

Time of day and outcomes of nonurgent percutaneous coronary intervention performed during working hours

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Background During daytime working hours, outcomes may be worse when percutaneous coronary intervention (PCI) is performed later in the day because of operator fatigue and differences in process of care.

Methods Using the APPROACH database, we analyzed 2,492 consecutive nonurgent PCI procedures performed during working hours. Patients undergoing PCI for acute coronary syndromes were excluded. Patients were separated into 2 groups based on whether PCI was started in the morning (7:00 AM-12:00 PM, n = 1,446) or after noon (12:01 PM-6:00 PM, n = 1,037). Outcomes included procedural complications; target vessel revascularization (TVR); and death at 7 days, 30 days, and 1 year.

Results Patients undergoing PCI in the afternoon were more likely to have heart failure, reduced ejection fraction, and Canadian Cardiovascular Society class IV or atypical angina symptoms; more likely to be inpatients; less likely to have stable angina; and less likely to receive glycoprotein IIb/IIIa inhibitors. Patients undergoing PCI in the afternoon had significantly higher unadjusted rates of the composite of death and TVR at 7 days (0.9% vs 0.3%, $P = .04$) and 30 days (2.0% vs 1.0%, $P = .04$) and death at 1 year (2.2% vs 1.1%, $P = .03$) compared with PCI performed in the morning. After multivariate adjustment, the differences in the composite of death and TVR at 30 days and at 1 year were not statistically significant.

Conclusion Patients undergoing nonurgent PCI during working hours after noon had higher rates of TVR in the first 30 days and death at 1 year. Further study is required to determine whether patient characteristics, operator fatigue, differences in process of care, or a combination of these factors accounts for the difference in outcomes. (*Am Heart J* 2010;159:1133-8.)

Previous studies have documented higher rates of procedural failure and death for patients undergoing emergent percutaneous coronary intervention (PCI) for acute myocardial infarction during off-hours compared with daytime working hours.¹ However, even during routine working hours, there may be differences in procedural and clinical outcomes when PCI is performed later in the day, perhaps because of operator fatigue, differences in process of care, and other factors. Fatigue among health care workers has been shown to adversely affect clinical care and operator performance in other settings,^{2,5} but its impact on PCI procedures has not been studied.

The Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease (APPROACH) is a large, population-based registry that captures detailed clinical information for all patients undergoing PCI in the Canadian province of Alberta.⁶ We analyzed consecutive nonurgent PCI procedures performed during working hours (7:00 AM-6:00 PM) in Alberta over a 5-year period to determine whether procedures performed later in the day were associated with higher rates of complications and adverse clinical outcomes compared with procedures performed earlier in the day.

Methods

The APPROACH is a clinical data collection initiative capturing all patients undergoing cardiac catheterization in Alberta, Canada, since 1995.^{6,7} It contains detailed information including patients' age, sex, ejection fraction, and the presence or absence of previous myocardial infarction (MI), congestive heart failure, diabetes, cerebrovascular disease, peripheral vascular disease, chronic pulmonary disease, elevated creatinine, dialysis, hyperlipidemia, hypertension, liver or gastrointestinal disease, or malignancy. It tracks therapeutic interventions such as previous thrombolytic therapy and previous or subsequent revascularization by coronary artery bypass graft surgery (CABG) or PCI. Coronary anatomy and procedural details are also recorded. Baseline clinical information is collected on patients by care providers in the cardiac catheterization laboratory at the time of PCI. Follow-up mortality

