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ORIGINAL ARTICLE

Holiday and weekend effects on mortality for acute myocardial infarction in Shanxi, China: a cross-sectional study

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Abstract

Objectives To examine the effects of holiday and weekend admission on in-hospital mortality for patients with acute myocardial infarction (AMI) in China.

Methods Patients with AMI in 31 tertiary hospitals in Shanxi, China from 2014 to 2017 were included ($N = 54{,}968$). Multivariable logistic regression models were used to examine the effects of holiday and weekend admission on in-hospital mortality.

Results Compared to non-holiday and weekday admissions, holiday and weekend admissions, respectively, were associated with increases in risk-adjusted mortality rates. Chinese National Day was associated with an additional 10 deaths per 1000 admissions (95% confidence interval (CI): (0, 20))—a relative increase from baseline mortality of 64% (95% CI: (1%, 128%)). Sunday was associated with an additional 4 deaths per 1000 admissions (95% CI: (0, 7))—a relative increase from baseline mortality of 23% (95% CI: (3%, 45%)). We found no evidence of gender differences in holiday or weekend effects on mortality.

Conclusions Holiday and weekend admissions were associated with in-hospital AMI mortality. The admissions on Chinese National Day and Sunday contributed to the observed “holiday effect” and “weekend effect,” respectively.

Keywords Holiday effect · Weekend effect · Mortality · Acute myocardial infarction · China

Introduction

Since the study of Bell and Redelmeier (2001), the relationship between weekend admission and patient outcome has been debated widely in scientific literature. The evidence of observed increases in mortality during holidays and weekends—so-called the “weekend effect”—has been provided in diverse clinical settings, especially the cardiology (Kostis et al. 2007; Isogai et al. 2015) and emergency medicine (Walker et al. 2017; Sun et al. 2019). Although there are expanding studies that seek to identify, measure, and explain these holiday and weekend effects span the globe, the empirical evidence on this subject is mixed and intensively debated (Bray and Steventon 2017).

Globally, ischemic heart disease (IHD) was the leading cause of death, accounting for 8.9 million deaths in 2015 (Wang et al. 2016). In China, IHD has overtaken hemorrhagic stroke as the first leading cause of death in recent years (Zhang et al. 2017). Acute myocardial infarction (AMI), as an acute form of IHD, has become the second leading cause of death in China, accounting for the

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majority of death due to IHD (Chen et al. 2018). The number of AMI cases in China is increasing rapidly and is expected to reach 23 million in 2030 (Wang et al. 2011).

Numerous studies have examined the “weekend effect” on AMI mortality, but the results were inconsistent across various studies (Kostis et al. 2007; Becker 2007; Hansen et al. 2013; Isogai et al. 2015; Fiorentino et al. 2018). Kostis et al. (2007) used the patient-level data from New Jersey (1987–2002) and found that patients admitted on weekends had higher 30-day and 1-year mortality than those admitted on weekdays and such effect became insignificant after adjusting for invasive cardiac procedures. Using a nationwide inpatient database in Japan, Isogai et al. (2015) reported that weekend admission was significantly associated with higher in-hospital mortality. However, in recent years, some studies found that the weekend effect on AMI mortality does not exist (Hong et al. 2006; Fiorentino et al. 2018). Hansen et al. (2013) reported that the AMI mortality decreased with the use of guideline-recommended invasive procedures, and they found an attenuated trend of the weekend effect on AMI mortality.

In China, the empirical evidence for the effect of weekend admission on mortality is limited. Tang et al. (2017) used the data from a single tertiary hospital in China and found that patients with ST-elevation myocardial infarction (STEMI) who underwent the primary percutaneous coronary intervention on holidays and weekends had higher rates of in-hospital mortality. Geng et al. (2016) reported that there was no association of off-hours admission for patients with STEMI with in-hospital and long-term mortality. Although these two studies from China had explored the “weekend effect” and the “off-hours effect” and reported mixed results, they were limited in the following aspects. First, they had the small sample size in a limited area, which may limit the generalizability of their results. Second, following the previous studies from Western countries (Fiorentino et al. 2018; Han et al. 2018), they assumed that the effects of weekends and holidays on mortality were similar and combined them together. However, compared with weekends, the length of Chinese statutory holidays is much longer, particularly in Spring Festival and National Day (7 days per year). A recent study from Taiwan (Lin et al. 2019) reported that, compared with weekday admissions, patients admitted on Chinese New Year holidays had 20% and 20% increased risks of in-hospital mortality and 30-day mortality, respectively. Third, previous studies mainly dichotomize hospital admissions as weekend and weekday groups rather than exploring patterns of specific admit days (Shi et al. 2016). Among all Chinese holidays, Spring Festival is the most important one. People usually have strong willingness to go home for family reunion. The hospital staffing level during Spring Festival may much lower compared with the common holidays or weekends, which may potentially affect patient prognosis.

