Procedural Characteristics and Outcomes of Patients Undergoing Percutaneous Coronary Intervention During Normal Work Hours Versus Non-work Hours

Brian C. Case, MD[a], Charan T. Yerasi, MD[a], Brian J. Forrestal, MBBS[a], Anees Musallam, MD[a], Yuefeng Chen, MD, PhD[a], Toby Rogers, MD, PhD[a,b], Lowell F. Satler, MD[a], Itsik Ben-Dor, MD[a], Hayder Hashim, MD[a], Nelson Bernardo, MD[a], Jason P. Wermers, BSc[a], Cheng Zhang, PhD[a], Rebecca Torguson, MPH[a], William S. Weintraub, MD[a], and Ron Waksman, MD[a,*]

Percutaneous coronary intervention (PCI) performed during non-work hours is believed to have inferior outcomes because of operator fatigue, differences in baseline patient characteristics, and fewer on-call catheterization laboratory staff. We aimed to analyze a cohort of patients who underwent PCI (all comers) at our tertiary-care center between January 1, 2006, and December 31, 2018, and compare procedural and in-hospital outcomes between 2 groups defined by whether PCI was performed during normal work hours (7:00 A.M. to 7:00 PM) versus non-work hours (7:01 P.M. to 6:59 A.M. weekdays; all hours weekends and holidays). Finally, we examined temporal changes throughout the 24-hour weekday. Primary outcomes were unadjusted in-hospital adverse outcomes (composite death, recurrent myocardial infarction, emergent coronary artery bypass grafting, and target lesion revascularization). We identified 21,848 patients who underwent PCI at our institution. The proportions of ST-elevation myocardial infarction (STEMI) and non-ST-elevation myocardial infarction (NSTEMI) were higher during non-work hours. Overall, unadjusted in-hospital adverse outcomes were higher during non-work hours than during normal work hours (8.80% vs 2.00%; p <0.001). These findings were consistent based on the patient's clinical presentation (STEMI, NSTEMI, unstable angina, and stable angina). Despite confounding variables in the patients' presentations preventing definite causal attribution, our analysis demonstrates that in-hospital adverse outcomes were higher for those patients who underwent PCI (all comers) who had their procedures during non-work hours than during normal work hours. **(Am J Cardiol 2020;135:32−39)**

Historical data in the early years of treating ST-elevation myocardial infarction (STEMI) demonstrated that circadian variations had an effect on the practice of primary angioplasty, resulting in a higher incidence of failed angioplasty and worse clinical outcomes during off hours.[1,2] In contrast, a recent study in a contemporary organized network of hospitals demonstrated that STEMI patients admitted during on hours or off hours have similar management and outcomes.[3] The timing of percutaneous coronary intervention (PCI) in patients with non-ST-elevation myocardial infarction (NSTEMI) has also been studied. Patients who underwent non-urgent PCI during normal work hours but after 12:00 P.M. did worse than patients who underwent PCI before 12:00 P.M.[4] Another study demonstrated that in patients who underwent elective PCI, the rate of periprocedural myocardial infarction (MI) was lower in the morning than in the afternoon.[5] We aimed to analyze a larger cohort over a longer period to determine whether the timing of PCI during normal work hours versus non-work hours impacts procedural and in-hospital clinical outcomes.

Methods

We analyzed a cohort of patients who underwent PCI (all comers) at our tertiary-care center between January 1, 2006, and December 31, 2018, using the MedStar Cardiovascular Research Network/MedStar Washington Hospital Center PCI database. Our PCI database utilizes standardized definitions to record clinical demographics, cardiovascular history, pertinent co-morbid diseases, procedural

[a]Section of Interventional Cardiology, MedStar Washington Hospital Center, Washington, District of Columbia; and [b]Cardiovascular Branch, Division of Intramural Research, National Heart, Lung and Blood Institute, National Institutes of Health, Bethesda, Maryland. Manuscript received June 12, 2020; revised manuscript received and accepted August 11, 2020.

Ron Waksman − Advisory Board: Amgen, Boston Scientific, Cardioset, Cardiovascular Systems Inc., Medtronic, Philips, Pi-Cardia Ltd.; Consultant: Amgen, Biotronik, Boston Scientific, Cardioset, Cardiovascular Systems Inc., Medtronic, Philips, Pi-Cardia Ltd.; Grant Support: AstraZeneca, Biotronik, Boston Scientific, Chiesi; Speakers Bureau: AstraZeneca, Chiesi; Investor: MedAlliance.

Toby Rogers − Advisory Board: Medtronic; Consultant and Proctor: Medtronic, Edwards Lifesciences.

William S. Weintraub: Consultant and grants: Amarin. Advisory board: AstraZeneca,

Consultant: scPharmaceuticals.

All other authors − None.

Funding: None.

***Corresponding author:** Tel: +1 (202) 877-2812; fax: +1 (202) 877-2715.

E-mail address: Ron.Waskman@medstar.net (R. Waksman).

0002-9149/
https://doi.org/10.1016/j.amjcard.2020.08.028

information, postprocedural complications, and angiographic and clinical outcomes. Inclusion criteria were adults who underwent PCI for STEMI, NSTEMI, unstable angina (UA), and stable angina.

