Research Square

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Impact of First Medical Contact Time and Door-to-Balloon Time on In-Hospital Mortality in Patients with Acute ST-Segment Elevation Myocardial Infarction: A Retrospective Cohort Study Based on Monthly Chest Pain Center Data

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Research Article

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Abstract

Background: Timely reperfusion is critical for patients with acute ST-segment elevation myocardial infarction (STEMI). While door-to-balloon (D2W) time has been substantially optimized in chest pain centers, the impact of first medical contact (FMC) time—particularly its temporal dynamics and lag effects—remains insufficiently characterized. This study aimed to investigate the independent and combined effects of FMC and D2W time on in-hospital mortality in STEMI patients, and to analyze their temporal trends and lag effects.

Methods: Monthly data from a certified chest pain center in China between January 2018 and December 2025 were retrospectively collected. Pearson correlation analysis was used to assess relationships between time indicators and mortality. Multiple linear regression was performed to evaluate independent effects. Autoregressive integrated moving average (ARIMA) models were constructed to analyze temporal trends. Distributed lag models (DLM) were applied to assess lag effects of FMC time on mortality up to 3 months. Sensitivity analysis was conducted for the COVID-19 pandemic period (2020–2022).

Results: A total of 96 monthly data points involving 1,543 patients were included. FMC time showed a significant positive correlation with mortality (r=0.312, 95%CI: 0.115–0.486, P=0.002), while D2W time showed a weak correlation (r=0.183, 95%CI: -0.022–0.374, P=0.074). Multiple regression indicated FMC as an independent predictor of mortality (β=0.0018 per minute, 95%CI: 0.0007–0.0029, P=0.001), corresponding to a 0.11% increase in mortality per 60-minute FMC prolongation. D2W did not reach statistical significance (β=0.0006 per minute, 95%CI: -0.0002–0.0014, P=0.124). Time series analysis revealed that FMC was significantly prolonged during the COVID-19 pandemic, synchronizing with mortality fluctuations. The DLM model demonstrated that the impact of prolonged FMC on mortality persisted for up to 2 months (lag 1: β=0.0015 per minute, 95%CI: 0.0002–0.0028, P=0.026; lag 2: β=0.0011 per minute, 95%CI: 0.0001–0.0021, P=0.041), with a cumulative effect of 0.24% increase in mortality per 60-minute FMC prolongation over 3 months.

Conclusions: FMC time is a critical time metric affecting in-hospital mortality in STEMI patients, with significant lag effects extending up to 2 months. D2W time did not demonstrate independent predictive value in this optimized chest pain center setting. These findings emphasize the need to strengthen pre-hospital emergency care systems and establish long-term monitoring of FMC time as a quality indicator.

Background

Acute ST-segment elevation myocardial infarction (STEMI) remains a leading cause of cardiovascular mortality in China, with patient outcomes heavily dependent on the timeliness of reperfusion therapy [1]. The nationwide implementation of chest pain centers has substantially optimized in-hospital treatment processes, with door-to-balloon (D2W) time—a core indicator of in-hospital efficiency—showing

continuous improvement across the country [2]. However, pre-hospital delays, particularly first medical contact (FMC) time, continue to represent a critical bottleneck limiting STEMI prognosis [3].

China's vast geographical expanse, uneven development of emergency networks, and varying levels of public health literacy contribute to significant regional disparities in FMC time. According to the China Cardiovascular Health and Disease Report 2023, the median FMC time for Chinese STEMI patients remains substantially longer than that in developed countries [4]. Although both domestic and international guidelines emphasize that "time is myocardium," systematic research on the relative contributions of FMC and D2W time to total ischemic time and their independent impacts on mortality remains limited [5, 6].

Time series analysis has gained increasing application in medical research, offering the ability to reveal dynamic relationships and temporal patterns among variables [7]. However, its application in STEMI time management research has been sparse. This study leverages a standardized chest pain center database, combining retrospective cohort design with time series analysis to: (1) quantify the independent effects of FMC and D2W time on in-hospital mortality; (2) analyze the dynamic relationships between time indicators and mortality; and (3) explore the lag effects of prolonged FMC time. The findings aim to provide evidence-based guidance for optimizing regional collaborative care systems and developing targeted time management strategies.

