Weekend Effect in the Management and Outcomes of Acute Myocardial Infarction in the United States, 2000-2016

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Abstract

Objective: To assess the effects of weekend admission vs weekday admission on the management and outcomes of acute myocardial infarction (AMI).

Methods: Adult ST-segment elevation myocardial infarction (STEMI) and non-STEMI (NSTEMI) hospital admissions were identified using the National (Nationwide) Inpatient Sample (2000-2016). Interhospital transfers were excluded. Timing of coronary angiography (CA) and percutaneous coronary intervention (PCI) relative to the day of admission was identified. Outcomes of interest included in-hospital mortality, receipt of early CA, timing of CA and PCI, resource utilization, and discharge disposition for weekend vs weekday admissions.

Results: Of the 9,041,819 AMI admissions, 2,406,876 (26.6%) occurred on weekends. Compared with 2000, in 2016 there was an increase in weekend STEMI (adjusted odds ratio [aOR], 1.12; 95% CI, 1.08-1.16; $P<.001$) but not NSTEMI (aOR, 1.01; 95% CI, 0.98-1.02; $P=.21$) admissions. Compared with weekday admissions, weekend admissions received comparable CA (59.9% vs 58.8%) and PCI (38.4% vs 37.6%) and specifically lower rates of early CA (hospital day 0) (26.0% vs 20.8%; $P<.001$). There was a steady increase in CA and PCI use during the 17-year period. Mean ± SD time to CA was higher in the weekend group vs the weekday group (1.2±1.8 vs 1.0±1.8 days; $P<.001$). Weekend admission did not influence in-hospital mortality (aOR, 1.01; 95% CI, 1.00-1.01; $P=.05$) but had fewer discharges to home (58.7% vs 59.7%; $P<.001$).

Conclusion: Despite small differences in CA and PCI, there were no differences in in-hospital mortality of AMI admissions on weekdays vs weekends in the United States in the contemporary era.

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During the past 2 decades, multiple reports have consistently demonstrated the importance of timely intervention in patients with acute myocardial infarction (AMI).[1-3] Current guidelines recommend shorter door-to-balloon times as well as early percutaneous coronary intervention (PCI) for ST-segment elevation myocardial infarction (STEMI) and high-risk non−STEMI (NSTEMI).[4,5] Despite these guidelines, there remain significant differences in the timing of intervention and the ability to achieve guideline-directed door-to-balloon times in STEMI.[6-9] Based on the timing of admission, previous data have shown differences in outcomes in AMI.[6-9] Studies evaluating these differences have reported an increase in mortality among patients admitted on weekends compared with weekdays.[10,11] This perceived weekend effect in AMI has been attributed to multiple factors, such as a lower likelihood of receiving prompt and optimal interventions, staffing variations, and a higher rate of complications.[6-8] However, there remains debate over the continued existence of this weekend effect during the contemporary era, with some recent studies reporting no difference in outcomes between weekend and weekday AMI admissions.[12-14]

Through this study we sought to assess the differences in clinical outcomes of weekend vs weekday AMI admissions. We hypothesized that with improvements in health care delivery

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and greater access to PCI, there would be a decrease in the weekend effect over time. Furthermore, we also sought to assess these disparities in several higher-risk subgroups.

MATERIALS AND METHODS

Study Population, Variables, and Outcomes

The National (Nationwide) Inpatient Sample (NIS) is the largest all-payer database of hospital inpatient stays in the United States. The NIS contains discharge data from a 20% stratified sample of community hospitals and is a part of the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality.[15] Information regarding each discharge includes patient demographic data, primary payer, hospital characteristics, principal diagnosis, up to 24 secondary diagnoses, and procedural diagnoses. The HCUP-NIS does not capture individual patients but captures all information for a given admission. Institutional review board approval was not sought due to the publicly available nature of this deidentified database. These data are available to other authors via the HCUP-NIS database.