In our primary analysis, we wanted to determine how procedural and in-hospital outcomes were impacted on the basis of the timing of PCI (normal work hours vs non-work hours). Patients were divided into 2 groups: Normal Work Hours (7:00 A.M. to 7:00 P.M. weekdays) and Non-work Hours (7:01 P.M. to 6:59 A.M. weekdays; all hours weekends and hospital-recognized holidays). In our secondary analysis, we divided all patients who underwent a PCI into 4 subgroups depending on the time of day that the procedure was performed: Morning (7:00 A.M. to 11:00 A.M.), Mid-Day (11:01 AM to 3:00 PM), Late Afternoon (3:01 P.M. to 7:00 P.M.), and Night (7:01 P.M. to 6:59 A.M.) to analyze temporal trends throughout the work day.

Baseline characteristics were collected, including age, gender, race, cardiac co-morbidities, and any previous history of coronary artery disease (CAD), MI, or history of revascularization. Then, the patients' presentations for the PCI were noted: STEMI, NSTEMI, UA, or stable angina. Other baseline characteristics collected included left ventricular ejection fraction, presence of cardiogenic shock, and troponin I and creatinine levels.

Next, we characterized the PCI procedure itself. Variables collected included access, number of diseased vessels, procedure length, amount of contrast used, stent used (bare metal stent vs drug-eluting stent), closure device, and intravascular ultrasound (IVUS) use during the procedure. Then, both procedural and angiographic success was recorded. Angiographic success was defined as the treatment of the lesion with at least a 20% reduction in the percent diameter stenosis and a final residual stenosis <50% in the lesion. Procedural success was defined as angiographic success without any major intraprocedural complications.

Our primary end point for each analysis was a composite of death, recurrent MI, emergent coronary artery bypass grafting, and target lesion revascularization (TLR) during the index hospitalization. Secondary end points included patient components of the composite end point, cardiac mortality, neurological event (transient ischemic attack and cerebrovascular accident), in-hospital renal insufficiency, length of stay, intensive care unit (ICU) days, vascular complications, and major bleeding. These outcomes were presented overall and then on the basis of clinical presentation, given the heterogeneity of the 2 groups.

Descriptive statistics, such as frequencies, means, and standard deviations, were used to describe the study population. Student's *t* test or analysis of variance was used to compare mean values of normally distributed data. Cox-regression methods were used to evaluate risk factors for the primary outcome. Two-tailed Fisher's exact test or chi-squared tests was used to compare categorical variables. Statistical significance was considered to be a p-value <0.05 for the primary end point.

Results

We identified 21,848 patients who underwent PCI for STEMI, NSTEMI, UA, or stable angina between January 1, 2006, and December 31, 2018. Of those, 19,082 patients received a PCI during normal work hours and 2,766 patients received a PCI during non-work hours. Figure 1 outlines the distribution of the patients' clinical presentations on the basis of procedure start time.

Overall baseline characteristics are summarized in Table 1. In both groups, the majority of patients were older (>60 years of age) and male. At our institution, we did note a degree of racial disparity. Caucasians were more likely to have a PCI performed during normal work hours, while African Americans and Hispanics were more likely to have a PCI done during non-work hours. Cardiac co-morbidities, hypertension, hyperlipidemia, diabetes mellitus, chronic renal failure, peripheral vascular disease, congestive heart failure, and personal or family history of CAD were more commonly seen in patients who underwent PCI during normal work hours. The only co-morbidity that was more prevalent during non-work-hours PCI was current or previous tobacco use.

Patients' clinical presentations are summarized in Table 2. As expected, stable angina and UA PCIs were more commonly done during normal work hours. In contrast, NSTEMI and STEMI PCIs were much more commonly performed during non-work hours. Patients who underwent PCI during non-work hours had a lower mean left ventricular ejection fraction, higher prevalence of cardiogenic shock, higher baseline and maximum troponin I levels, and worsening creatinine upon presentation. The number of patients with STEMI, NSTEMI, and cardiogenic

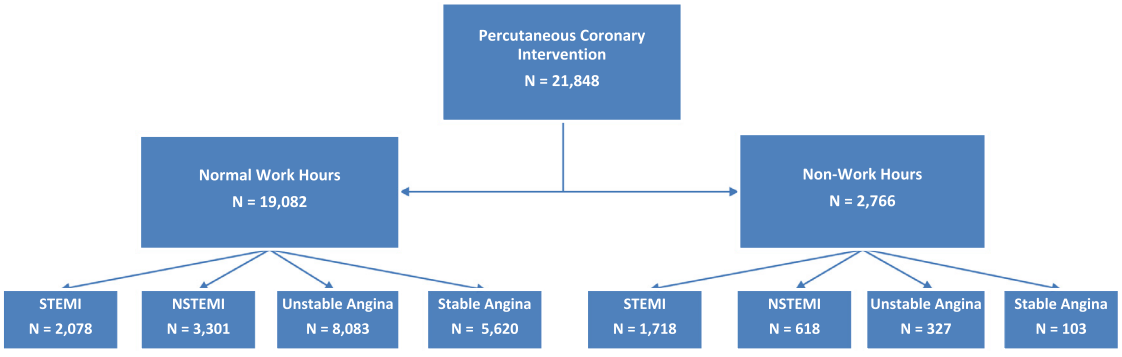

Figure 1. Distribution of percutaneous coronary interventions based on time of day and patient's clinical presentation. NSTEMI: Non-ST-elevation myocardial infarction; STEMI: ST-elevation myocardial infarction