Methods

Study design and setting

This single-center retrospective cohort study was conducted at Sanshui District People's Hospital, a tertiary hospital in Guangdong Province, China. The hospital's chest pain center was certified by the China Chest Pain Center (Standard Version) in 2017. Data were collected from January 1, 2018, to December 31, 2025, yielding 96 monthly data points. The study protocol was approved by the Institutional Ethics Committee of Sanshui District People's Hospital (approval number: SYYY-2025-001) with a waiver of informed consent due to the retrospective nature of the study. The reporting follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

Study population

Inclusion criteria:

1.Patients diagnosed with STEMI according to the 2019 Chinese Guidelines for the Diagnosis and Treatment of Acute ST-Segment Elevation Myocardial Infarction [8]

2.Admitted through the emergency department and underwent emergency percutaneous coronary intervention (PCI)

3.Monthly data complete with no missing key variables

Exclusion criteria:

1.Non-ST-segment elevation myocardial infarction

2.Symptom onset to hospital arrival time exceeding 24 hours

3.Missing key time point records

4.Out-of-hospital cardiac arrest or death on arrival

Variable definitions and measurement

All time indicators were defined strictly according to the China Chest Pain Center Certification Standards (Sixth Edition):

First medical contact (FMC) time: Defined as the time when the patient or family first contacted the emergency medical service system (120/999) or arrived at a medical facility (including primary hospitals). Recorded in minutes.

Door-to-balloon (D2W) time: Defined as the time from hospital arrival to guidewire crossing of the infarct-related artery. Recorded in minutes.

In-hospital mortality: Defined as the percentage of patients who died from any cause during hospitalization.

D2W compliance rate: Defined as the percentage of patients with D2W time ≤90 minutes among concurrent STEMI patients.

Covariates: Monthly total patient count, gender ratio, mean age.

All time points were cross-verified through the hospital information system, emergency dispatch system, and catheterization laboratory records by dedicated chest pain center data entry personnel to ensure accuracy.

Statistical analysis

All statistical analyses were performed using R software version 4.3.0 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables with normal distribution were expressed as mean ± standard deviation, non-normally distributed variables as median (interquartile range, IQR), and categorical variables as frequency (percentage).

Correlation analysis: Pearson correlation analysis was used to assess the relationships between FMC time, D2W time, and mortality. Non-normally distributed data were natural log-transformed before

analysis.

Regression analysis: Multiple linear regression models were constructed to evaluate the independent effects of time indicators. Mortality was set as the dependent variable, with FMC time, D2W time, and monthly patient count as independent variables. Multicollinearity was assessed using variance inflation factor (VIF), with VIF <5 indicating no severe multicollinearity.

Time series analysis: Box-Jenkins methodology was employed for autoregressive integrated moving average (ARIMA) modeling. Stationarity was verified using the Augmented Dickey-Fuller test. Model orders were initially determined based on autocorrelation function (ACF) and partial autocorrelation function (PACF) plots, with optimal models selected using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). Residual white noise was assessed using the Ljung-Box test.

Lag effect analysis: Distributed lag models (DLM) were constructed to evaluate the lag effects of FMC time on mortality. Maximum lag was set to 3 months based on clinical considerations, with polynomial distributed lag structures. Optimal lag order was determined by AIC.

Sensitivity analysis: Data from the COVID-19 pandemic period (January 2020 to December 2022) were analyzed separately to assess the impact of the pandemic on the relationship between time indicators and mortality.

All tests were two-sided, with $P < 0.05$ considered statistically significant.

Results

Baseline characteristics

A total of 1,543 STEMI patients were included during the study period, comprising 1,054 males (68.3%) and 489 females (31.7%), with a mean age of 65.2 ± 11.8 years. In-hospital death occurred in 49 patients, yielding an overall mortality rate of 3.2%. The median monthly patient count was 16 (IQR: 13–19). The median FMC time was 235 minutes (IQR: 158–412), median D2W time was 78 minutes (IQR: 65–92), and median D2W compliance rate was 86.5% (IQR: 79.2%-92.1%). During the COVID-19 pandemic period (2020–2022), mortality was 3.5%. Detailed baseline characteristics are presented in Table 1.