Using HCUP-NIS data from 2000-2016, a retrospective cohort study of adult admissions (>18 years old) with AMI in the primary diagnosis field (*International Classification of Diseases, Ninth Revision, Clinical Modification* code 410.x and *International Classification of Diseases, Tenth Revision, Clinical Modification* codes I21.x-22.x) were identified. Similar to previous literature, we defined weekend admissions as those occurring from 12:01 AM Saturday through 11:59 PM on Sunday and considered all other admissions to be weekday admissions.[12] We excluded admissions that did not have information on weekend vs weekday admission and interhospital transfers. The Deyo modification of the Charlson Comorbidity Index was used to identify the burden of comorbid diseases (Supplemental Table 1, available online at http://www.mcpiqojournal.org).[16] Demographic characteristics, hospital characteristics, acute organ failure, mechanical circulatory support, cardiac procedures, and noncardiac organ support use were identified for all admissions using previously used methods from our group.[17-36] Similar to previous literature, we defined early coronary angiography (CA) as that performed on the day of hospital admission (day 0).[21,30,31] We identified the timing of CA and PCI relative to the day of admission.[18,25,27,31]

The primary outcome was in-hospital mortality in weekend vs weekday AMI admissions. The secondary outcomes included receipt of early CA; timing of CA, PCI, and mechanical circulatory support use; hospital length of stay; hospitalization costs; and discharge disposition in weekend vs weekday AMI admissions. Hospitalization costs were calculated as total charges, which do not include professional fees and noncovered charges. If the source provided HCUP-NIS with total charges with professional fees, then the professional fees were removed from the charge during HCUP processing.[15] Multiple subgroup analyses classified by age (≤75 vs >75 years), sex, race (white vs nonwhite), presence of cardiac arrest, and cardiogenic shock, in admissions stratified by type of AMI (STEMI vs NSTEMI), were performed to identify high-risk cohorts.

Statistical Analyses

As recommended by HCUP-NIS, survey procedures using discharge weights provided with the HCUP-NIS database were used to generate national estimates.[37] Using the trend weights provided by the HCUP-NIS, samples from 2000-2011 were reweighted to adjust for the 2012 HCUP-NIS redesign.[37] χ^2 and *t* tests were used to compare categorical and continuous variables, respectively. Multivariable logistic regression was used to analyze trends over time (referent year 2000). The inherent restrictions of the HCUP-NIS database related to research design, data interpretation, and data analysis were reviewed and addressed.[37] Pertinent considerations include not assessing individual hospital—level volumes (due to changes to sampling design detailed previously herein), treating each entry as an admission as opposed to individual patients, restricting the study details to inpatient factors because the HCUP-NIS does not include outpatient data, and limiting administrative codes to those previously validated and used for similar studies. Univariable analysis for trends and outcomes was performed and is represented as odds ratio (OR) with 95%