Table 1
Baseline characteristics of patients who underwent PCI either during normal work hours or non-work hours

Baseline Characteristics Comparing Normal Work Hours versus Non-work Hours				
Baseline Characteristics	Work Hours (n = 19,082)	Non-work Hours (n = 2,766)	Overall (n = 21,848)	p value
Age (mean ± STD)	65.59 ± 11.93	61.67 ± 13.10	65.1 ± 12.16	<0.001
				0.811
Male	65.60%	66.50%	65.70%	
Female	34.40%	34.50%	34.30%	
White	60.30%	51.50%	59.10%	<0.001
Black	31.50%	37.50%	32.30%	<0.001
Asian	2.30%	2.60%	2.30%	0.506
Hispanic	1.30%	2.30%	1.40%	<0.001
Native American	0.30%	0.30%	0.30%	0.700
Hypertension	88.30%	78.60%	87.10%	<0.001
Hyperlipidemia	85.30%	70.40%	83.40%	<0.001
Diabetes mellitus	38.60%	30.80%	37.60%	<0.001
Chronic renal failure	15.90%	11.40%	15.30%	<0.001
Dialysis	3.80%	2.50%	3.60%	<0.001
Peripheral vascular disease	15.00%	8.50%	14.20%	<0.001
Smoker	50.50%	56.70%	51.30%	<0.001
Heart failure	16.60%	15.00%	16.40%	0.027
Family history of CAD	42.70%	35.90%	41.90%	<0.001
Prior coronary artery disease	42.70%	24.70%	40.40%	<0.001
Prior myocardial infarction	20.80%	13.50%	19.80%	<0.001
PTCA	27.60%	16.00%	26.10%	<0.001
CABG	19.70%	8.70%	18.30%	<0.001

CABG: Coronary artery bypass grafting; CAD: Coronary artery disease; PTCA: Percutaneous transluminal coronary angioplasty; STD: Standard deviation.

shock increased throughout the day, while stable angina and UA decreased (Figure 2).

Procedural characteristics are outlined in Table 3. The majority of PCIs were performed through femoral access. The number of diseased vessels, procedural length, and amount of contrast used did not differ between the work hours and non-work hours groups. A bare metal stent was more commonly used during non-work hours, while drug-eluting stent was more commonly used during normal work hours. In addition, closure device and IVUS were more commonly used during normal work hours than during non-work hours. Finally, both angiographic success and procedural success were higher in patients who underwent PCI during the day.

Overall unadjusted in-hospital outcomes based on timing of the PCI are reported in Table 4. In terms of our primary

Table 2
Clinical presentation of patients who underwent PCI either during normal work hours or non-work hours

Patient Presentation Comparing Normal Work Hours versus Non-work Hours				
Patient Presentation	Work Hours (n = 19,082)	Non-work Hours (n = 2,766)	Overall (n = 21,848)	p value
Stable coronary Artery disease	29.45%	3.72%	26.19%	<0.001
Unstable angina Pectoris	42.36%	11.82%	38.49%	<0.001
NSTEMI	17.30%	22.34%	17.94%	<0.001
STEMI	10.89%	62.11%	17.37%	<0.001
Left ventricular ejection fraction (mean ± SD)	48% ± 16%	41% ± 15%	47% ± 16%	<0.001
Cardiogenic shock	2.00%	10.00%	3.00%	<0.001
Creatinine baseline (mean ± SD)	1.31 ± 1.37	1.22 ± 1.09	1.30 ± 1.34	<0.001
STEMI				
Troponin I baseline (mean ± SD)	19.67 ± 169.15	31.43 ±± 328.17	24.60 ± 248.55	0.305
Troponin I maximum (mean ± SD)	55.01 ± 92.41	100.05 ± 546.65	75.44 ± 375.03	<0.001
NSTEMI				
Troponin I baseline (mean ± SD)	7.39 ± 19.62	17.86 ± 50.46	8.94 ± 26.82	<0.001
Troponin I maximum (mean ± SD)	18.13 ± 96.36	39.79 ± 60.75	21.55 ± 92.01	<0.001

NSTEMI: Non-ST-elevation myocardial infarction; SD: Standard deviation.