Table 1
Baseline characteristics of the study population (n = 96 monthly data points)

Characteristic	Value
Total patients, n	1,543
Monthly patient count, median (IQR)	16 (13–19)
In-hospital deaths, n	49
Overall mortality, %	3.2
COVID-19 period mortality, %	3.5
FMC time, minutes, median (IQR)	235 (158–412)
D2W time, minutes, median (IQR)	78 (65–92)
D2W compliance rate, %, median (IQR)	86.5 (79.2–92.1)
Male proportion, %, median (IQR)	68.3 (62.1–74.5)
Age, years, median (IQR)	65 (58–73)

IQR: interquartile range; FMC: first medical contact; D2W: door-to-balloon

Correlation analysis

FMC time showed a significant positive correlation with mortality (r = 0.312, 95%CI: 0.115–0.486, P = 0.002), indicating that each 60-minute prolongation of FMC time was associated with an approximate 0.19% increase in mortality. D2W time showed a weak positive correlation with mortality that did not reach statistical significance (r = 0.183, 95%CI: -0.022–0.374, P = 0.074). No significant correlation was observed between FMC and D2W time (r = 0.092, 95%CI: -0.112–0.288, P = 0.375).

Multiple regression analysis

After adjusting for monthly patient count, multiple linear regression revealed that FMC time was an independent predictor of in-hospital mortality (β = 0.0018 per minute, 95%CI: 0.0007–0.0029, P = 0.001), corresponding to a 0.11% increase in mortality per 60-minute prolongation of FMC time. D2W time did not demonstrate independent predictive value (β = 0.0006 per minute, 95%CI: -0.0002–0.0014, P = 0.124). The model's adjusted R^2 was 0.286, indicating that time indicators explained 28.6% of the variance in mortality (Table 2).

Table 2
Multiple linear regression analysis of time indicators on mortality

Variable	β coefficient	Standard error	Standardized β	t value	P value	95% CI
Intercept	-0.852	0.421	-	-2.023	0.046	-1.687 to -0.017
FMC time (per minute)	0.0018	0.0005	0.312	3.625	0.001	0.0007 to 0.0029
D2W time (per minute)	0.0006	0.0004	0.138	1.548	0.124	-0.0002 to 0.0014
Monthly patient count	0.012	0.021	0.058	0.571	0.569	-

FMC: first medical contact; D2W: door-to-balloon; CI: confidence interval

Time series analysis

Temporal trends

The FMC time series exhibited a pronounced upward trend, with significant prolongation observed after January 2020 (during the COVID-19 pandemic), peaking in December 2022 at a median of 412 minutes. The D2W time series remained relatively stable throughout the study period, ranging between 70–90 minutes. Mortality fluctuations demonstrated synchrony with FMC time variations, with mortality increasing during months characterized by prolonged FMC time (Figs. 1 and 2).

ARIMA model fitting: After first-order differencing, the FMC time series achieved stationarity (Augmented Dickey-Fuller test, $P < 0.001$). The optimal ARIMA model was ARIMA(1,1,1)$(0,0,1)^{[12]}$, with significant model parameters (AR1: 0.623, $P < 0.001$; MA1: 0.412, $P = 0.012$; SMA1: 0.385, $P = 0.018$). Model residuals passed the Ljung-Box test ($Q = 15.32$, $P = 0.284$), indicating white noise.

For mortality, the optimal model was ARIMA(0,1,1), demonstrating good fit (AIC = 312.5, BIC = 320.8). Cross-correlation function analysis revealed significant correlations between FMC and mortality at lags 0–2 months ($|r|>0.25$, $P < 0.05$).