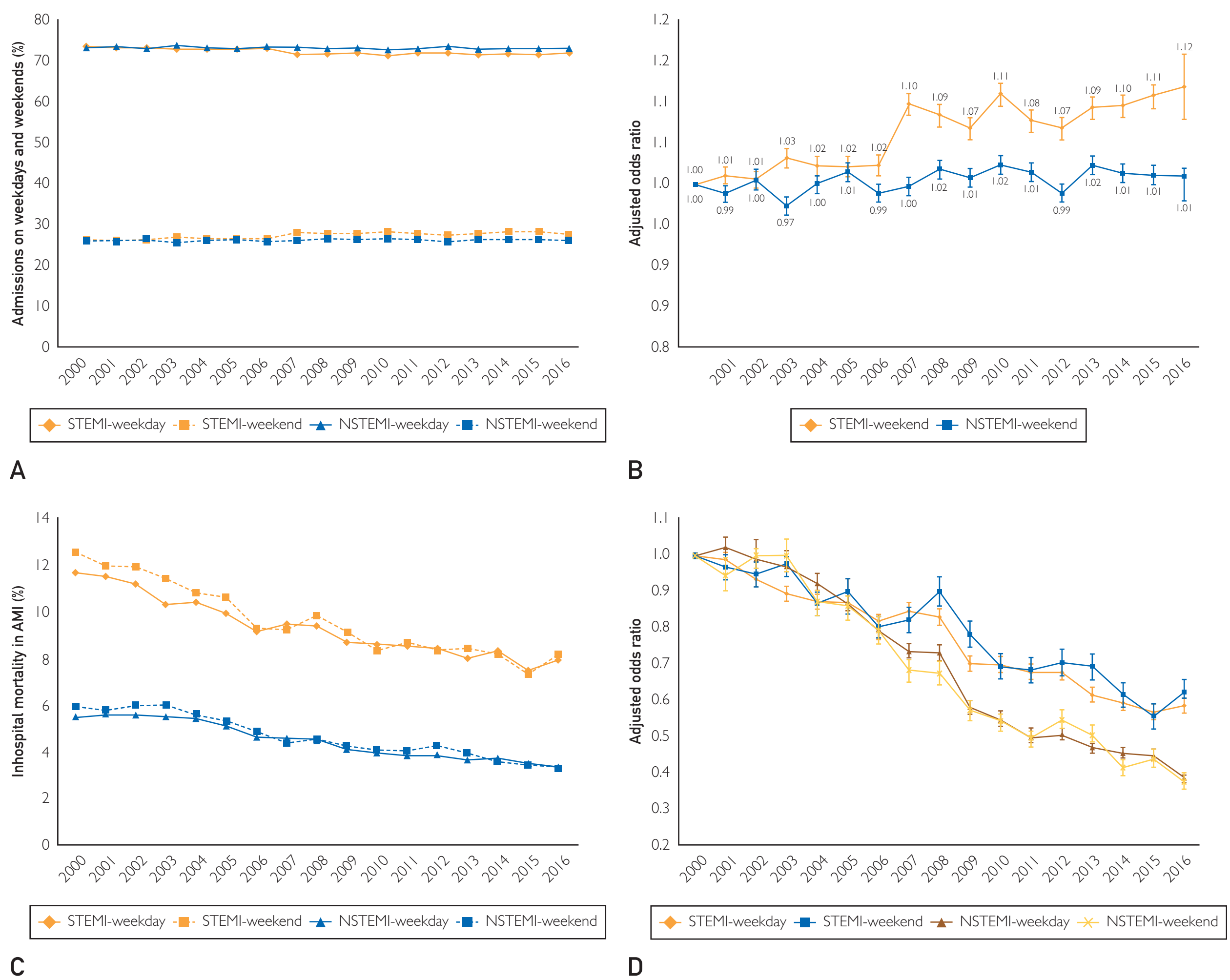

FIGURE 1. Trends in the prevalence and in-hospital mortality of acute myocardial infarction (AMI) admissions stratified by type of AMI and weekend vs weekday admission. A, Unadjusted temporal trends of the proportion of AMI admissions stratified by type of AMI and weekend vs weekday admission (*P*<.001 for trend over time). B, Adjusted odds ratio for ST-segment elevation myocardial infarction (STEMI) and non-STEMI (NSTEMI) weekend admissions by year (with 2000 as the referent) adjusted for age, sex, race, comorbidity, primary payer, hospital region, hospital location and teaching status, and hospital bed count (*P*<.001 for trend over time). C, Unadjusted in-hospital mortality in AMI admissions stratified by type of AMI and weekend vs weekday admission (*P*<.001 for trend over time). D, Adjusted odds ratio for in-hospital mortality by year (with 2000 as the referent) in AMI admissions stratified by type of AMI and weekend vs weekday admission adjusted for age, sex, race, comorbidity, primary payer, hospital region, hospital location and teaching status, hospital bed count, acute organ failure, cardiogenic shock, cardiac arrest, coronary angiography, percutaneous coronary intervention, pulmonary artery catheterization, mechanical circulatory support, invasive mechanical ventilation, and acute hemodialysis (*P*<.001 for trend over time).

CI. Multivariable logistic regression analysis incorporating age, sex, race, primary payer status, socioeconomic stratum, hospital characteristics, comorbidities, acute organ failure, AMI type, cardiac procedures, and noncardiac procedures was performed for assessing temporal trends of prevalence and in-hospital mortality. To confirm the results of the primary analysis, multiple subgroup analyses were performed. Multivariable logistic regression analyses were performed to calculate the OR (95% CI) for in-hospital mortality in weekend admissions compared with weekday admissions stratified by age (≤75 vs >75

TABLE 1. Baseline Characteristics of Weekend and Weekday AMI Admissions[a]