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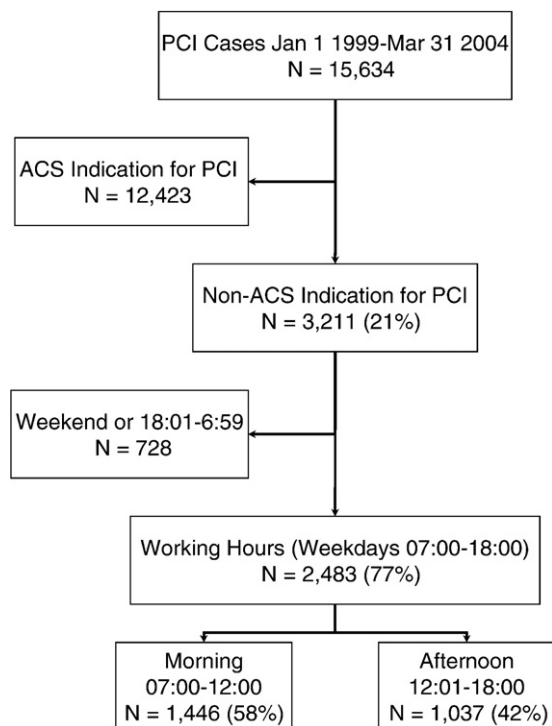
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Figure 1



Selection of PCI cases for analysis.

is ascertained through semiannual linkage to data from the Alberta Bureau of Vital Statistics. For the purpose of this study, data from January 1, 1999, to March 31, 2004, were used.

Time of procedure is routinely recorded in APPROACH. This information was used to group PCI patients into 2 time-of-day groupings based on whether procedure was started in the morning (7:00 AM-12:00 PM) or after noon (12:01 PM-6:00 PM).

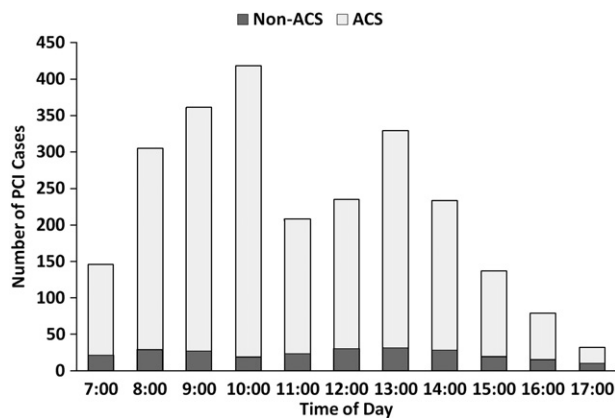
The selection process for PCI procedures to be included in the analysis is shown in Figure 1. Procedures with acute coronary syndrome identified as the indication, procedures for patients with Canadian Cardiovascular Society (CCS) class IVb or IVc angina, and procedures performed on weekends or after regular working hours (6:00 PM-7:00 AM) were excluded. The result of this selection procedure was a cohort of patients undergoing nonurgent PCI procedures.

The clinical outcomes of interest were death, target vessel revascularization (TVR), and the composite end point of death or TVR assessed at 7 days, 30 days, and 1 year. *Target vessel revascularization* was defined as bypass surgery or repeated PCI for the same vessel. Procedural complications were also assessed; and these included coronary dissection, failure to deploy stent, coronary perforation, transient "slow-reflow" or "no-reflow," or new thrombus formation. Complications were determined by careful review of the records generated at the time of PCI, which are contained in the APPROACH database.

Statistics

Patient characteristics, clinical outcomes, and complications for the time of starting PCI were compared using χ^2 tests.

Figure 2



Timing of PCI cases.

Kaplan-Meier plots were used to determine crude survival rates and event-free rates for nonfatal end points for the 2 timing groups. Survival time was calculated from the date of PCI to the date on which the patient was censored or the outcome event occurred. Data were censored if a patient was lost to follow-up or was still alive at the end of the study.

Adjustment was done for all of the baseline demographic and clinical characteristics available in the APPROACH database (including inpatient status). Odds ratios for the composite of death and TVR at 30 days and 1 year were then calculated using separate logistic regression models for both time points.

Sensitivity analysis was done repeating the same analysis above for stable angina patients only as well as for outpatients only.

Statistical analyses were performed using SAS, version 8.2 (SAS Institute, Cary, NC).

No extramural funding was used to support this work. The authors are solely responsible for the design and conduct of this study, all study analyses, and the drafting and editing of the paper.