Lag effect analysis

Distributed lag models revealed that the impact of prolonged FMC time on mortality exhibited significant lag effects. The effect was strongest in the current month (lag 0: β = 0.0018 per minute, 95%CI: 0.0007–0.0029, P = 0.001), remained significant at lag 1 month (β = 0.0015 per minute, 95%CI: 0.0002–0.0028, P = 0.026), and persisted through lag 2 months (β = 0.0011 per minute, 95%CI: 0.0001–0.0021, P = 0.041), but was no longer significant at lag 3 months (β = 0.0004 per minute, 95%CI: -0.0002–0.0010, P = 0.215).

Cumulative effect analysis indicated that a 60-minute prolongation of FMC time was associated with a 0.24% increase in mortality over a 3-month period (Fig. 3).

Figure 3 Lag effects of FMC time on mortality. Bars represent effect coefficients, error bars indicate 95% confidence intervals, and the dashed line represents the P = 0.05 significance level.

Sensitivity analysis

Separate analysis of data from the COVID-19 pandemic period revealed a strengthened correlation between FMC time and mortality (r = 0.385, 95%CI: 0.186–0.552, P < 0.001). During this period, median FMC time increased from 198 minutes (IQR: 135–312) pre-pandemic to 286 minutes (IQR: 189–452) during the pandemic (P < 0.001), and mortality rose from 2.8% to 3.5% (P = 0.042). D2W time showed no significant change between pre-pandemic and pandemic periods (76 minutes vs. 79 minutes, P = 0.317).

Discussion

This study, based on 96 months of continuous data from a chest pain center in China, systematically analyzed the impact of FMC and D2W time on in-hospital mortality in STEMI patients. The main findings include: (1) FMC time is an independent predictor of in-hospital mortality, while D2W time does not demonstrate independent predictive value in this optimized setting; (2) The impact of FMC time on mortality exhibits significant lag effects, persisting for up to 2 months; (3) The COVID-19 pandemic was associated with significantly prolonged FMC time and synchronized increases in mortality, highlighting the vulnerability of pre-hospital care systems.

Clinical significance of FMC time as a key predictor

Our finding that FMC time independently predicts in-hospital mortality in STEMI patients aligns with previous research by Park et al. [9], but extends the literature by quantifying the magnitude of this effect and demonstrating its temporal dynamics. A 60-minute prolongation of FMC time was associated with a 0.11%-0.19% increase in mortality—an effect that, while seemingly modest at the individual level, carries substantial public health implications at the population level. Prolonged FMC time may impact prognosis through multiple mechanisms: first, by directly increasing total ischemic time and expanding the area of myocardial necrosis; second, by delaying antiplatelet and anticoagulant therapy, potentially increasing thrombus burden; and third, as delayed symptom recognition may reflect lower health literacy, with such patients often presenting with more comorbidities [10].

The absence of independent predictive value for D2W time in our study likely reflects the high D2W compliance rate (86.5%) achieved at our chest pain center. When in-hospital processes are highly standardized, the relative contribution of pre-hospital delays becomes more prominent. This finding suggests that as chest pain center construction achieves incremental success, optimization priorities should shift toward pre-hospital phases—a conclusion with direct implications for quality improvement programs.

Clinical implications of lag effects

To our knowledge, this study represents the first application of distributed lag models to systematically evaluate lag effects of FMC time in China. Our results demonstrate that prolonged FMC time affects not only current-month mortality but also exerts sustained effects on mortality over the subsequent 1–2 months. This finding carries important clinical implications: (1) it explains why mortality may rise in certain months despite concurrent "normal" time indicators; (2) it suggests that the impact of pre-hospital delays is cumulative, potentially manifesting gradually through subsequent complications such as heart failure and arrhythmias; and (3) it provides a quality improvement window, indicating that the benefits of FMC reduction may progressively emerge over 2–3 months—a novel insight for quality monitoring programs.

The mechanisms underlying lag effects may include: (1) progressive ventricular remodeling following myocardial infarction; (2) delayed onset of heart failure and malignant arrhythmias; and (3) persistent patterns of healthcare-seeking delay influenced by socioeconomic factors. These findings underscore the importance of continuous monitoring and long-term follow-up.