Characteristic	Weekend admissions (n=2,406,876)	Weekday admissions (n=6,634,942)	*P* value
Age (y), mean ± SD	68.0±14.6	68.2±14.4	<.001
Female sex (%)	40.5	40.7	<.001
Race (%)			<.001
White	63.1	63.2	
Black	8.3	8.1	
Others[b]	28.6	28.7	
Primary payer (%)			<.001
Medicare	58.0	58.9	
Medicaid	5.9	5.8	
Others[c]	36.1	35.2	
Quartile of median household income for zip code (%)			<.001
0-25th	23.1	23.1	
26th-50th	26.7	26.8	
51st-75th	25.1	25.1	
76th-100th	25.1	25.0	
Charlson Comorbidity Index (%)			<.001
0-3	35.2	34.3	
4-6	45.5	46.3	
≥7	19.3	19.4	
Hospital teaching status and location (%)			<.001
Rural	12.8	12.7	
Urban nonteaching	44.0	43.3	
Urban teaching	43.2	44.1	
Hospital bed count (%)			<.001
Small	11.4	11.4	
Medium	26.4	26.1	
Large	62.2	62.5	
Hospital region (%)			<.001
Northeast	18.6	19.0	
Midwest	22.8	22.7	
South	40.8	40.7	
West	17.8	17.6	
AMI type (%)			
STEMI	38.6	37.7	<.001
NSTEMI	61.4	62.3	<.001
Acute organ failure (%)			
Respiratory	8.6	8.1	<.001
Renal	11.3	11.1	<.001
Hepatic	0.9	0.8	<.001
Hematologic	3.4	3.4	.004
Neurologic	3.1	2.9	<.001
Out-of-hospital cardiac arrest (%)	4.9	4.5	<.001
Cardiogenic shock (%)	4.6	4.4	<.001
Pulmonary artery catheterization (%)	1.0	1.0	<.001

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TABLE 1. Continued

Characteristic	Weekend admissions (n=2,406,876)	Weekday admissions (n=6,634,942)	*P* value
Invasive mechanical ventilation (%)	6.3	5.8	<.001
Acute hemodialysis (%)	0.6	0.6	.06

[a]AMI = acute myocardial infarction; NSTEMI = non–ST-segment elevation myocardial infarction; STEMI = ST-segment elevation myocardial infarction.
[b]Hispanic, Asian or Pacific Islander, Native American, others.
[c]Private, self-pay, no charge, others.

years), sex, race (white vs nonwhite), presence of cardiac arrest, and cardiogenic shock. For the multivariable modeling, regression analysis with purposeful selection of statistically (liberal threshold of $P<.20$ in univariate analysis) and clinically relevant variables was conducted. Two-tailed $P<.05$ was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp).

RESULTS

From January 1, 2000, through December 31, 2016, there were 10,893,694 admissions for AMI, of which, 9,041,819 (83%) met the final inclusion criteria (excluded admissions: no data on weekend status [n=5 (<.001%)], interhospital transfers [n=1,851,870 (17%)]). Compared with those transferred, the population that was not transferred was admitted more frequently on weekends, was older, had higher comorbidity, was admitted to a small rural hospital, had comparable rates of STEMI and NSTEMI, had comparable rates of organ failure, and had lower rates of cardiogenic shock (Supplemental Table 2, available online at http://www.mcpiqojournal.org). Of these admissions, 2,406,876 (26.6%) occurred during weekend hours and the remaining on weekdays. There was an overall decrease in STEMI prevalence during the study period (Supplemental Figure 1, available online at http://www.mcpiqojournal.org). The 17-year unadjusted and adjusted temporal trends of weekend admissions stratified by AMI type are presented in Figure 1A and B. Although both STEMI and NSTEMI had comparable distribution of weekday and weekend admissions, there was a slight increase in the percentage of STEMI admissions during the weekend. In an adjusted analysis, NSTEMI admissions showed a stable weekend trend, whereas there has been a temporal increase in the proportion of weekend STEMI admissions. Compared with weekday admissions, weekend admissions had comparable age, sex, and race demographic data and frequencies of STEMI, acute organ failure, cardiac arrest, and cardiogenic shock (Table 1).

Compared with weekday admissions, AMI admissions on weekends received slightly less frequent CA (59.9% vs 58.8%), especially early CA (26.0% vs 20.8%) (all $P<.001$). The weekend AMI admissions received PCI less frequently but had comparable rates of mechanical circulatory support use (Table 2). The 17-year temporal trends showed a steady increase in early CA, all CA, and PCI stratified by AMI type (Figure 2A-C). Although there was an overall increase, weekend NSTEMI admissions had persistently lower rates of early CA compared with weekday admissions. Mean ± SD time to CA was higher in the weekend group compared with the weekday group (1.2±1.8 days vs 1.0±1.8 days) (Table 2), with differences between the STEMI (0.5±1.5 vs 0.5±1.5 days) and NSTEMI (1.7±1.9 vs 1.3±1.9 days) admissions. The temporal trends in the median time to CA in the weekday and weekend groups stratified by AMI type demonstrated a significant disparity between weekend and weekday NSTEMI admissions throughout the study and during the earlier years of the study for STEMI admissions (Figure 2D).