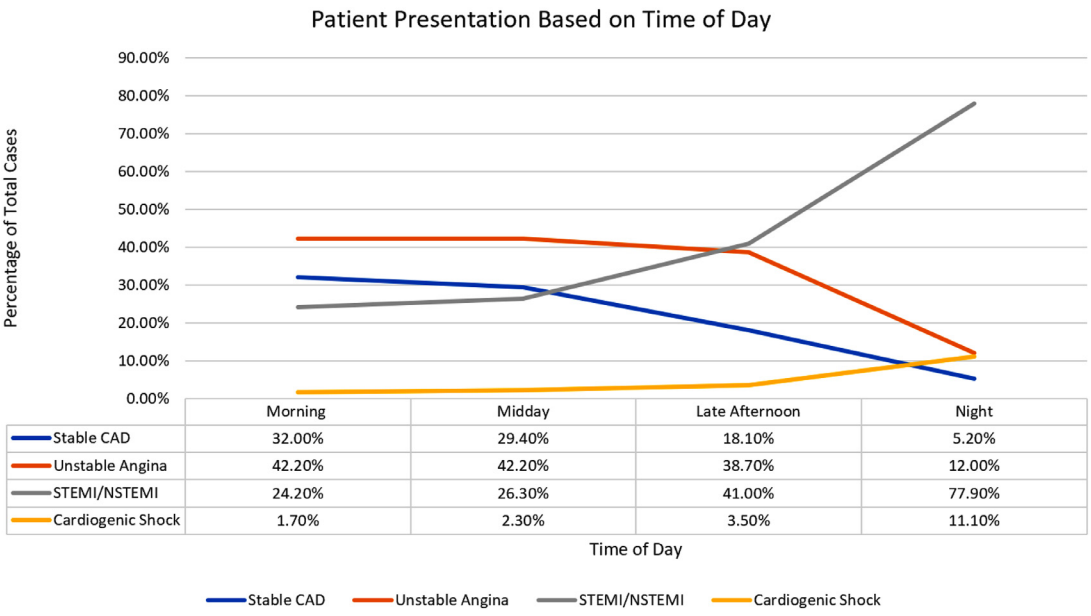

Figure 2. Distribution of patients' clinical presentations for percutaneous coronary intervention throughout the day. CAD: Coronary artery disease; NSTEMI: Non-ST-elevation myocardial infarction; STEMI: ST-elevation myocardial infarction

end point, the incidence was significantly higher during non-work hours versus normal work hours (8.80% vs 2.00%; p <0.001). Secondary outcomes demonstrated that neurological events (transient ischemic attack and cerebrovascular accident), in-hospital renal insufficiency, major bleeding, and vascular complications were all more significant in those patients who underwent PCI during non-work hours. Finally, length of stay overall and number of days in the ICU were higher for patients who had a PCI during non-work hours (Table 4).

An outline of the patients' baseline characteristics (Table 1) and clinical presentations (Table 2) demonstrates that the work hours and non-work hours cohorts overall are inherently different. Thus, we further analyzed in-hospital outcomes on the basis of the patients' clinical presentations (STEMI, NSTEMI, UA, and stable angina). When analyzing STEMI patients specifically, our primary end point was significant higher if the PCI was performed during off-hours (11.40% vs 8.60%; p = 0.005), driven by TLR. However, there were no differences in secondary end points (Table 5). NSTEMI patients demonstrated similar findings, with the primary outcome being worse in patients who presented during non-work hours (7.90% vs 3.00%; p <0.001) driven by all-cause mortality and coronary artery bypass grafting . In addition, secondary outcomes demonstrated a statistical increase in cardiac mortality, renal insufficiency, major bleeding, length of stay, and days in the ICU hours (Table 6).

Similarly, in patients with UA or stable angina, the outcomes were worse for those patients who had a PCI done during non-work hours. In UA, the primary outcome was 4.30% during non-work hours versus 1.20% during normal work hours (p <0.001), driven by all-cause mortality. In addition, the secondary end points showed an increase in

Table 3
Procedural characteristics of patients who underwent percutaneous coronary intervention either during normal work hours or non-work hours

Procedural Characteristics Comparing Normal Work Hours versus Non-work Hours				
Procedural Characteristics	Work Hours (n = 19,082)	Non-work Hours (n = 2,766)	Overall (n = 21,848)	p value
Femoral access	90.79%	90.68%	90.70%	0.856
Radial access	8.71%	8.80%	8.80%	0.83
Number vessel diseased (mean ± SD)	1.75 ± 0.81	1.76 ± 0.82	1.75 ± 0.81	0.384
Procedure length (mins. mean ± SD)	65.81 ± 37.35	65.05 ± 56.3	65.68 ± 41.02	0.448
Contrast amount (ml. mean ± SD)	164.19 ± 93.15	162.94 ± 83.63	163.99 ± 91.63	0.421
Bare metal sent	19.30%	36.00%	21.20%	<0.001
Drug eluting stent	69.00%	51.30%	66.90%	<0.001
Closure device	59.30%	55.50%	58.70%	<0.001
Procedural success	97.80%	90.50%	96.90%	<0.001
Angiographic success	97.80%	97.40%	97.80%	0.048
IVUS performed	50.90%	12.90%	46.50%	<0.001

IVUS: Intravascular ultrasound; SD: Standard deviation.

