 20 (8.2%) | .88 |
| 30-day PCI/CABG | 31 (9.4%) | 21 (8.6%) | .75 |
| | Pre-CSA: PCI Subset (n = 86) | Post-CSA: PCI Subset (n = 102) | P |
| Procedural success | 82 (95.3%) | 96 (94.1%) | .71 |
| In-hospital death | 2 (2.3%) | 3 (2.9%) | .79 |
| In-hospital MI | 2 (2.3%) | 2 (2.0%) | .86 |
| In-hospital CABG | 0 (0.0%) | 0 (0.0%) | |
| In-hospital death/MI CABG/target lesion revascularization | 4 (4.7%) | 5 (4.9%) | .94 |
| 12-month death ^a | 5 (6.0%) | 9 (9.4%) | .39 |
| 12-month death/MI ^a | 7 (8.4%) | 14 (14.5%) | .20 |
| 12-month death/MI CABG/target lesion revascularization ^a | 9 (10.8%) | 16 (16.6%) | .25 |

CABG indicates coronary artery bypass graft; CSA, catheterization service availability; MI, myocardial infarction; PCI, percutaneous coronary intervention.
^aTwo PCI episodes were excluded in long-term clinical analyses given multiple procedures per patient (85 pre-CSA and 101 post-CSA PCI-treated patients included in 12-month outcomes analyses).

implementation, however, persisted in adjusted analyses with an estimated mean LOS reduction of 1.73 days (LOS: 3.98 days post-CSA vs 5.71 days pre-CSA; 95% CI of difference, 0.97-2.48).

DISCUSSION

A key goal of CSA expansion to Saturdays for stable inpatients was improved process efficiency while maintaining clinical quality of care. The major findings of this study are that Saturday CSA for inpatients was associated with a) significantly reduced LOS, b) significantly higher PCI utilization as a proportion of cases, c) excellent clinical outcomes in-hospital and during follow-up with no signal of an excess hazard for weekend cases, d) similar total costs of care due to offsetting utilization (a and b).

Although emergent procedures for acute MI, cardiogenic shock, and other acute clinical syndromes have long been available at Mayo Clinic and nearly all tertiary care cardiac centers, historically, many hospitals do not provide routine cath lab services on weekends. This practice change was an effort to improve quality and efficiency of care. The findings confirm the major goal of establishing

Saturday CSA in order to safely eliminate the need for inpatients to wait until the following week for nonemergent procedures. LOS, both adjusted and unadjusted, fell significantly, confirming the utility of weekend cath services.

Interestingly, a significantly higher proportion of patients underwent PCI after expanded CSA, suggesting a shift in case mix with known availability of weekend cath services. As a nonrandomized study, case selection likely played an important role in this analysis. Anecdotally, clinicians and operators favored more urgent patients for the limited Saturday cath procedures on clinical grounds. Patients with ongoing or unstable chest pain were prioritized for early catheterization. This effect likely shifted a number of nonurgent cases to Monday post-CSA, which would increase the risk of Saturday cases. Despite this potential selection bias, our observations confirm the safety of this practice, at least in the environment in which it was tested. Due to the increased PCI use, overall hospital costs were similar despite a lower mean LOS. Overall, we

believe these results are indicative of higher-value care: [quality or service] / [cost]. Whether these favorable outcomes could be replicated in lower-volume centers with less support staff cannot be inferred from our data.

To our knowledge, we are the first to assess the impact of weekend CSA on outcomes for nonemergent inpatient admissions. Although many have investigated the association between admission day and time and outcomes

Table 3. Odds and Hazard Ratio for Adverse Events After CSA Implementation

| Variable | Odds Ratio (entire cohort) | 95% CI |
|-------------------------|-------------------------------|-----------|
| In-hospital death | 0.67 | 0.19-2.43 |
| 30-day postdischarge MI | 1.03 | 0.31-3.42 |
| 30-day PCI/CABG | 1.14 | 0.62-2.07 |
| | Hazard Ratio (PCI subset) | 95% CI |
| Death | 1.23 | 0.52-2.91 |
| Death/MI | 1.58 | 0.78-3.20 |

CABG indicates coronary artery bypass graft; CSA, catheterization service availability; MI, myocardial infarction; PCI, percutaneous coronary intervention.