Weekend AMI admissions had higher unadjusted all-cause in-hospital mortality (6.8% vs 6.5%; OR, 1.05; 95% CI, 1.04-1.05; $P<.001$) but comparable adjusted in-hospital mortality in a multivariable logistic regression analysis (OR, 1.01; 95% CI, 1.00-1.01;

TABLE 2. Clinical Outcomes of Weekend and Weekday AMI Admissions

Characteristic	Weekend admissions (n=2,406,876)	Weekday admissions (n=6,634,942)	*P* value
Coronary angiography (%)	58.8	59.9	<.001
Early coronary angiography (%)	20.8	26.0	<.001
Time to angiography (d), mean ± SD	1.2±1.8	1.0±1.8	<.001
Percutaneous coronary intervention	37.6	38.4	<.001
Mechanical circulatory support	4.4	4.4	<.001
In-hospital mortality	6.8	6.5	<.001
Length of stay (d), mean ± SD	5.0±5.4	5.0±5.6	<.001
Hospitalization costs (×1000 $), mean ± SD	55±70	55±70	.27
Discharge disposition (%)			
Home	58.7	59.7	<.001
Transfer	16.2	15.2	
Skilled nursing facility	14.2	14.1	
Home with HHC	10.0	10.2	
Against medical advice	0.9	0.9	

AMI = acute myocardial infarction; HHC = home health care.

P=.05) (Supplemental Table 3, available online at http://www.mcpiqojournal.org). The 17-year unadjusted and adjusted temporal trends of in-hospital mortality in admissions on weekends and weekdays are presented in Figure 1C and D. There was a steady decrease in unadjusted and adjusted in-hospital mortality during the study period. The STEMI admissions had higher in-hospital mortality compared with the NSTEMI cohort, which was independent of the day of admission. The weekend AMI admissions had similar hospital length of stay and hospitalization costs but less frequent discharges to home (Table 2).

To confirm the results of the primary analysis and to identify high-risk populations, we performed a variety of subgroup analyses. Compared with weekday admissions, NSTEMI weekend admissions had more pronounced disparities in early CA compared with STEMI weekend admissions across all subgroups (Figure 3A and B). Weekend STEMI admissions had modestly elevated adjusted in-hospital mortality in all admissions except those with concomitant cardiogenic shock or cardiac arrest. In NSTEMI admissions, minor differences in in-hospital mortality were noted in female sex (OR, 0.97; 95% CI, 0.96-0.98; *P*<.001) and white race (OR, 0.98; 95% CI, 0.97-0.99; *P*<.001) admissions on the weekends compared with weekdays (Figure 3C and D).

DISCUSSION

In the largest study evaluating the weekend effect on the management and outcomes of nearly 10 million AMI admissions, we noted a temporal increase in STEMI admissions on weekends during this 17-year period. Weekend AMI admissions received less frequent early CA and PCI. Although temporal trends in STEMI showed near equalization during the latter half of the study period, weekend NSTEMI admissions continued to receive less frequent early CA. In-hospital mortality was not different between admissions on weekdays and weekends. In subgroup analyses, minor differences in in-hospital mortality were noted in weekend and weekday admissions across the various subgroups.

The perceived disadvantage of being admitted for acute care, including in patients with AMI, during a weekend has been reported in multiple previous studies.[10,11] Studies of the AMI population reported significantly lower utilization of revascularization strategies and increased time to intervention