Table 4
In-hospital outcomes of patients who underwent PCI during normal work hours as compared with non-work hours

Overall In-Hospital Outcomes Comparing Normal Work Hours versus Non-work Hours				
	Work Hours (n = 19,082)	Non-work Hours (n = 2,766)	Overall (n = 21,848)	p value
In-hospital complication (Death/MI/CABG/TLR)	2.00%	8.80%	2.90%	<0.001
All-cause mortality	1.20%	5.40%	1.70%	<0.001
MI in-hospital	0.10%	0.40%	0.20%	0.006
CABG in-hospital	0.80%	3.40%	1.10%	<0.001
TLR	0.30%	1.00%	0.40%	<0.001
Cardiac mortality	0.90%	4.50%	1.40%	<0.001
Neurological event (TIA/CVA)	0.30%	0.90%	0.40%	<0.001
Vascular complications	1.60%	2.60%	1.80%	<0.001
In-hospital renal insufficiency	4.40%	8.40%	4.90%	<0.001
In hospital subacute thrombosis	0.10%	0.40%	0.10%	<0.001
Length of stay (days, mean ± SD)	2.92 ± 4.04	4.81 ± 5.17	3.16 ± 4.24	<0.001
ICU days (days, mean ± SD)	0.49 ± 1.75	1.79 ± 2.99	0.68 ± 2.03	<0.001
Major bleeding	1.70%	5.50%	2.20%	<0.001

CABG: Coronary artery bypass grafting; CVA: Cerebrovascular accident; ICU: Intensive care unit; MI: Myocardial infarction; SD: Standard deviation; TIA = Transient ischemic attack; TLR: Target lesion revascularization.

cardiac mortality, in-hospital renal insufficiency, vascular complications, length of stay, and ICU length of stay for UA patients who received a PCI during non-work hours (Table 7). In patients with stable angina, the primary outcome was 2.90% during non-work hours versus 0.80% during normal work hours (p = 0.018), driven by all-cause mortality. Furthermore, secondary end points demonstrated an increase in cardiac mortality, renal insufficiency, and length of stay for those patients who had a PCI performed for stable angina during non-work hours (Table 8).

Discussion

Our 12-year analysis, including over 21,000 patients, suggests that PCIs that are performed during non-work hours are associated with in an increased incidence of in-hospital adverse outcomes. All-cause death, cardiac death, recurrent MI, TLR, neurological events, vascular complications, major bleeding, and in-hospital renal insufficiency were all higher in patients who underwent PCI during non-work hours. In addition, these patients were more commonly in the ICU and had longer lengths of stay. Unsurprisingly, PCIs performed during non-work hours tended to be for STEMI or NSTEMI, while normal work hours had higher rates of stable angina and UA. When these patients were analyzed on the basis of clinical presentation (STEMI, NSTEMI, UA, and stable CAD), there was still a difference in primary outcome among the 4 groups. In addition, there was a trend for higher rates of cardiac mortality, vascular complications, and increased length of stay when the PCI was performed during non-work hours. This is the first study to analyze the impact of timing of PCI for all comers over a long period.

Table 5
In-hospital outcomes of patients who underwent STEMI PCI during normal work hours as compared with non-work hours

In-Hospital Outcomes Comparing Normal Work Hours versus Non-work Hours in STEMI Patients				
In-Hospital Outcomes	Work Hours (n = 2,078)	Non-work Hours (n =1,718)	Overall (n = 3,796)	p value
In-hospital complication (death/MI/CABG/TLR)	8.60%	11.40%	9.9%	0.005
All-cause mortality	4.80%	6.0%	5.30%	0.107
MI in-hospital	0.20%	0.45%	0.20%	0.136
CABG in-hospital	3.40%	4.30%	3.40%	0.134
TLR	0.60%	1.30%	0.90%	0.024
Cardiac mortality	4.30%	5.10%	4.70%	0.286
Neurological event (TIA/CVA)	1.10%	1.30%	1.20%	0.529
Vascular complications	2.70%	2.90%	2.80%	0.755
In-hospital renal insufficiency	8.40%	8.40%	8.40%	0.961
In-hospital stent thrombosis	0.30%	0.50%	0.40%	0.250
Length of stay (days, mean ± SD)	5.18 ± 5.68	5.28 ± 5.43	5.23 ± 5.57	0.564
ICU days (days, mean ± SD)	1.94 ± 3.25	2.11 ± 3.15	2.02 ± 3.20	0.145
Major bleeding	6.50%	5.20%	5.80%	0.095

CABG: Coronary artery bypass grafting; CVA: Cerebrovascular accident; ICU: Intensive care unit; MI: Myocardial infarction; SD: Standard deviation; STEMI: ST-elevation myocardial infarction; TIA = Transient ischemic attack; TLR: Target lesion revascularization.

Table 6
In-hospital outcomes of patients who underwent NSTEMI PCI during normal work hours as compared with non-work hours

In-Hospital Outcomes Comparing Normal Work Hours versus Non-work Hours in NSTEMI Patients				
In-Hospital Outcomes	Work Hours (n = 3,301)	Non-work Hours (n = 618)	Overall (n = 3,919)	p value
In-hospital complication (death/MI/CABG/TLR)	3.00%	7.90%	3.70%	<0.001
All-cause mortality	1.90%	4.90%	2.40%	<0.001
MI in-hospital	0.10%	0.30%	0.10%	0.059
CABG in-hospital	0.90%	2.90%	1.20%	<0.001
TLR	0.30%	0.30%	0.3%	0.823
Cardiac mortality	1.40%	4.00%	1.80%	<0.001
Neurological event (TIA/CVA)	0.30%	0.50%	0.40%	0.554
Vascular complications	2.00%	1.80%	1.90%	0.762
In-hospital renal insufficiency	6.20%	9.60%	6.70%	0.003
In-hospital stent thrombosis	0.10%	0.30%	0.20%	0.237
Length of stay (days, mean ± SD)	4.00 ± 4.94	4.58 ± 5.14	4.10 ± 4.97	0.008
ICU days (days, mean ± SD)	0.65 ± 2.09	1.42 ± 2.68	0.77 ± 2.20	<0.001
Major bleeding	2.60%	5.30%	3.00%	<0.001

CABG: Coronary artery bypass grafting; CVA: Cerebrovascular accident; ICU: Intensive care unit; MI: Myocardial infarction; NSTEMI: Non-ST-elevation myocardial infarction; SD: Standard deviation; TIA = Transient ischemic attack; TLR: Target lesion revascularization.