To address these limitations, we conducted a cross-sectional study to examine holiday and weekend effects on in-hospital AMI mortality using a provincial administrative database in Shanxi Province, China. We focused on AMI patients for four reasons. First, AMI is a very common disease for hospitalization which allows us to make estimations in a relatively large sample size. Second, the mortality of AMI patients has been adopted as a measure of overall medical quality by various researchers (Kostis et al. 2007; Isogai et al. 2015; Han et al. 2018), which depicts the quality of care partially. Third, compared with other common diseases like pneumonia and cold, AMI patients have less discretion in choosing hospitals since the time from symptom onset to hospital admission is crucial to patients’ prognosis (Cannon 2000). Therefore, they will be sent to hospitals right after the symptoms of AMI exhibition, which reduces the chance of selection bias in this study. Fourth, clinical practice in the treatment of AMI did not change significantly during our study period in ways that could affect mortality. Thus, any changes in mortality are less likely be driven by differential uptake of new medical technologies. In this study, we separated the “weekend effect” and the “holiday effect” and examined the effects of individual holiday and day of the week on AMI in-hospital mortality. We hypothesize that patients admitted on weekends and holidays have greater in-hospital mortality compared with those admitted on weekdays and non-holidays.

Methods

Data sources

We used the front pages of inpatient medical records provided and authorized by Health Commission of Shanxi Province, China. The inpatient record data were routinely collected by Center for Health Statistics Information and audited by Health Commission of Shanxi Province. The database covers all hospitals in Shanxi and contains information on patients’ demographic, admission and discharge information. The demographic information includes age, gender, health insurance (urban employment basic medical insurance (UEBMI), urban residents basic medical insurance (URBMI), new cooperative medical scheme (NCMS), and others). The admission information includes the admission date, principal, and secondary diagnoses (identified using the International Classification of Diseases, 10th Revision (ICD-10) codes), up to 7 procedure records (identified using the International

Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes). The discharge information includes discharge date, discharge status, and inpatient costs during hospitalization.

Using the principal diagnosis (ICD-10: I21.x), we identified 61278 patients with AMI who admitted in 31 tertiary hospitals in Shanxi between January 1, 2014 and December 31, 2017. We excluded patients who aged less than 18 ($n = 4$) because AMI is very uncommon in that group. Patients who were discharged alive within 1 day after admission were also excluded ($n = 160$) because they were likely to leave against medical advice and the treatment time in hospital was very limited. In addition, we excluded patients who were transferred to another hospital or community health service center ($n = 2810$) because subsequent treatment information in other facilities was unavailable for our study. Patients with missing data on age, gender, date of admission and discharge, and discharge status were also excluded ($n = 3336$). Finally, a total of 54968 AMI patients from 31 tertiary hospitals in Shanxi were identified in this study.

Study variables

The primary outcome measure was in-hospital mortality. In-hospital mortality was a binary variable, with one indicated all-cause death during the patient's hospitalization while zero indicated non-death. The independent variables of interest in this study were holiday and weekend admission. Holidays were defined as the Chinese statutory holidays, including New Year (3 days per year), Spring Festival (7 days per year), Qing Ming Festival (3 days per year), Labor Day (3 days per year), Dragon Boat Festival (3 days per year), Mid-Autumn Festival (3 days per year) and Chinese National Day (7 days per year), and non-holiday as the other days. Weekends were defined as Saturday and Sunday, and weekdays were from Monday to Friday. We also explored the effects of individual holiday and day of week on in-hospital mortality separately. The reference groups for these two analyses were non-holidays and Wednesday, respectively. Wednesday was selected as the reference group because it is associated with lowest admission risk of mortality (Fiorentino et al. 2018).

To explore the effects of holiday and weekend admission on in-hospital mortality, we adjusted for both patient and hospital characteristics. The patient characteristics include age, gender, health insurance, type of AMI, cardiac procedures, and the Elixhauser comorbidities. The Elixhauser comorbidities include 30 disease conditions (Elixhauser et al. 1998), which have been validated in its prediction of in-hospital mortality using Chinese population (Cai et al. 2020). The patients were categorized into three types of AMI according to the principal diagnosis code: ST-Elevation Myocardial Infarction (ICD-10 codes: I21.0–I21.3), non-ST-Elevation Myocardial Infarction (ICD-10 code: I21.4), and unspecified AMI (ICD-10 code: I21.9). Cardiac procedure is a dummy variable that indicated whether patients receive any cardiac procedure during hospitalizations. The cardiac procedures included percutaneous coronary intervention (ICD-9-CM codes: 00.66, 36.01, 36.02, 36.05), coronary artery bypass grafting (ICD-9-CM code: 36.1), and coronary angiography (ICD-9-CM codes: 88.55, 37.22, 37.23). In terms of hospital characteristics, we included hospital volume and whether the specialist hospital. Based on the annual AMI admissions of each hospital, hospital volume was categorized into quartiles for each year. A hospital might be in a high-volume group in one year but a mid-volume group in another year. Because the sample of our study came from tertiary hospitals and all of them are public non-profit hospitals, thus we did not include other variables such as hospital level, ownership, and for-profit. In the pooled analysis, we also included year and city dummy variables to capture unobserved factors that varied by financial year and city.