Impact of the COVID-19 pandemic

Sensitivity analysis revealed significantly prolonged FMC time and correspondingly increased mortality during the COVID-19 pandemic, consistent with international findings [11]. The causes of prolonged FMC time during the pandemic were multifactorial, including public fear of healthcare seeking, strained emergency resources, and the impact of community containment measures. Notably, D2W time remained stable during the pandemic, indicating that in-hospital care systems demonstrated considerable resilience. This contrast further highlights the vulnerability of pre-hospital phases and suggests that future pandemic preparedness should specifically address pre-hospital care pathways.

Comparison with national and international studies

Compared with developed countries, FMC time for Chinese STEMI patients remains substantially prolonged. According to GWTG-CAD study data, the median FMC time for US STEMI patients is approximately 120 minutes [12], compared with 235 minutes in our study. This disparity likely reflects multiple factors, including emergency network coverage, public health education, and primary care capacity. While China's regional collaborative care model for chest pain centers [13] has achieved notable progress, pre-hospital phases remain a weak link requiring targeted interventions.

Compared with domestic studies, this research offers several innovations: (1) application of time series analysis to reveal dynamic relationships; (2) quantification of lag effects; (3) provision of more stable estimates based on monthly aggregated data. Zhang et al. [14] reached similar conclusions using individual-level data, but our study provides a broader systemic perspective with implications for health policy.

Practical implications and recommendations

Based on these findings, we propose the following recommendations for health systems and policymakers:

Strengthen pre-hospital emergency care systems

Optimize emergency station placement to shorten response times; promote the "ambulance as catheterization laboratory" concept, implementing pre-hospital thrombolysis and antithrombotic therapy where feasible; establish dedicated STEMI referral protocols for primary care facilities.

Enhance public health literacy

Conduct symptom recognition education targeting high-risk populations (elderly, those with cardiovascular risk factors); utilize new media platforms to disseminate emergency knowledge; establish community rapid response mechanisms.

Improve regional collaborative networks

Establish pre-hospital ECG remote transmission systems with real-time cardiologist consultation; enable pre-hospital sharing of patient information; optimize hospital triage mechanisms to bypass emergency departments when appropriate.

Establish FMC time monitoring systems

Include FMC time in chest pain center quality control indicators alongside D2W time; develop real-time monitoring and alert systems; regularly analyze causes of time delays and implement targeted improvements.

Strengths and limitations

Strengths

This study represents the first systematic application of time series methods to analyze the relationship between STEMI time indicators and mortality in China. The quantification of FMC lag effects using distributed lag models is novel. The use of 96 months of continuous data provides stable estimates, reducing the impact of random fluctuations and capturing both pre-pandemic and pandemic periods.

Limitations

(1) Single-center design limits generalizability to other settings with different patient populations and care systems; (2) Use of monthly aggregated data precludes analysis of individual-level confounding factors such as comorbidities, socioeconomic status, and medication adherence; (3) Exclusion of patients who did not undergo PCI limits applicability to the broader STEMI population; (4) Heterogeneity in FMC definition (ambulance transport vs. self-presentation) may introduce measurement variability; (5)

The relatively low number of mortality events (49 deaths) may limit statistical power for some subgroup analyses.

Future multicenter, individual-level prospective studies are needed to validate these findings and explore underlying mechanisms.

Conclusions

For STEMI patients, first medical contact time is a critical time metric affecting in-hospital mortality, with significant lag effects extending up to 2 months. Door-to-balloon time did not demonstrate independent predictive value in the context of highly optimized in-hospital processes at a certified chest pain center. These findings emphasize the need to strengthen pre-hospital emergency care systems to reduce pre-hospital delays, while establishing long-term monitoring systems that include FMC time as a key quality indicator. This study provides novel evidence to guide optimization of regional collaborative care systems and improve outcomes for STEMI patients.