Results

From January 1, 1999, to March 31, 2004, a total of 15,634 PCI procedures were performed in Alberta. Of these, acute coronary syndrome was listed as the indication for PCI in 12,423 cases; and 719 procedures were performed outside of working hours, leaving 2,483 nonurgent PCI cases for this analysis (Figure 1). The distribution of nonurgent PCI cases by time of day during working hours is shown in Figure 2. The time of starting PCI was morning (7:00 AM-12:00 PM) in 1,446 (58%) cases and after noon (12:01 PM-6:00 PM) in 1,037 (42%) cases.

Baseline characteristics

Baseline clinical characteristics for the patients in these 2 time groups are shown in Table I. Patients

Table I. Baseline clinical characteristics

Characteristics	Early (7:00 AM-12:00 PM) n = 1446	Late (12:01 PM-6:00 PM) n = 1037	P value*
Male	1144 (79.1%)	814 (78.5%)	.71
Age	62.7 (10.6)	62.5 (10.7)	.56
Pulmonary disease	168 (11.6%)	96 (9.3%)	.06
Cerebrovascular disease	81 (5.6%)	50 (4.8%)	.39
Renal disease	30 (2.1%)	22 (2.1%)	.94
Dialysis	15 (1.0%)	12 (1.2%)	.78
Congestive heart failure	80 (5.5%)	92 (8.9%)	.001
Diabetes	330 (22.8%)	208 (20.1%)	.10
Hypertension	893 (61.8%)	620 (59.8%)	.32
Hyperlipidemia	1137 (78.6%)	748 (72.1%)	.0002
Liver/GI disease	67 (4.6%)	44 (4.2%)	.64
Malignancy	46 (3.2%)	27 (2.6%)	.40
Current smoker	269 (18.6%)	200 (19.3%)	.67
Prior CABG	154 (10.7%)	113 (10.9%)	.85
Prior MI	494 (34.2%)	334 (32.2%)	.31
Prior PCI	161 (11.1%)	92 (8.9%)	.07
Prior lytic	1 (0.06%)	0	.00†
Peripheral vascular disease	103 (7.1%)	80 (7.7%)	.58
Inpatient	124 (8.6%)	184 (17.7%)	<.0001
Indication for PCI			.0003
Stable angina	1326 (91.7%)	905 (87.3%)	
Other‡	120 (8.3%)	132 (12.7%)	
Ejection fraction			.01
>50%	962 (66.5%)	623 (60.1%)	
35%-50%	205 (14.2%)	186 (17.9%)	
20%-34%	40 (2.8%)	42 (4.1%)	
<20%	33 (2.3%)	22 (2.1%)	
Not done	58 (4.0%)	55 (5.3%)	
Missing	148 (10.2%)	109 (10.5%)	
CCS class			.02
Not entered	138 (9.5%)	108 (10.4%)	
None	44 (3.0%)	32 (3.1%)	
I	80 (5.5%)	42 (4.1%)	
II	696 (48.1%)	502 (48.4%)	
III	413 (28.6%)	267 (25.8%)	
IV	42 (2.9%)	57 (5.5%)	
Atypical	33 (2.3%)	29 (2.8%)	

Data are expressed as number (percentage) of cases or mean (SD). GI, Gastrointestinal.

* P value calculated using χ^2 test.

† P value calculated using Fisher exact test.