Statistical analyses

First, we presented patient and hospital characteristics using frequencies and percentages for categorical variables, means and standard deviations for normally distributed continuous variables. Differences in patient and hospital characteristics between holiday and non-holiday admissions as well as between weekend and weekday admissions were tested using Fisher's exact tests for categorical variables (some cells has sample size fewer than 5) and t-tests for continuous variables.

Second, we used multivariable logistic regression model to examine the effects of weekend and holiday admission on in-hospital mortality separately. To account for potential correlations of patient outcomes within the same hospitals, we used cluster-robust standard errors to reduce the bias in statistical inference (Arellano 1987). In previous studies, the weekend admissions were usually defined as those occurring on holidays and weekends (Hansen et al. 2013; Isogai et al. 2015; Fiorentino et al. 2018; Han et al. 2018). However, the effect of holiday admission on mortality and the effect of weekend admission on mortality might be different in magnitude and statistical significance (Smith et al. 2014; Lin et al. 2019). To prevent our estimates of the "weekend effect" being contaminated by the effects arising from the "holiday effect," we dropped the admissions during holidays from our full sample and examined the "weekend effect" in the non-holiday sample. In addition, we explored the effects of individual holiday and day of week on mortality separately. We used the method proposed by Norton and Dowd (2018) to report the marginal effects of admissions occurring on the holidays or weekends. Standard errors and 95% confidence intervals (CIs) on marginal effects were computed using the delta-method (Dowd et al. 2014).

Lastly, we tested the gender differences in holiday and weekend effects on mortality by adding interaction terms to the empirical model specifications (Karaca-Mandic et al. 2012).

All data management and visualization were processed in R (Version 3.5.2, The R Foundation), while the statistical analyses were performed in Stata (Version 15.1, Stata Crop, Chicago, IL, USA).

Results

Descriptive statistics

Table 1 presents the summary statistics for patient and hospital characteristics between holiday and non-holiday admissions, as well as weekend and weekday admissions. A total of 54968 AMI admissions during the study period were identified, including 3399 (6.2%) holiday admissions, 9936 (18.1%) weekend admissions and 41633 (75.7%) weekday admissions. Overall, the in-hospital mortality was 18.2‰. Patients with AMI were the elderly and more likely to be STEMI (51.0%). The UEBMI and NCMS were two major health insurances, accounting for 37.1% and 41.8% of our sample, respectively. Most patients (84.9%) seek care in the general tertiary hospitals, and over 60 percentage of patients received cardiac procedures during hospitalizations. Compared with non-holiday admissions, patients admitted on holidays were slightly older, more likely to be NSTEMI and less likely to receive cardiac procedures. The holiday admissions had higher proportions of patients with congestive heart failure, cardiac arrhythmias, and chronic pulmonary disease. Compared with weekday admissions, patients admitted on weekends were more likely to be STEMI and less likely to receive cardiac procedures.

In-hospital mortality

In Tables 2, we report the unadjusted mortality rates per 1000 hospital admissions on holidays compared to non-holidays and on weekends compared to weekdays, respectively. Patients admitted on holidays had a higher risk of in-hospital mortality than those admitted on non-holidays (25.6‰ vs. 17.7‰, $p = 0.001$). Specifically, admissions on Qing Ming, Mid-Autumn Festival and National Day had significantly greater in-hospital mortality ($p = 0.047$, $p = 0.016$, and $p = 0.009$, respectively). The mortality for patients admitted on weekends was significantly higher than that of weekday admissions (21.2‰ vs. 16.9‰, $p = 0.004$). Compared with weekday admissions, Saturday and Sunday admissions had higher risk of in-hospital mortality ($p = 0.031$ and $p = 0.027$, respectively). Compared with patients admitted on Wednesday, patients admitted on Sunday experienced significantly higher risk of in-hospital death (21.5‰ vs. 17.3‰, $p = 0.049$).

Holiday and weekend effects on in-hospital mortality

Tables 3 and 4 summarize the marginal effects of the holiday and weekend admission on in-hospital mortality, respectively. The results were generally consistent in unadjusted and adjusted model specifications. As shown in Table 3, after adjusting for covariates, holiday admissions had higher risk of mortality than non-holiday admissions (relative effect: 1.30, 95% CI: (1.03, 1.56)). Admissions on National Day were significantly associated with in-hospital mortality, with an estimated increase in risk-adjusted mortality associated with 10 deaths per 1000 admissions (95% CI: (0, 20)). In relative terms, National Day was associated with an increase in risk adjusted mortality rates of 64% (95% CI: (1%, 128%)). There is no association between the admissions during Spring Festival and in-hospital mortality (relative effect: 0.98, 95% CI: (0.54, 1.41)).

Table 4 shows that compared with patients admitted on weekdays, patients admitted on weekends had higher risk of in-hospital death (relative effect: 1.18, 95% CI: (1.04, 1.32)). Specifically, Sunday admission was significantly associated with increased in-hospital mortality (relative effect: 1.24, 95% CI: (1.02, 1.46)). Replacing the series of holidays in Table 3 with the series of days in the week, we found that Sunday admission was associated with an increase in risk-adjusted mortality rates of 4 deaths per 1000 patients (95% CI: (0, 7)), which corresponded to a relative increase of 23% (95% CI: (2%, 45%)) from baseline (Wednesday) mortality.