Our secondary analysis of evaluating the trends of PCIs during the normal weekday hours demonstrates that most stable angina and UA PCIs were performed in the morning, with a steady decline of these procedures throughout the day (Figure 2). This reflects common practice in cardiac catheterization laboratories, as outpatient, elective PCIs are usually scheduled for the morning during normal work hours. PCIs for STEMI and NSTEMI gradually increase throughout the day, which probably reflects the practice of more inpatient, urgent PCIs performed ad hoc after the elective outpatient procedures have been completed.

When analyzing the procedural characteristics during the study period, most PCIs at our center were performed through femoral approach (90.7%), which reflects US clinical practice over the past 12 years.[6] More interestingly, our analysis demonstrated that the total procedural time and amount of contrast used did not differ between normal work hours and non-work hours. In addition, the use of a closure device for access was more common during the day than during non-work hours. Finally, both procedural and angiographic success were higher in those patients who underwent PCI during normal work hours than during non-work hours. This finding is probably a reflection of simple, elective cases being performed during normal work hours as compared with STEMI and NSTEMI patients during non-work hours.

It has been postulated before that worse outcomes later in the day may be due to a combination of operator fatigue, patient characteristics, and difference in process of care through the catheterization laboratory, with less staff available to deliver patient care. One can challenge whether circadian variations have an effect on the procedure as demonstrated in our analysis, in which the procedure time and the amount of contrast used did not differ between normal work hours and non-work hours. This lack of difference may reflect that the operators' process of performing a

Table 7
In-hospital outcomes of patients who underwent PCI for UA during normal work hours as compared with non-work hours

In-Hospital Outcomes Comparing Normal Work Hours versus Non-Work Hours in UA Patients				
In-hospital Outcomes	Work Hours (n = 8,083)	Non-work Hours (n = 327)	Overall (n = 8,410)	p value
In-hospital complication (death/MI/CABG/TLR)	1.20%	4.30%	1.30%	<0.001
All-cause mortality	0.50%	3.40%	0.60%	<0.001
MI in-hospital	0.20%	0.00%	0.20%	0.422
CABG in-hospital	0.40%	0.30%	0.4%	0.804
TLR	0.30%	0.60%	0.30%	0.231
Cardiac mortality	0.30%	2.40%	0.40%	<0.001
Neurological event (TIA/CVA)	0.30%	0.30%	0.30%	0.991
Vascular complications	1.50%	3.10%	1.60%	0.026
In-hospital renal insufficiency	3.40%	6.10%	3.50%	0.014
In-hospital stent thrombosis	0.10%	0.00%	0.10%	0.652
Length of stay (days, mean ± SD)	2.51 ± 3.35	3.13 ± 3.31	2.53 ± 3.35	<0.001
ICU days (days, mean ± SD)	0.18 ± 0.90	0.84 ± 2.36	0.21 ± 1.03	<0.001
Major bleeding	1.20%	1.20%	1.20%	0.958

CABG: Coronary artery bypass grafting; CVA: Cerebrovascular accident; ICU: Intensive care unit; MI: Myocardial infarction; SD: Standard deviation; TIA = Transient ischemic attack; TLR: Target lesion revascularization; UA = Unstable angina.

Table 8
In-hospital outcomes of patients who underwent PCI for stable angina during normal work hours as compared with non-work hours

In-hospital Outcomes Comparing Normal Work Hours versus Non-work Hours in Stable Angina Patients				
In-hospital Outcomes	Work Hours (n = 5,620)	Non-work Hours (n = 103)	Overall (n = 5,723)	p value
In-hospital complication (death/MI/CABG/TLR)	0.80%	2.90%	0.80%	0.018
All-cause mortality	0.30%	2.90%	0.40%	<0.001
MI in-hospital	0.10%	0.00%	0.10%	0.787
CABG in-hospital	0.20%	0.00%	0.20%	0.626
TLR	0.20%	0.00%	0.20%	0.653
Cardiac mortality	0.20%	2.90%	0.20%	<0.001
Neurological event (TIA/CVA)	0.10%	0.00%	0.10%	0.720
Vascular complications	1.30%	1.00%	1.30%	0.792
In-hospital renal insufficiency	3.40%	10.30%	3.50%	<0.001
In-hospital stent thrombosis	0.00%	0.00%	0.00%	0.892
Length of stay (days, mean ± SD)	2.08 ± 3.11	3.33 ± 3.98	2.10 ± 3.13	0.002
ICU days (days, mean ± SD)	0.15 ± 0.95	0.62 ± 1.94	0.16 ± 0.98	0.052
Major bleeding	0.60%	1.00%	0.60%	0.637

CABG: Coronary artery bypass grafting; CVA: Cerebrovascular accident; ICU: Intensive care unit; MI: Myocardial infarction; SD: Standard deviation; TIA = Transient ischemic attack; TLR: Target lesion revascularization.

procedure does not differ depending on the time of day and that more external factors may contribute to the worse outcomes during non-work hours.