Table 4. Observed Economic Outcomes by CSA Era

| Outcome | Pre-CSA (n = 331) | Post-CSA (n = 244) | Mean Difference (95% CI) ^a | P |
|------------------------------------|--------------------------|--------------------------|------------------------------------------|-------|
| Total costs, \$ ^{b,c} | 25,400 (16,440) ± 23,851 | 23,829 (14,887) ± 23,233 | -1571 (-5405 to 2428) | .43 |
| Hospital costs, \$ ^{b,c} | 21,990 (14,217) ± 21,132 | 20,673 (12,485) ± 20,913 | -1317 (-4735 to 2275) | .46 |
| Physician costs, \$ ^{b,c} | 3587 (2490) ± 3129 | 3398 (2356) ± 2865 | -189 (-653 to 321) | .46 |
| LOS, days ^b | 5.91 (4) ± 5.85 | 3.82 (2) ± 4.37 | 2.09 (1.27-2.95) | <.001 |

CSA indicates catheterization service availability; LOS, length of stay; SD, standard deviation.
^aBootstrap 95% CI using the percentile method.
^bObserved mean (median) ± SD.
^cCosts represent 2010 constant dollars.

in emergency settings, research is limited in nonemergent settings and on interventions aimed to mitigate weekend effects. One recent study of hospitals in England found weekend admissions to be an independent risk factor for in-hospital death that was more pronounced in an elective compared with emergent setting. The authors suggest unobserved patient risk factors are not likely to contribute to this increased risk given the planned nature of elective admissions. Instead, perhaps there is “generic dimension” to the weekend effect, which may be more marked in elective settings. Yet, the authors note this finding is novel and warrants further investigation before informing efforts to improve weekend care in an elective setting.²

Certainly, many emergency admission studies attribute weekend effects to reduced service availability or less aggressive off-hour care.^{6,11,30} Emerging care process research suggests weekend effects may be mitigated with clinical pathways or specialized disease centers with continuous availability of expert clinical teams and necessary diagnostic and treatment modalities.^{15,31} It is possible that as a high-volume referral center with existing care pathways and experienced clinical teams, weekend effects were not present in our setting, even prior to increased CSA. Further research is needed on enhanced weekend availability for other diagnostic and therapeutic services, particularly in elective admissions and across practice settings, to ensure similar care processes and outcomes, regardless of which day admission occurs.

Limitations

Our analysis has a number of important limitations. As a retrospective study, patients were not randomly assigned to treatment cohorts, and the usual limitations of this design are relevant. For example, the post-CSA cohort may have been systematically different in ways unaccounted for, which caused them to have reduced LOS. Similarly, the higher rate of PCI following expanded CSA suggests a possible shift in the type of patients selected for cath. We adjusted for observed characteristics

between groups, but unobserved differences may remain as confounding results.

For optimal “apples to apples” comparison, we would have preferred to include only nonemergent inpatients whose cath was truly delayed with lack of Saturday CSA in our pre-CSA cohort. Unfortunately, the scheduling tool overrides original cath dates and times with final service dates when performed. This may have caused inclusion of some patients whose cath was not truly delayed by lack of weekend CSA, but instead, was scheduled later in the hospitalization with Monday treatment. We speculate we would have observed more substantial economic benefits with weekend CSA had data afforded a cleaner study design.

Our reliance on claims to identify incident MIs during follow-up poses additional limitations. ICD-9-CM diagnosis codes for MI have been shown to have a high positive predictive value, but we could have missed events that occurred outside our facility.^{32,33} Although we may have underestimated MI rates in the 30 days following hospitalization, it is unlikely that the comparison groups were differently affected by this potential measurement error. Additionally, primary diagnosis billing codes associated with hospitalizations are not date specific; thus, we were not able to include MIs occurring after cath without PCI during remaining hospital stay as adverse events, as we lacked data for these patients on when an in-hospital MI occurred. If in-hospital MI rates varied pre- and post-CSA, we did not capture that effect. For PCI-treated patients, however, all

Table 5. Adjusted Economic Outcomes by CSA Era

| Outcome | Pre-CSA (n = 331) | Post-CSA (n = 244) | Mean Difference (95% CI) ^a |
|----------------------------------|----------------------|-----------------------|------------------------------------------|
| Total costs, \$ ^b | 24,817 | 24,753 | -64 (-3611 to 3576) |
| Hospital costs, \$ ^b | 21,394 | 21,343 | -51 (-3163 to 3149) |
| Physician costs, \$ ^b | 3497 | 3504 | 7 (-456 to 471) |
| LOS, days | 5.71 | 3.98 | 1.73 (0.97-2.48) |

CSA indicates cardiac service availability; LOS, length of stay.
^aBootstrap 95% CI using the percentile method.
^bMean costs per hospital episode in 2010 constant dollars.

MIs from cath onward were considered adverse events, as captured by the PCI Registry. No differences in adverse events were observed between groups, yet we also acknowledge limited statistical power to detect differences with few observed events. Clinically relevant differences between patients treated pre-and post-CSA may exist.

Finally, our study reflects the experience of a single, high-volume referral center. Patients and results may differ in other practice settings.

Conclusions

The availability of inpatient Saturday cath lab services significantly reduced LOS and maintained excellent clinical outcomes with no signal of an excess hazard for weekend cases. Total costs of care were similar due to offsetting utilization. Further research is needed on enhanced weekend service availability, particularly in elective admissions and across practice settings, to ensure similar care processes and outcomes, regardless of which day admission occurs.

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