The interaction tests for gender differences in holiday and weekend effects were reported in Table 5. The results revealed that there were no significant gender differences in holiday and weekend effects, even after adjusting for potential covariates. The interaction term between gender and holiday variable was statistically non-significant for in-hospital mortality ($p = 0.593$), as well as the interaction term between gender and weekend variable ($p = 0.356$).

Table 1 Characteristics of hospital admissions for acute myocardial infarction in Shanxi, China (2014–2017)

Variables	Holiday (n = 3399)	Non-holiday (n = 51,569)	p-value	Weekend (n = 9936)	Weekday (n = 41,633)	p-value	Overall (n = 54,968)
Patient characteristics							
Age, mean (SD)	61.9 (12.9)	61.3 (12.6)	0.005	61.2 (12.9)	61.3 (12.5)	0.44	61.3 (12.6)
Female	849 (25.0)	12,347 (23.9)	0.17	2256 (22.7)	10,091 (24.2)	0.001	13,196 (24.0)
Insurance			0.017			< 0.001	
UEBMI	1326 (39.0)	19,045 (36.9)		3691 (37.1)	15,354 (36.9)		20,371 (37.1)
URBMI	241 (7.1)	3661 (7.1)		742 (7.5)	2919 (7.0)		3902 (7.1)
NCMS	1333 (39.2)	21,620 (41.9)		4002 (40.3)	17,618 (42.3)		22,953 (41.8)
Other	499 (14.7)	7243 (14.0)		1501 (15.1)	5742 (13.8)		7742 (14.1)
Elixhauser comorbidities							
Congestive heart failure	2179 (64.1)	31,575 (61.2)	< 0.001	6210 (62.5)	25,365 (60.9)	0.004	33,754 (61.4)
Cardiac arrhythmias	822 (24.2)	11,041 (21.4)	< 0.001	2412 (24.3)	8629 (20.7)	< 0.001	11,863 (21.6)
Valvular disease	46 (1.4)	671 (1.3)	0.8	120 (1.2)	551 (1.3)	0.36	717 (1.3)
Pulmonary circulation disorders	11 (0.3)	193 (0.4)	0.64	39 (0.4)	154 (0.4)	0.74	204 (0.4)
Peripheral vascular disorders	285 (8.4)	5445 (10.6)	< 0.001	894 (9.0)	4551 (10.9)	< 0.001	5730 (10.4)
Hypertension	1465 (43.1)	23,012 (44.6)	0.084	4358 (43.9)	18,654 (44.8)	0.089	24,477 (44.5)
Paralysis	1 (< 0.1)	7 (< 0.1)	0.46	1 (< 0.1)	6 (< 0.1)	0.74	8 (< 0.1)
Neurodegenerative disorders	14 (0.4)	158 (0.3)	0.29	29 (0.3)	129 (0.3)	0.77	172 (0.3)
Chronic pulmonary disease	141 (4.1)	1784 (3.5)	0.034	345 (3.5)	1439 (3.5)	0.94	1925 (3.5)
Diabetes, uncomplicated	627 (18.4)	9041 (17.5)	0.17	1698 (17.1)	7343 (17.6)	0.2	9668 (17.6)
Diabetes, complicated	41 (1.2)	491 (1.0)	0.14	78 (0.8)	413 (1.0)	0.056	532 (1.0)
Hypothyroidism	34 (1.0)	455 (0.9)	0.48	69 (0.7)	386 (0.9)	0.026	489 (0.9)
Renal failure	35 (1.0)	420 (0.8)	0.18	77 (0.8)	343 (0.8)	0.63	455 (0.8)
Liver disease	281 (8.3)	4928 (9.6)	0.013	853 (8.6)	4075 (9.8)	< 0.001	5209 (9.5)
Peptic ulcer disease, no bleeding	25 (0.7)	358 (0.7)	0.78	65 (0.7)	293 (0.7)	0.59	383 (0.7)
AIDS	0 (0.0)	0 (0.0)	–	0 (0.0)	0 (0.0)	–	0 (0.0)
Lymphoma	0 (0.0)	8 (< 0.1)	–	0 (0.0)	8 (< 0.1)	–	8 (< 0.1)
Metastatic cancer	0 (0.0)	25 (< 0.1)	–	2 (< 0.1)	23 (0.1)	0.15	25 (< 0.1)
Solid tumor without metastasis	15 (0.4)	130 (0.3)	0.037	25 (0.3)	105 (0.3)	0.99	145 (0.3)
Rheumatoid arthritis/collagen vascular diseases	25 (0.7)	281 (0.5)	0.15	52 (0.5)	229 (0.6)	0.75	306 (0.6)
Coagulopathy	5 (0.1)	86 (0.2)	0.78	22 (0.2)	64 (0.2)	0.14	91 (0.2)
Obesity	2 (0.1)	25 (< 0.1)	0.79	7 (0.1)	18 (< 0.1)	0.27	27 (< 0.1)
Weight loss	0 (0.0)	6 (< 0.1)	–	0 (0.0)	6 (< 0.1)	–	6 (< 0.1)
Fluid and electrolyte disorders	107 (3.1)	1520 (2.9)	0.5	329 (3.3)	1191 (2.9)	0.017	1627 (3.0)
Blood loss anemia	1 (< 0.1)	23 (< 0.1)	0.68	4 (< 0.1)	19 (< 0.1)	0.82	24 (< 0.1)
Deficiency anemia	4 (0.1)	94 (0.2)	0.39	22 (0.2)	72 (0.2)	0.31	98 (0.2)
Alcohol abuse	0 (0.0)	11 (< 0.1)	–	3 (< 0.1)	8 (< 0.1)	0.5	11 (< 0.1)
Drug abuse	0 (0.0)	0 (0.0)	–	0 (0.0)	0 (0.0)	–	0 (0.0)
Psychosis	1 (< 0.1)	25 (< 0.1)	0.62	4 (< 0.1)	21 (0.1)	0.68	26 (< 0.1)
Depression	2 (0.1)	21 (< 0.1)	0.62	4 (< 0.1)	17 (< 0.1)	0.98	23 (< 0.1)
AMI type			0.07			< 0.001	
STEMI	1689 (49.7)	26,333 (51.1)		5256 (52.9)	21,077 (50.6)		28,022 (51.0)
NSTEMI	925 (27.2)	13,122 (25.4)		2408 (24.2)	10,714 (25.7)		14,047 (25.6)
Other	785 (23.1)	12,114 (23.5)		2272 (22.9)	9842 (23.6)		12,899 (23.5)
Cardiac procedures	2066 (60.8)	33,556 (65.1)	< 0.001	6227 (62.7)	27,329 (65.6)	< 0.001	35,622 (64.8)
Hospital characteristics							
Hospital volume			0.34			< 0.001	
Quartile 1	953 (28.0)	13,904 (27.0)		2835 (28.5)	11,069 (26.6)		14,857 (27.0)