‡ Arrhythmia, congestive heart failure, silent ischemia.

undergoing nonurgent PCI in the afternoon were more likely to have congestive heart failure, reduced ejection fraction, and CCS class IV or atypical angina symptoms and were more likely to be inpatients. Patients undergoing PCI in the morning were more likely to have hyperlipidemia and typical stable angina. Baseline procedural and angiographic characteristics are listed in Table II. Patients undergoing PCI later in the day had more stents used and were less likely to have received intravenous glycoprotein IIb/IIIa inhibitors. There was a trend toward more complex lesions (American College of Cardiology/American Heart Association classification B2 or C) in afternoon procedures. There were no

Table II. Procedural and angiographic characteristics

Characteristics	Early (7:00 AM-12:00 PM) n = 1446	Late (12:01 PM-6:00 PM) n = 1027	P value*
Single-vessel PCI	1271 (87.9%)	935 (90.2%)	.08
Multivessel PCI	175 (12.1%)	102 (9.8%)	
No. of stents used	1.34 (2.74)	1.54 (6.13)	.26
GP IIb/IIIa inhibitor use	625 (43.2%)	401 (38.7%)	.02
Lesion complexity			.03
A	29 (2.0%)	15 (1.5%)	
B1	171 (11.8%)	152 (14.7%)	
B2	63 (4.4%)	60 (5.8%)	
C	146 (10.1%)	120 (11.6%)	
Missing	1037 (71.7%)	690 (66.5%)	
Final diameter stenosis >50%	44 (3.0%)	45 (4.3%)	.09
Final diameter stenosis <30%	1276 (93.6%)	894 (94.5%)	.38
Final flow grade			.87†
TIMI 0	16 (1.1%)	13 (1.3%)	
TIMI 1	15 (1.0%)	8 (0.8%)	
TIMI 2	2 (0.1%)	2 (0.2%)	
TIMI 3	1413 (97.7%)	1014 (97.8%)	

Data are expressed as number (percentage) of cases or mean (SD). GP, Glycoprotein; TIMI, Thrombolysis in Myocardial Infarction.

* P value calculated using χ^2 test.

† P value calculated using Fisher exact test.

significant differences in the rates of failed PCI (residual stenosis >50%) or in the final Thrombolysis in Myocardial Infarction flow grade.

Procedural complications

Complications occurring in the catheterization laboratory are listed in Table III and generally low for all events studied. No significant differences were seen in the incidence of procedural complications for PCI cases performed in the afternoon compared with morning, although there was a trend toward higher rates of failed stent deployment in the afternoon (1.5% vs 0.8%, $P = .10$).

Clinical outcomes

Clinical outcomes at 7 days, 30 days, and 1 year after PCI are shown in Table IV. Compared with patients undergoing PCI in the morning, patients undergoing PCI in the afternoon had significantly higher unadjusted rates of TVR (PCI or CABG) at 7 days (0.6% vs 0.1%, $P = .07$) and 30 days (1.5% vs 0.7%, $P = .04$), the composite of death or TVR at 7 days (0.9% vs 0.3%, $P = .04$) and 30 days (2.0% vs 1.0%, $P = .04$), and death at 1 year (2.2% vs 1.1%, $P = .03$). The event-free Kaplan-Meier survival curves to 1 year of follow-up, based on timing of PCI, are presented in Figure 3 and show numerically higher rates of events for patients undergoing PCI later in the day ($P = .03$). The corresponding crude and risk-adjusted odds ratios for the composite of death and TVR at 30 days and 1 year are presented in Table V. The odds ratios for procedures

Table III. Procedural complications

Characteristics	Early (7:00 AM- 12:00 PM) n = 1446	Late (12:01 PM- 6:00 PM) n = 1037	P value*
Coronary dissection	50 (3.5%)	43 (4.2%)	.37
Failure to deploy stent	11 (0.8%)	15 (1.5%)	.10
Coronary perforation	3 (0.2%)	1 (0.1%)	.64 [†]
Transient "slow-reflow" or "no-reflow"	4 (0.3%)	0	.15
New thrombus formation	1 (0.1%)	1 (0.1%)	1.00 [†]

Data are expressed as number (percentage) of cases or mean (SD).

* P value calculated using χ^2 test.

[†] P value calculated using Fisher exact test.

performed later in the day are 3.16 (0.97-10.28) at 7 days, 1.97 (1.01-3.84) at 30 days, and 1.24 (0.98-1.56) at 1 year post-PCI. Multivariable risk adjustment had little effect on the point estimate and CIs of the odds ratios.