Furthermore, one could argue that more experienced operators will perform similarly on and off hours, while non-experienced operators may have differences in their procedural outcomes based on the time of day. Sometimes, junior attending may have the benefit of reviewing their cases with senior members during the day, and that option may not be readily available at night. However, previous investigations have demonstrated that in-hospital PCI outcomes are not affected by operator volume, experience, or board certification. Rather, the emphasis is on a well-organized, high-volume healthcare system to minimize the impact of operator factors on outcomes of PCI.[7] Causality in our findings could be related to lack of full staff, lack of utilization of intravascular imaging, and less use of equipment for lesion modification or preparation (atherectomy, etc.), which may impact having a well-organized, high-volume healthcare system and, in turn, result in poor PCI outcomes.

IVUS was used at a much higher rate during normal work hours than during non-work hours. The use of intravascular imaging can potentially help improve outcomes. We predominantly use IVUS at our center, with over 50% of PCIs performed during normal work hours done under IVUS guidance. However, this rate drops substantially during non-work hours to less than 20%. It has been described previously that PCI outcomes are improved when the PCI is performed under IVUS as compared with angiographic guidance.[8–11] Increased use of intravascular imaging during non-work hours may improve outcomes overall. However, this may be difficult for an institution to implement. The use of intravascular imaging may result in an increased use of resources and staff members on call who are familiar with the equipment.[12] In addition, one may argue that the use of intravascular imaging may increase overall procedural time overnight, which may not be appealing for the operator performing the procedure. Implementing best institution-based practices of intravascular imaging overnight may improve outcomes in non-work-hours patients.

There are other potential institutional-based practices that can be performed to reduce this overall rate of poor outcomes during non-work hours. First, all non-urgent/elective cases should be performed during normal working hours. Based on our analysis, there is no benefit to have a patient undergo a PCI during non-work hours for stable angina or UA, as this just increases the patient's risk. Second, STEMI patients are emergent cases, so it is unpredictable to determine when these patients will need treatment. However, having a STEMI network in your community ensures adequate door-to-balloon time and minimizes adverse outcomes. In addition, depending on hospital resources, having multiple teams in the catheterization laboratory off hours ensures proper management of the patients. Finally, NSTEMI patients need to be properly triaged, and correct timing of PCI needs to be determined. NSTEMI presentation can be heterogeneous, as some patients present as relatively stable, while others can be in cardiogenic shock. The use of a Global Registry of Acute Coronary Events (GRACE) score[13] or Thrombolysis in Myocardial Infarction (TIMI) score[14] can help determine when a patient needs to be urgently taken for a PCI. This would help minimize a delay in primary PCI and, potentially, minimize procedures on nights and weekends.

Our analysis has limitations. It is retrospective in nature, meaning there is an inherent selection bias. We compared 2 groups on the basis of the time the procedure was started. The decision of when to perform the procedure depended on the operator, catheterization lab schedule, and available resources, and that bias is difficult to capture in our analysis. Second, as demonstrated in Tables 1 and 2, the work hours and non-work-hours groups are inherently different. By study design, and in real-world practice, stable, elective cases are not routinely done at night. We overcame this difference by reporting outcomes on the basis of the patients' clinical presentations (STEMI, NSTEMI, UA, and stable angina). Third, we report only in-hospital outcomes.

In conclusion, despite confounding variables in the patients' presentations preventing definite causal attribution, in-hospital adverse events are more common in patients who underwent PCI (all comers) who had their procedures done during non-work hours than during normal work hours. Worse outcomes during non-work hours were consistent based on the patient's clinical presentation (STEMI, NSTEMI, UA, and stable angina). Resources and training should be applied to minimize the gap in outcomes for patients who underwent PCI during non-work hours.

Authors Contribution

Brian C. Case, MD – Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing – original draft and review & editing.

Charan T. Yerasi, MD - Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing – original draft and review & editing.

Brian J. Forrestal, MBBS - Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing – original draft and review & editing.

Anees Musallam, MD – Writing – review & editing.

Yuefeng Chen, MD, PhD - Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing – review & editing.

Toby Rogers, MD, PhD - Supervision; Writing – review & editing.

Lowell F. Satler, MD - Supervision; Writing – review & editing.

Itsik Ben-Dor, MD - Supervision; Writing – review & editing.

Hayder Hashim, MD – Data curation; Methodology; Supervision.

Nelson Bernardo, MD – Data curation; Methodology; Supervision.

Jason P. Wermers, BSc – Writing – review & editing.

Cheng Zhang, PhD – Data curation; Formal analysis; Methodology.

Rebecca Torguson, MPH - Data curation; Formal analysis; Methodology; Supervision; Project administration.

William S. Weintraub, MD – Conceptualization; Formal analysis; Investigation; Methodology; Project administration; Supervision; Validation; Visualization; Writing – review & editing.