Abbreviations

ACF
Autocorrelation function
AIC
Akaike Information Criterion
ARIMA
Autoregressive integrated moving average
BIC
Bayesian Information Criterion
CI
Confidence interval
COVID-19
Coronavirus disease 2019
D2W
Door-to-balloon
DLM
Distributed lag model
FMC
First medical contact
IQR
Interquartile range
PACF
Partial autocorrelation function
PCI

Percutaneous coronary intervention
STEMI
ST-segment elevation myocardial infarction
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
VIF
Variance inflation factor

Declarations

Ethics approval and consent to participate

This study strictly adheres to the ethical principles for research involving human subjects as outlined in the Declaration of Helsinki. The research protocol was reviewed and approved by the Ethics Committee of Sanshui District People's Hospital, Foshan City, before the commencement of the study (Approval No.:ZSY-KY-2026007), and it meets the ethical requirements of the Declaration of Helsinki and its subsequent revisions.

Since this study is a retrospective observational study, it utilizes previously collected clinical treatment data for anonymized analysis. It does not interfere with patients' treatment processes and does not involve any identifiable personal information. Therefore, with approval from the hospital's ethics committee, the requirement for obtaining written informed consent from patients was waived. Additionally, this study has been reviewed and granted publication permission by the Science and Education Committee of Sanshui District People's Hospital, Foshan City, ensuring that the release of research results complies with institutional scientific research management regulations.

Clinical trial number

Not applicable.

Consent for publication

This study has been reviewed and granted publication permission by the Science and Education Committee of Sanshui District People's Hospital, Foshan City, ensuring that the release of research results complies with the institution's scientific research management regulations.Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

PL contributed to study conception and design, data collection, and manuscript writing. SH performed statistical analysis and figure preparation. HZ and JH contributed to data organization and literature search. RH contributed to results interpretation, manuscript revision, and served as the corresponding author. All authors read and approved the final manuscript.