Sensitivity analysis limiting to stable angina patients only revealed very similar results with crude odds ratios for procedures performed later in the day as 3.93 (1.04-14.86) at 7 days, 2.17 (1.06-4.41) at 30 days, and 1.21 (0.95-1.56) at 1 year post-PCI. When inpatients were excluded from the analysis, the target vessel PCI rates at 30 days remained higher for afternoon procedures (1.5% vs 0.6%, $P = .03$); but the difference in death at 1 year no longer reached statistical significance (1.9% vs 1.0%, $P = .08$).

Discussion

To our knowledge, this study is the first to evaluate the relationship between the time of day that a nonurgent PCI procedure is performed during working hours and the clinical and procedural outcomes. Nonurgent PCI procedures performed during working hours after noon are associated with a higher incidence of repeated TVR at 7 days and 30 days and death at 1 year than nonurgent PCI procedures performed in the morning. Patients undergoing PCI later in the day tended to be sicker and with more advanced left ventricular dysfunction, heart failure, and severe angina.

Previous work has demonstrated that primary PCI for ST-elevation MI is associated with higher procedural failure and mortality during off-hours compared with working hours¹. A number of explanations for this difference have been proposed, including circadian rhythms in hemodynamic and hemostatic parameters, delays in reperfusion while awaiting off-site cardiac catheterization laboratory staff to arrive, and possibly operator fatigue.⁸ However, no previous study has examined the impact of procedural timing for nonurgent PCI procedures performed during regular working hours.

Table IV. Clinical outcomes

Outcomes	Early (7:00 AM- 12:00 PM) n = 1446	Late (12:01 PM- 6:00 PM) n = 1037	P value*
Target vessel PCI at 7 d	2 (0.1%)	6 (0.6%)	.07 [†]
CABG at 7 d	0	2 (0.2%)	.17 [†]
TVR [‡]	2 (0.1%)	8 (0.8%)	.02 [†]
Death at 7 d	2 (0.1%)	1 (0.1%)	1.00 [†]
Composite end point at 7 d	4 (0.3%)	9 (0.9%)	.04
Target vessel PCI at 30 d	10 (0.7%)	16 (1.5%)	.04
CABG at 30 d	2 (0.1%)	2 (0.2%)	1.00 [†]
Death at 30 d	3 (0.2%)	3 (0.3%)	.70 [†]
Composite end point at 30 d [§]	5 (1.0%)	21 (2.0%)	.04
Target vessel PCI at 1 y	127 (8.8%)	98 (9.5%)	.57
CABG at 1 y	46 (3.2%)	41 (4.0%)	.30
Death at 1 y	16 (1.1%)	23 (2.2%)	.03
Composite end point at 1 y [§]	181 (12.5%)	156 (15.0%)	.07

Data are expressed as number (percentage) of cases.

* P value calculated using χ^2 test.

[†] P value calculated using Fisher exact test.

[‡] Either target vessel PCI or CABG.

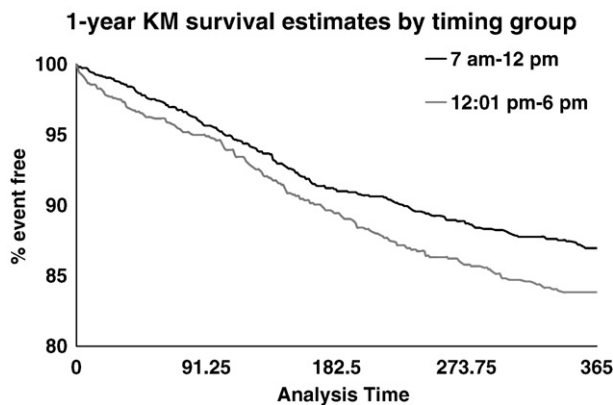
[§] Death, target vessel PCI, or CABG.