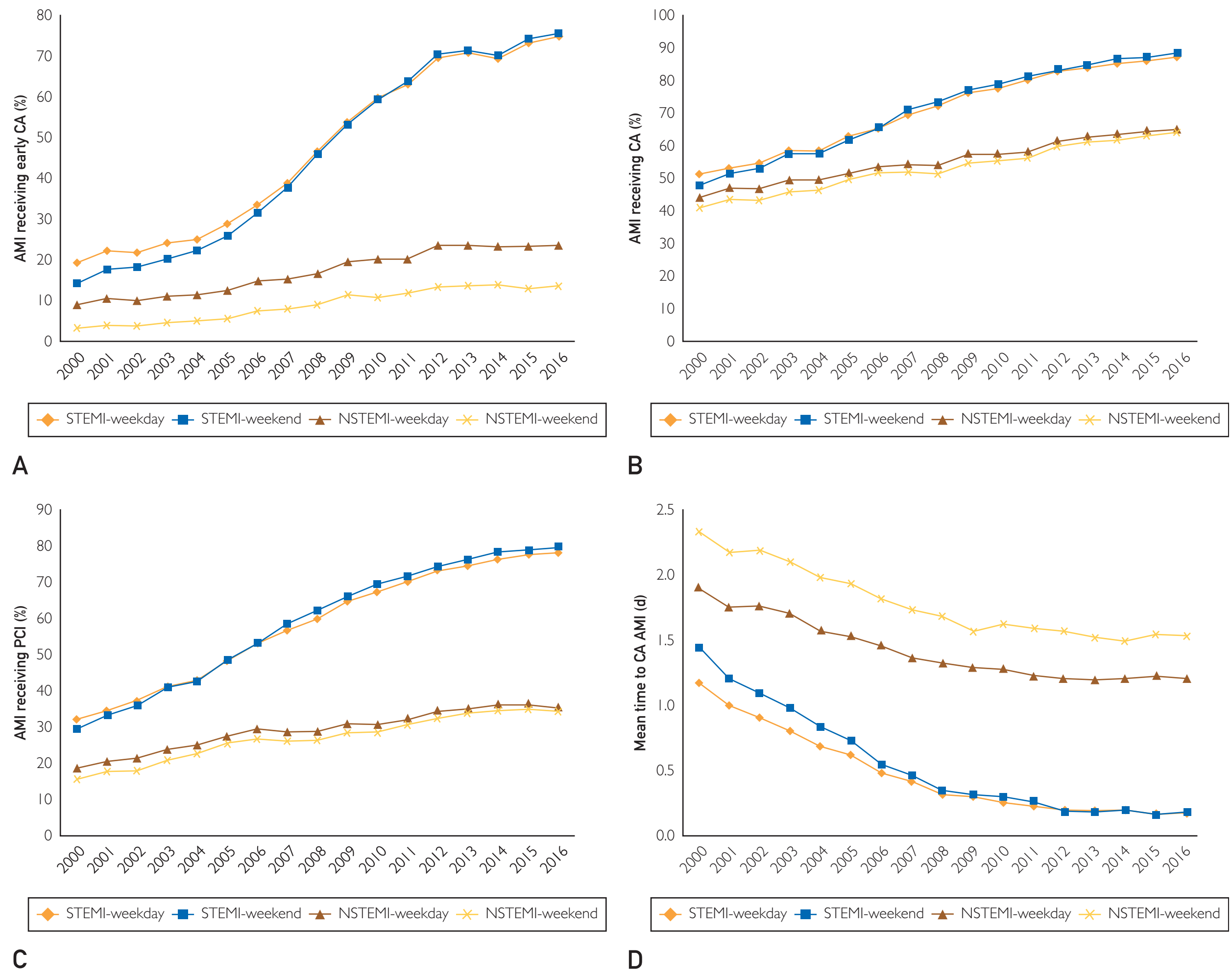

FIGURE 2. The 17-year temporal trends in the use of early coronary angiography (CA) (A), all CA (B), percutaneous coronary intervention (PCI) (C), and mean time to CA (D) in acute myocardial infarction (AMI) admissions stratified by type of AMI and weekend vs weekday admission; all *P*<.001 for trend over time. NSTEMI = non–ST-segment elevation myocardial infarction; STEMI = ST-segment elevation myocardial infarction.

on the weekends compared with weekday admissions.[8,9] These factors, along with lower rates of staffing, were attributed to the higher mortality seen in weekend admissions.[8,9] Large studies from national registries also found significantly higher mortality in weekend STEMI admissions compared with admissions during regular hours.[7,9] However, these differences were attenuated after adjustment for time to reperfusion and utilization of invasive procedures.[7] A meta-analysis of studies reporting outcome differences based on time of admission until 2013 also reported higher mortality among patients with AMI admitted during off-hours.[38] Contrastingly, several other studies have reported that there are no differences in mortality between weekend and weekday admissions.[12,39] Whereas studies from high-volume centers showed similar delivery of care and outcomes irrespective of time of admission,[40,41] others showed no differences in mortality despite having longer door-to-balloon times and lower utilization of revascularization among weekend admissions.[14,42] Consistent with these data we found comparable adjusted mortality for all