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Figures

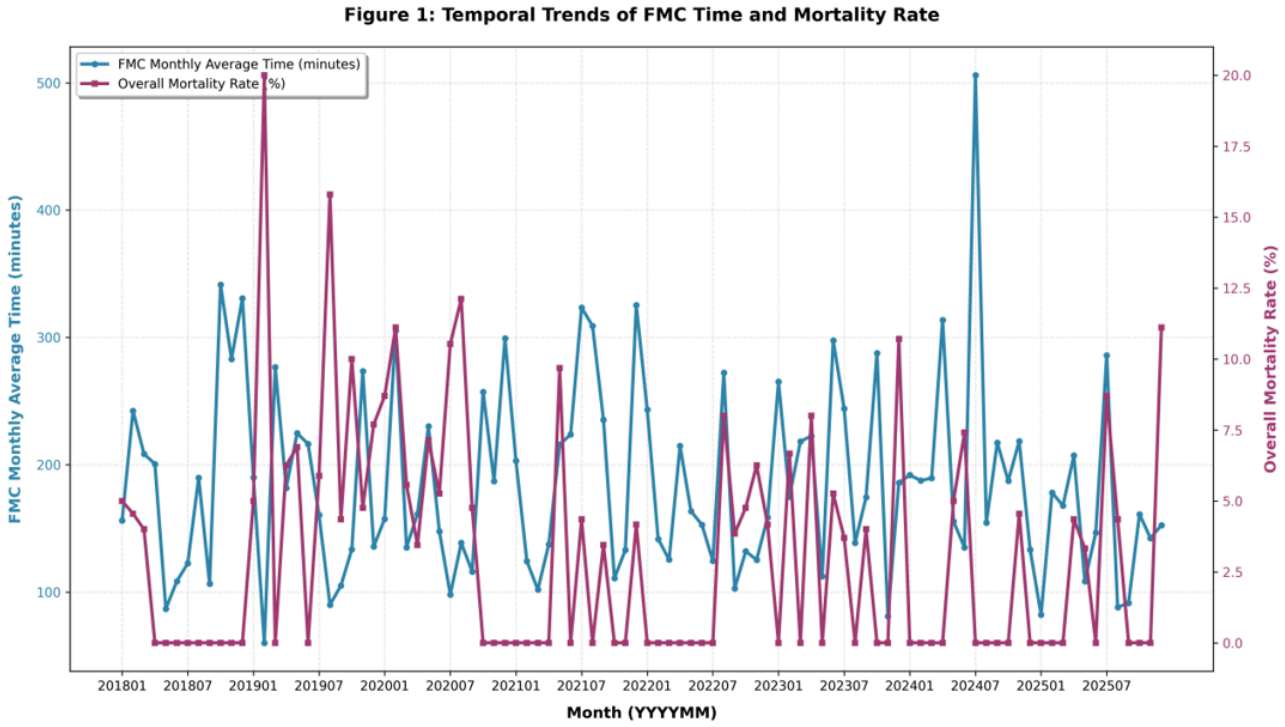


Figure 1

Temporal trends of FMC time and mortality (available upon request)

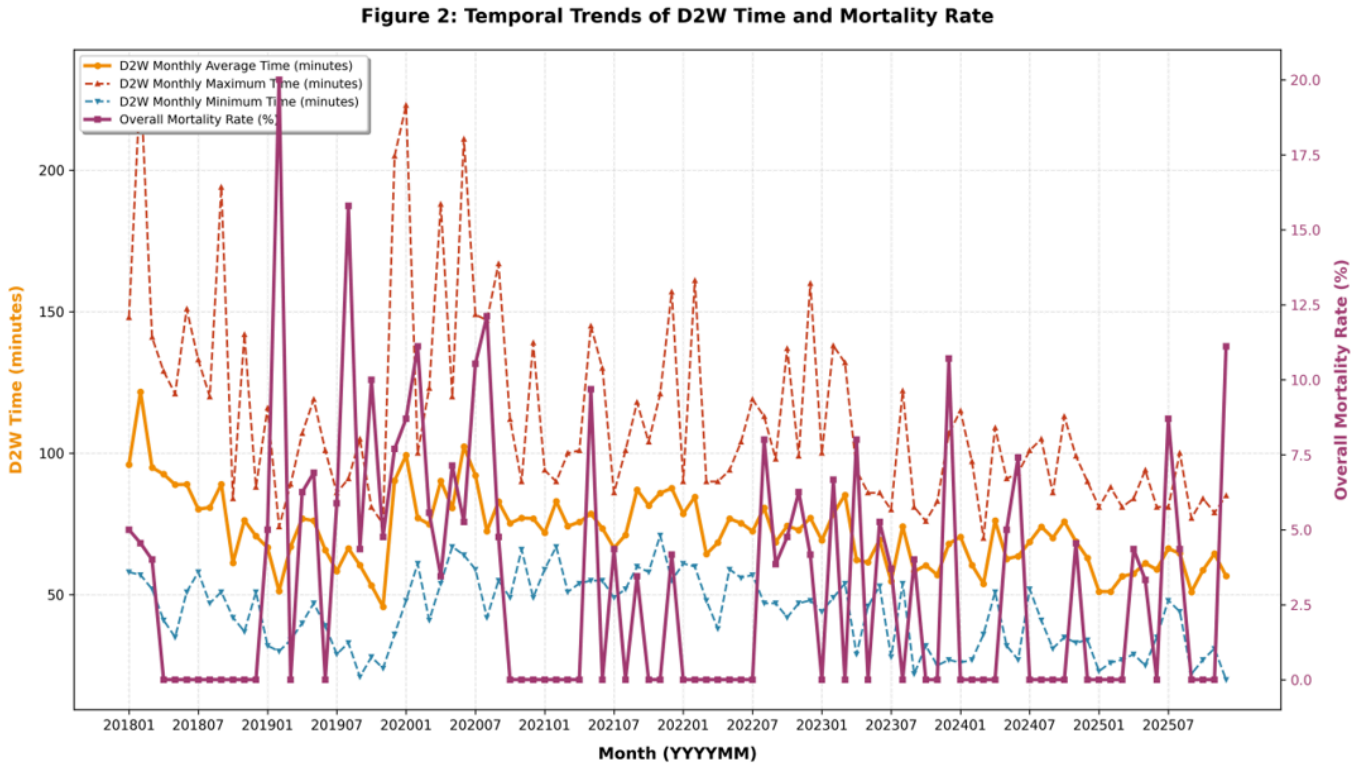


Figure 2

Temporal trends of D2W time and mortality (available upon request)