Differences in baseline patient characteristics likely account for at least some of the differences in outcomes observed in this study. Our data indicate that inpatients (including patients with lower ejection fractions, previous congestive heart failure, and more severe angina) and patients with more complex coronary anatomy were selectively scheduled toward the end of the day. The adjusted odds ratios in the multivariable analysis were very similar to the crude odds ratios, suggesting that these factors do not completely account for the observed differences in event rates. Furthermore, the difference in TVR at 30 days remained significant even after excluding inpatients, although the difference in mortality at 1 year was no longer statistically significant.

Operator fatigue may be higher toward the end of a long working day. Fatigue among health care workers has been reported to be associated with medical errors.² There is a large body of laboratory data suggesting that fatigue impairs human performance.⁹ In clinical practice, sleep deprivation has been shown to adversely affect hand-eye coordination during laparoscopy.⁴ It is possible that operator fatigue may contribute to higher complications and worse outcomes when procedures are performed late in the day. Further research is required to determine whether operator fatigue contributes to worse outcomes for nonurgent PCI procedures performed during regular working hours. Nevertheless, measures to minimize operator fatigue should be considered.

It is also possible that operators may feel more rushed to complete cases quickly later in the day, which may lead

Figure 3



One-year Kaplan-Meier plot for event-free survival by timing of PCI.

to judgment errors (such as choosing inappropriately sized stents or attempting to stent calcified vessels without adequate predilation or rotational atherectomy) and less perseverance in trying to deliver stents in calcified or tortuous vessels. These factors may account for the trend to higher rate of failed stent delivery that was observed during afternoon cases.

Differences in the overnight care for patients undergoing angioplasty at the end of the day may also contribute to differences in clinical outcomes. The communication of the management plan from the physicians performing the procedure to the house staff or on-call physicians may be less adequate. Patients may not be observed as closely overnight as during the day, and the identification and treatment of complications may be delayed.

Circadian rhythms do not vary considerably during working hours and are unlikely to have a major impact on procedural outcomes during daytime hours. However, it is possible that the declining cardioprotective effect of medications given on the morning of the procedure may lead to increased risk for ischemic complications when PCI is performed late in the day.

A number of limitations of this analysis need to be acknowledged. As an observational study, the timing of PCI was nonrandomized; and differences in baseline characteristics may have confounded the results. Although the odds ratios for the composite end point were adjusted for measured differences, it is possible that other unmeasured severity factors also contributed to the outcomes. Detailed angiographic characteristics were not available for the majority of patients in this analysis and therefore could not be adjusted for in the multivariable model. Target vessel revascularization was used for this analysis because target lesion revascularization was not available. Other clinical end points, such as bleeding, vascular complications, and stroke, could not be evalu-

Table V. Crude and risk-adjusted odds ratios for primary composite end point

Composite end point of death, repeated PCI in same vessel, and/or repeated CABG	Crude OR (95% CI)	Adjusted* OR (95% CI)
7 d		
7:00 AM-12:00 PM	1.00	Too few events to permit multivariable adjustment
12:01 PM-6:00 PM	3.16 (0.97-10.28)	
30 d		
7:00 AM-12:00 PM	1.00	1.00
12:01 PM-6:00 PM	1.97 (1.01-3.84)	1.88 (0.94-3.76)
1 y		
7:00 AM-12:00 PM	1.00	1.00
12:01 PM-6:00 PM	1.24 (0.98-1.56)	1.23 (0.97-1.56)

OR, Odds ratio.

* Adjusted for the clinical characteristics in Table I.

ated in this database. Although the results of this study are intriguing, they should be considered as hypothesis generating and require further assessment.

Conclusions

Patients undergoing nonurgent PCI procedures performed during working hours after noon have more advanced left ventricular dysfunction, heart failure, and severe angina and are at higher risk for TVR in the first 30 days and death at 1 year. Further study is required to confirm these findings and determine whether patient characteristics, operator fatigue, differences in process of care, or a combination of these factors accounts for the difference in outcomes.

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