Table 1 (continued)

Variables	Holiday (n = 3399)	Non-holiday (n = 51,569)	p-value	Weekend (n = 9936)	Weekday (n = 41,633)	p-value	Overall (n = 54,968)
Quartile 2	836 (24.6)	12,602 (24.4)		2317 (23.3)	10,285 (24.7)		13,438 (24.4)
Quartile 3	886 (26.1)	13,477 (26.1)		2674 (26.9)	10,803 (25.9)		14,363 (26.1)
Quartile 4	724 (21.3)	11,586 (22.5)		2110 (21.2)	9476 (22.8)		12,310 (22.4)
Whether specialist hospital	453 (13.3)	7822 (15.2)	0.004	1351 (13.6)	6471 (15.5)	< 0.001	8275 (15.1)
Year			0.002			< 0.001	
2014	612 (18.0)	10,563 (20.5)		2134 (21.5)	8429 (20.2)		11,175 (20.3)
2015	784 (23.1)	11,989 (23.3)		2285 (23.0)	9704 (23.3)		12,773 (23.2)
2016	992 (29.2)	13,979 (27.1)		2537 (25.5)	11,442 (27.5)		14,971 (27.2)
2017	1011 (29.7)	15,038 (29.2)		2980 (30.0)	12,058 (29.0)		16,049 (29.2)

Unless otherwise indicated, data are expressed as weighted number (percentage) of row totals for each group

The non-holiday sample is a subsample excluding admissions on New Year, Spring Festival, Qing Ming, Labor Day, Dragon Boat Festival, Mid-Autumn Festival, and National Day. The non-holiday sample is divided into two subsamples: weekend and weekday admissions

UEBMI, urban employment basic medical insurance; URBMI, urban resident basic medical insurance; NCMS, new cooperative medical scheme; STEMI, ST-elevation myocardial infarction; NSTEMI, Non-ST-elevation myocardial infarction

Discussion

Using the data from 31 tertiary hospitals in Shanxi, China, our empirical study examined whether the “holiday effect” and “weekend effect” existed among patients with AMI. Our findings suggest that holiday admissions and weekend admissions are significantly associated with higher risk of in-hospital mortality for patients with AMI. Further analyses reveal that in-hospital mortality rates are higher for patients admitted on National Day and Sunday, which may contribute to the observed “holiday effect” and “weekend effect,” respectively. To the best of our knowledge, this is the first provincial population-based study in China to investigate whether weekend admissions and holiday admissions influence in-hospital death for patients admitted with AMI.