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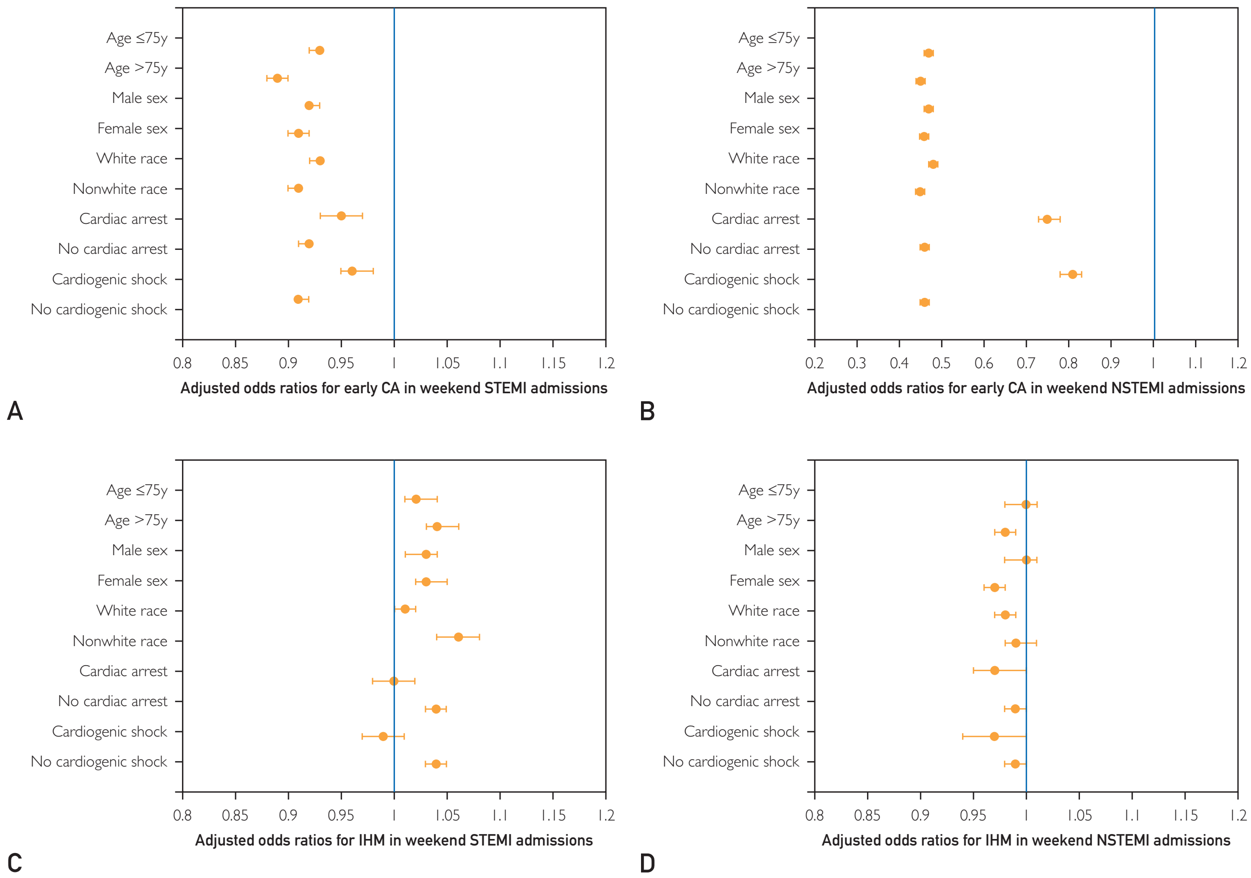

FIGURE 3. Subgroup sensitivity analyses for the use of early coronary angiography (CA) and in-hospital mortality (IHM) in weekend acute myocardial infarction (AMI) admissions. Multivariable-adjusted odds ratios (95% CIs) for early CA in ST-segment elevation myocardial infarction (STEMI) (A) and non-STEMI (NSTEMI) (B) (adjusted for age, sex, race, comorbidity, primary payer, hospital region, hospital location and teaching status, hospital bed count, cardiogenic shock, and cardiac arrest) and IHM in STEMI (C) and NSTEMI (D) (adjusted for age, sex, race, comorbidity, primary payer, hospital region, hospital location and teaching status, hospital bed count, acute organ failure, cardiogenic shock, cardiac arrest, CA, percutaneous coronary intervention, pulmonary artery catheterization, mechanical circulatory support, invasive mechanical ventilation, and acute hemodialysis) in weekend admissions compared with weekday admissions (all *P*<.001). Blue line denotes odds ratio of 1.0; odds ratio less than 1 show lower use of early CA (A and B) and lower IHM (C and D).

weekend AMI admissions after adjusting for CA and PCI use. In contrast, a more recent study using the HCUP-NIS database found weekend admissions to be associated with higher mortality and lower utilization of invasive procedures for patients with STEMI and those with NSTEMI.[8] These differences could potentially be due to the more robust adjustment in the present study for additional confounders, such as organ failure and use of circulatory support devices. In addition, the present study encompasses a longer and more recent period during which adherence to management guidelines has resulted in considerable decline in overall mortality associated with all types of AMI. We also found an increase in STEMI admissions during the weekends over time, which could have contributed to the diminishing weekend effect in this population in more recent times.