Ron Waksman, MD – Conceptualization; Methodology; Project administration; Supervision; Validation; Visualization; Writing – review & editing.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relations that could have appeared to influence the work reported in this study.

1. Henriques JP, Haasdijk AP, Zijlstra F, Zwolle Myocardial Infarction Study Group. Outcome of primary angioplasty for acute myocardial infarction during routine duty hours versus during off-hours. *J Am Coll Cardiol* 2003;41:2138–2142.
2. Dominguez-Rodriguez A, Garcia-Gonzalez M, Abreu-Gonzalez P. Outcome of primary angioplasty for ST-segment elevation myocardial infarction during routine duty hours versus during off-hours. Results of a single-center in Spain. *Int J Cardiol* 2007;119:227–229.
3. Lattuca B, Kerneis M, Saib A, Nguyen LS, Payot L, Barthelemy O, Le Feuvre C, Helft G, Choussat R, Collet JP, Montalescot G, Silvain J, Group AS. On- versus off-hours presentation and mortality of st-segment elevation myocardial infarction patients treated with primary percutaneous coronary intervention. *JACC Cardiovasc Interv* 2019;12:2260–2268.
4. Cantor WJ, Strauss BH, Graham MM, Southern DA, Woo K, Tyrrell B, Knudtson M, Ghali WA. Time of day and outcomes of nonurgent percutaneous coronary intervention performed during working hours. *Am Heart J* 2010;159:1133–1138.
5. Fournier S, Puricel S, Morawiec B, Eeckhout E, Mangiacapra F, Trana C, Tapponnier M, Iglesias JF, Michiels V, Stauffer JC, Beggah A, Monney P, Gobet S, Vogt P, Cook S, Muller O. Relationship between time of day and periprocedural myocardial infarction after elective angioplasty. *Chronobiol Int* 2014;31:206–213.
6. Writing Group Members, Mozaffarian D, Benjamin EJ, Go AS, Arnett DK, Blaha MJ, Cushman M, Das SR, de Ferranti S, Despres JP, Fullerton HJ, Howard VJ, Huffman MD, Isasi CR, Jimenez MC, Judd SE, Kissela BM, Lichtman JH, Lisabeth LD, Liu S, Mackey RH, Magid DJ, McGuire DK, Mohler ER 3rd, Moy CS, Muntner P, Mussolino ME, Nasir K, Neumar RW, Nichol G, Palaniappan L, Pandey DK, Reeves MJ, Rodriguez CJ, Rosamond W, Sorlie PD, Stein J, Towfighi A, Turan TN, Virani SS, Woo D, Yeh RW, Turner MB. American heart association statistics committee, stroke statistics subcommittee. heart disease and stroke statistics-2016 update: a report from the american heart association. *Circulation* 2016;133:e38–360.
7. Harjai KJ, Berman AD, Grines CL, Kahn J, Marsalese D, Mehta RH, Schreiber T, Boura JA, O'Neill WW. Impact of interventionalist volume, experience, and board certification on coronary angioplasty outcomes in the era of stenting. *Am J Cardiol* 2004;94:421–426.
8. Zhang J, Gao X, Kan J, Ge Z, Han L, Lu S, Tian N, Lin S, Lu Q, Wu X, Li Q, Liu Z, Chen Y, Qian X, Wang J, Chai D, Chen C, Li X, Gogas BD, Pan T, Shan S, Ye F, Chen SL. Intravascular ultrasound versus angiography-guided drug-eluting stent implantation: the ULTIMATE trial. *J Am Coll Cardiol* 2018;72:3126–3137.
9. Ye Y, Yang M, Zhang S, Zeng Y. Percutaneous coronary intervention in left main coronary artery disease with or without intravascular ultrasound: A meta-analysis. *PLoS One* 2017;12:e0179756.
10. Jensen LO, Vikman S, Antonsen L, Kosonen P, Niemela M, Christiansen EH, Kervinen K, Erglis A, Harnek J, Kumsars I, Thuesen L, Niemela K. Intravascular ultrasound assessment of minimum lumen area and intimal hyperplasia in in-stent restenosis after drug-eluting or bare-metal stent implantation. The Nordic Intravascular Ultrasound Study (NIVUS). *Cardiovasc Revasc Med* 2017;18:577–582.
11. Sakakura K, Yamamoto K, Taniguchi Y, Tsurumaki Y, Momomura SI, Fujita H. Intravascular ultrasound enhances the safety of rotational atherectomy. *Cardiovasc Revasc Med* 2018;19:286–291.
12. Alberti A, Giudice P, Gelera A, Stefanini L, Priest V, Simmonds M, Lee C, Wasserman M. Understanding the economic impact of intravascular ultrasound (IVUS). *Eur J Health Econ* 2016;17:185–193.
13. Tang EW, Wong CK, Herbison P. Global Registry of Acute Coronary Events (GRACE) hospital discharge risk score accurately predicts long-term mortality post acute coronary syndrome. *Am Heart J* 2007;153:29–35.
14. Antman EM, Cohen M, Bernink PJ, McCabe CH, Horacek T, Papuchis G, Mautner B, Corbalan R, Radley D, Braunwald E. The TIMI risk score for unstable angina/non-ST elevation MI: A method for prognostication and therapeutic decision making. *JAMA* 2000;284:835–842.