Higher mortality associated with weekend admissions for AMI has been observed in many countries and regions, although the magnitude of weekend effect differs (Bray and Steventon 2017). Our findings are consistent with previous studies that demonstrated the association of weekend and holiday admissions with increased in-hospital mortality (Kostis et al. 2007; Smith et al. 2014; Isogai et al. 2015; Mizuno et al. 2018; Lin et al. 2019; Jayawardana et al. 2019). Our estimated magnitude of the weekend effect (relative effect: 1.18, 95% CI: (1.04, 1.32)) was similar to the pooled odds ratio for weekend mortality effect reported in the recent meta-analyses (Pauls et al. 2017; Chen et al. 2019). Lin et al. (2019) conducted a cohort study to examine the holiday effects on hospital mortality using a nationwide population database in Taiwan. They reported that patients admitted to internal medicine departments on Chinese New Year holiday (Spring Festival) have higher risk of in-hospital and 30-day mortality than those admitted on weekdays. However, we did not observe such “Chinese New Year effect” in our study. The differences in healthcare system, sampling framework, study period and model settings may contribute to this discrepancy.

Theoretically, hospitals are open 24 h a day, 7 days a week, including holidays and weekends. Patients admitted on weekends or during holidays deserve the same level care as those admitted on weekdays. In clinical practice, however, the differences in staffing level, patient characteristics, and organization factors between weekends and weekdays make this challenging. There are two possible explanations that may explain our findings of holiday and weekend effects. First, it is possible that the staffing level and the availability of diagnostic or therapeutic interventions may be lower on weekends and holidays than on other days (Kostis et al. 2007; Becker 2007). The staff on duty at weekends and holidays may not be experienced in performing the invasive procedures, and the number of staff members may not enough for providing the care required to

Table 2 In-hospital mortality for acute myocardial infarction on holiday, weekend and other days in Shanxi, China (2014–2017)

Time of admission	Mortality per 1000 admissions, mean (SD)	*p*-value[c]
Non-holiday[a]	17.7 (132.0)	Ref
Holiday	25.6 (157.9)	0.001
Non-holiday	17.7 (132.0)	Ref
New Year	30.1 (171.2)	0.118
Spring Festival	20.6 (142.1)	0.528
Qing Ming	32.1 (176.5)	0.047
Labor Day	8.6 (92.2)	0.303
Dragon Boat Festival	22.8 (149.5)	0.416
Mid-Autumn Festival	39.5 (195.2)	0.016
National Day	30.6 (172.4)	0.009
Weekday[b]	16.9 (128.8)	Ref
Weekend	21.2 (144.2)	0.004
Weekday	16.9 (128.8)	Ref
Saturday	21.1 (143.8)	0.031
Sunday	21.3 (144.5)	0.027
Wednesday	17.3 (130.3)	Ref
Thursday	17.0 (129.1)	0.902
Friday	17.6 (131.3)	0.902
Saturday	21.3 (144.4)	0.106
Sunday	21.5 (145.0)	0.049
Monday	15.7 (124.2)	0.435
Tuesday	16.6 (127.6)	0.758

Table entries are rates of in-hospital mortality per 1000 hospital admissions

[a] Sample for holiday and non-holiday comparison includes all eligible patients with a principal diagnosis of acute myocardial infarction in 31 tertiary hospitals in Shanxi, China between 2014 and 2017 ($n = 54{,}968$)

[b] The sample for weekend and weekday comparison is a subsample excluding admissions on New Year, Spring Festival, Qing Ming, Labor Day, Dragon Boat Festival, Mid-Autumn Festival, and National Day ($n = 51{,}569$)

[c] *p*-values were calculated using Fisher exact test

rescue these patients. Patients with AMI are recommended to receive invasive procedures promptly, such as percutaneous coronary intervention and coronary angiography, thus the delay of receiving invasive procedures might affect patient prognosis negatively. Second, as observed by Sun et al. (2019) and Anselmi et al. (2017), patients admitted on weekends and holidays may be sicker than on other days. If patients admitted on weekends and holidays have more severe AMI, it would increase the difficulty of rescue and the risk of mortality.

Despite staffing level and the severity of illness are two commonly cited explanations in previous studies (Bray and Steventon 2017), there is only a few studies that test these explanations with empirical data. Aldridge et al. (2016) conducted a large cross-sectional study of hospitals in England and found that the weekend staffing of hospital specialists was not associated with mortality risk for emergency admissions, although the staffing level was indeed lower on weekends. A recent cross-sectional study from Portugal reported that although the delay in invasive cardiac procedures was significantly higher during weekends, there was no significant correlation between the delay in invasive cardiac procedures and in-hospital mortality (Fiorentino et al. 2018). Jayawardana et al. (2019) investigated the association between the off-hours admissions for primary percutaneous coronary intervention and the mortality for patients with STEMI in England, pointing out that the differences in door-to-balloon time could partially explain the observed “off-hours effects” on hospital mortality. On the other hand, some literature attempted to explain the weekend effect by the difference in the severity of illness between weekend and weekday admissions (Anselmi et al. 2017; Mohammed et al. 2017; Sun et al. 2019; Huang et al. 2019). They argued that patients admitted on weekends are sicker than those admitted on weekdays and more likely to die. Anselmi et al. (2017) used the arrival of ambulance as a marker of severity of illness and found that the impact of weekend admission on in-hospital mortality following emergency admission became insignificant after accounting for the mode of

Table 3 The holiday effects on in-hospital mortality for acute myocardial infarction in Shanxi, China (2014–2017)