Previous studies have shown that weekend admissions were less likely to receive invasive procedures such as CA and PCI.[6,8] In the present study, these discrepancies were more prevalent only during the early period of the investigation among STEMI admissions. Recent studies evaluating temporal differences have also found similar results for the AMI population.[12,43] A meta-analysis evaluating results from 1990-2016 has also reported that these discrepancies, although more prevalent during the earlier period, have considerably diminished during recent times.[44] Most recently, results from a STEMI network study showed uniformity in management, clinical characteristics, and outcomes in patients with STEMI admitted during weekdays and weekends due to well-organized and focused plans of care.[40] In contrast to the STEMI subgroup, the present results showed that the NSTEMI population admitted over the weekend continued to have a lower rate of early CA and a higher median time to angiography compared with weekday admissions. In addition, studies have shown that access to specialized care and level of expertise is reduced during weekends, which could be influencing the lower rates of procedures being performed for the NSTEMI population.[11,45] However, in patients with stable NSTEMI, early CA does not seem to confer any additional mortality benefit over guideline-directed medical management.[46] Last, despite epidemiologic data showing an increase in NSTEMI diagnosis after the introduction of cardiac troponins (compared with creatine kinase), this study noted a relatively stable trend of NSTEMI.[47] It is possible that the inclusion of a primary diagnosis of NSTEMI might have led to an underestimation of the frequency as some have argued that type 2 AMI should not be called NSTEMI or STEMI events.[48]

Weekend AMI admissions in the present study were more likely to be younger and male and tended to be sicker, similar to earlier reports.[6-8] There was a higher incidence of organ failure and cardiogenic shock in weekend admissions. In subgroup analysis of these high-risk populations of AMI, we continued to see a lower rate of utilization of early CA across all groups for both STEMI and NSTEMI. More importantly, we found higher adjusted in-hospital mortality for patients with STEMI in most of the high-risk groups. However, this difference was not seen in those with cardiogenic shock or cardiac arrest because these constitute a spectrum of sicker patients with AMI with potentially greater access and monitoring during health care delivery.[21,31,49]

This study has several limitations, despite the HCUP-NIS database's attempts to mitigate potential errors by using internal and external quality control measures. The administrative codes for AMI have been previously validated to reduce the errors inherent in the study. Echocardiographic data, angiographic variables, and hemodynamic parameters were unavailable in this database, which limits physiologic assessments of disease severity. Although procedural timing can be timed to day of procedure, ie, a 24-hour interval, we were unable to assess further detailed metrics, such as total ischemic time and door-to-balloon time. Important factors such as the delay in presentation from time of onset of AMI symptoms, timing of cardiogenic shock and/or cardiac arrest, reasons for not receiving aggressive medical care, timing of multiple organ failure, and treatment-limiting decisions of organ support could not be reliably identified in this database. The HCUP-NIS does not permit risk stratification of the NSTEMI population due to its administrative nature. Being an in-hospital database, this study cannot comment on the long-term outcomes of these AMI admissions. It is possible that despite best attempts at controlling for confounders by a multivariate analysis, weekend admission was a marker of greater illness severity due to residual confounding. Despite these limitations, this study addresses an important knowledge gap highlighting the national temporal evolution of the weekend effect in AMI care.

CONCLUSION

In this study of nearly 10 million AMI admissions, there remain significant disparities in early CA in NSTEMI, but not STEMI, admissions. No differences in outcomes of AMI admissions on weekdays vs weekends were noted in this large contemporary national study of AMI admissions.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **AMI** = acute myocardial infarction; **HCUP** = Healthcare Cost and Utilization Project; **NIS** = National (Nationwide) Inpatient Sample; **NSTEMI** = non−ST-segment elevation myocardial infarction; **OR** = odds ratio; **PCI** = percutaneous coronary intervention; **STEMI** = ST-segment elevation myocardial infarction

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