Admissions	Unadjusted incremental effects		Adjusted incremental effects	
	(95% confidence interval)[a]		(95% confidence interval)[b]	
	Absolute effect per 1000 admissions	Relative effect	Absolute effect per 1000 admissions	Relative effect
Non-holiday	Ref	Ref	Ref	Ref
Any holiday	7.87 (2.90, 12.84)	1.44 (1.17, 1.72)	4.87 (0.88, 8.86)	1.30 (1.03, 1.56)
Non-holiday	Ref	Ref	Ref	Ref
New year	12.37 (− 5.12, 29.87)	1.70 (0.73, 2.66)	6.50 (− 6.77, 19.78)	1.40 (0.56, 2.24)
Spring festival	2.88 (− 5.20, 11.00)	1.16 (0.69, 1.63)	− 0.39 (− 7.67, 6.89)	0.98 (0.54, 1.41)
Qing Ming	14.36 (− 5.04, 33.77)	1.81 (0.79, 2.83)	8.76 (− 4.12, 21.6)	1.54 (0.71, 2.37)
Labor day	− 9.18 (− 18.45, 0.10)	0.48 (− 0.04, 1.01)	− 8.35 (− 19.40, 2.70)	0.51 (− 0.10, 1.13)
Dragon boat festival	5.07 (− 6.87, 17.01)	1.29 (0.61, 1.96)	2.22 (− 7.24, 11.69)	1.13 (0.55, 1.72)
Mid-autumn festival	21.80 (− 11.96, 55.57)	2.23 (0.27, 4.19)	18.65 (− 10.01, 47.32)	2.19 (0.22, 4.17)
National day	12.90 (2.62, 23.18)	1.73 (1.18, 2.28)	10.28 (0.42, 20.14)	1.64 (1.01, 2.28)

[a] 95% confidence intervals are computed from delta-method standard errors

[b] Adjusted estimates are adjusted for continuous age, gender, insurance, 30 Elixhauser comorbidities, type of acute myocardial infarction, cardiac procedure, hospital volume, whether specialist hospital, year, and city dummies

Table 4 The weekend effects on in-hospital mortality for acute myocardial infarction in Shanxi, China (2014–2017)

Admissions	Unadjusted incremental effects		Adjusted incremental effects	
	(95% confidence interval)[a]		(95% confidence interval)[b]	
	Absolute effect per 1000 admissions	Relative effect	Absolute effect per 1000 admissions	Relative effect
Weekday	Ref	Ref	Ref	Ref
Weekend	4.35 (1.63, 7.07)	1.26 (1.11, 1.41)	2.88 (0.68, 5.08)	1.18 (1.04, 1.32)
Weekday	Ref	Ref	Ref	Ref
Saturday	4.25 (− 0.08, 8.58)	1.25 (1.01, 1.50)	2.14 (− 1.19, 5.46)	1.13 (0.93, 1.34)
Sunday	4.46 (0.75, 8.16)	1.26 (1.04, 1.49)	3.73 (0.29, 7.18)	1.24 (1.02, 1.46)
Wednesday	Ref	Ref	Ref	Ref
Thursday	− 0.34 (− 5.90, 5.23)	0.98 (0.66, 1.30)	0.25 (− 4.88, 5.37)	1.02 (0.76, 1.22)
Friday	0.27 (− 3.95, 4.48)	1.02 (0.77, 1.26)	− 0.68 (− 4.93, 3.57)	0.96 (0.70, 1.21)
Saturday	4.03 (− 0.88, 8.93)	1.23 (0.92, 1.55)	2.27 (− 2.08, 6.62)	1.14 (0.85, 1.43)
Sunday	4.20 (1.02, 7.37)	1.24 (1.02, 1.47)	3.59 (0.34, 6.83)	1.23 (1.01, 1.45)
Monday	− 1.61 (− 5.77, 2.55)	0.91 (0.69, 1.13)	− 0.17 (− 3.88, 3.54)	0.99 (0.76, 1.22)
Tuesday	− 0.73 (− 5.50, 4.04)	0.96 (0.69, 1.22)	− 0.47 (− 5.01, 4.06)	0.97 (0.69, 1.25)

[a] 95% confidence intervals are computed from delta-method standard errors

[b] Adjusted estimates are adjusted for continuous age, gender, insurance, 30 Elixhauser comorbidities, type of acute myocardial infarction, cardiac procedure, hospital volume, whether specialist hospital, year, and city dummies

arrival at hospital. Mohammed et al. (2017) and Sun et al. (2019) chose the National Early Warning Score as the measure of the severity of illness and also found the similar results. In Taiwan, Huang et al. (2019) found that the weekend effect on stroke mortality disappeared after controlling stroke severity and other confounders.

In this study, an unexpected result is that the admission during Spring Festival is not associated with higher in-hospital AMI mortality, which is different from the results of National Day. We consider that there are two possible explanations for this unexpected result. First, the differences in the experience of the staff on duty between the

Table 5 Interaction tests for gender differences in holiday and weekend effects for acute myocardial infarction in Shanxi, China (2014–2017)

Effect	Unadjusted absolute effects per 1000 (95% confidence interval)[a]		
	Females	Males	Difference
Holiday	14.30 (0.13, 28.47)	5.54 (0.69, 10.40)	8.76 (− 6.68, 24.20)
Weekend	3.58 (− 2.55, 9.71)	4.85 (1.24, 8.47)	− 1.28 (− 9.15, 6.60)
Effect	Adjusted absolute effects per 1000 (95% confidence interval)[b]		
	Females	Males	Difference
Holiday	6.85 (− 1.60, 15.31)	3.90 (− 1.33, 9.13)	2.96 (− 7.87, 13.79)
Weekend	1.15 (− 2.21, 4.50)	3.65 (0.40, 6.90)	− 2.50 (− 7.80, 2.80)

[a] 95% confidence intervals are computed from delta-method standard errors

[b] Adjusted estimates are adjusted for continuous age, gender, insurance, 30 Elixhauser comorbidities, type of acute myocardial infarction, cardiac procedure, hospital volume, whether specialist hospital, year, and city dummies

Spring Festival and the National Day may explain such result. In China, most of the new employees, including physicians and nurses, who graduated from medical universities or schools usually join the hospitals and participate in the clinical practice in July every year. Although they are receiving further training in clinical practices, they account for a considerable part of the staff on duty, especially on holidays. The reason is that the senior physicians and nurses who are experienced in clinical practices have higher priority to vacation than these new employees. Until the National Day in October, these new employees have been trained for only 3 months. However, until the Spring Festival (usually in February), they have received the clinical training for about 8 months. Therefore, it is reasonable to believe that the new staff on duty during National Day are less experienced than those on Spring Festival, which may affect patient outcomes. Second, it might be related to the differences in the patterns of discharge and admission between Spring Festival and National Day. Online supplementary Figure S1 shows the changes of AMI patients' discharge and admission during the period of 2 weeks before and after Spring Festival. The shaded area of Figure S1 represents the range of Spring Festival. In 2 weeks before Spring Festival, there is a wave crest of patient discharge, while the number of admissions decreases continuously. As a result, there are less patients who stay in hospitals at the beginning of Spring Festival than non-holidays. This phenomenon could be explained by the culture of Spring Festival. People usually have strong willingness to family reunion in Spring Festival, and thus patients tend to discharge from hospitals and avoid hospitalization before Spring Festival. National Day, however, shows different patterns (Online supplementary Figure S2). The shaded area of Figure S2 represents the range of National Day. The curves of patient discharge and admission are almost flat and close in terms of the case number every day, particularly in 2014 and 2015. Therefore, it is reasonable to believe that the number of patients who stay in hospitals at the beginning of National Day is similar to that of non-holidays. Compared with National Day, physicians and nurses on duty during Spring Festival provide medical services for less patients. Thus, the patients admitted during Spring Festival may receive more attention and appropriate care than those admitted during National Day, which decreases their risk of in-hospital death.

Overall, our study provides empirical evidence to support the existence of the "holiday effect" and "weekend effect" on in-hospital mortality and elucidate the impacts of Sunday admission and National Day admission on in-hospital mortality following AMI in China. Our results highlight the need for improving health care delivery system to provide consistent quality of care for patients admitted for AMI.

This study has several technical limitations inherent in the study dataset. First, this study only covered AMI patients in tertiary hospitals in Shanxi, and it might not be generalizable to other populations in terms of hospital levels, disease diagnoses and geography. Second, the data unavailability and the observational nature of this study restricted us to determine the cause of the excess in-hospital mortality, therefore, it is difficult to establish a causal inference for our findings. Third, our study was conducted using the administrative database from Health Commission of Shanxi, China. Given that the administrative database is not designed and built for researching, there are concerns regarding the quality of data and the lack of clinical data (Fedeli et al. 2017). We were unable to measure illness severity as this information was unavailable in the administrative database, thus the inadequate adjustment for disease severity may bias our findings. However, with the available data, we used the Elixhauser comorbidities to capture the complexity of illness, and this may reduce the potential bias to some extent. Fourth, this study only considered in-hospital mortality which is not a particularly sensitive measure of quality. Further research should turn their attention to other important patient-centered outcomes such as patient satisfaction, functional outcomes and long-term outcomes. Lastly, the administrative database we used in this study provided the specific day but not the hour of admission, which does not allow us to further determine the "night-time effects" on patients' outcomes.

Conclusion

This study revealed that both weekend and holiday admissions for AMI were significantly associated with higher in-hospital mortality in the tertiary hospitals in Shanxi, China. The admissions on Chinese National Day and Sunday contributed to the observed "holiday effect" and "weekend effect," respectively. Further investigation is urgently needed to evaluate the causal mechanisms of the "weekend effect" and the "holiday effect" on patient outcomes. It is imperative to improve the health care delivery system to provide consistent quality of care for patients admitted for AMI.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional research committee (the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology, IORG No.: IORG0003571) and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent The requirement for informed consent for this study was exempted because all patient data were de identified.

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