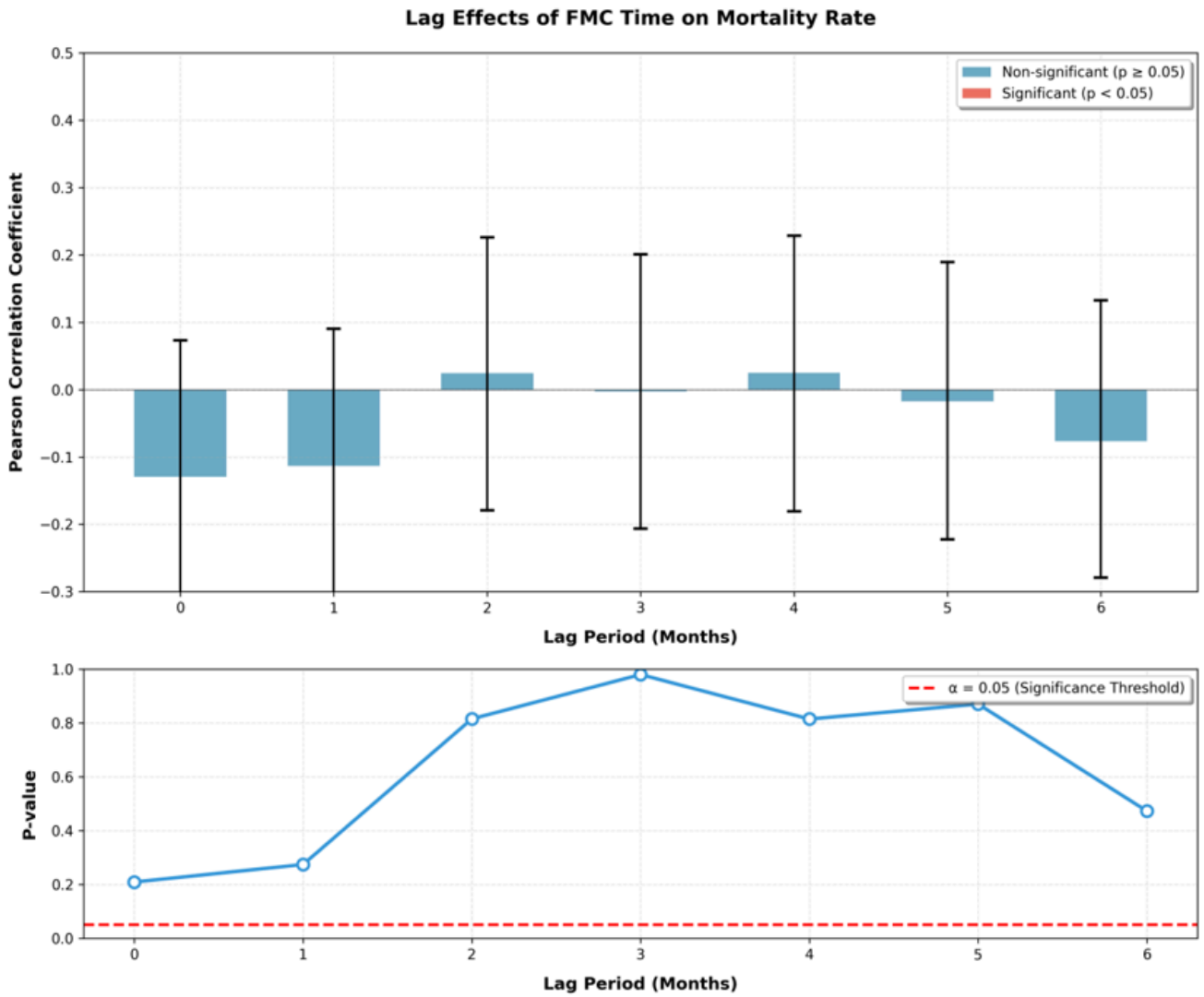


Figure 3

Lag effects of FMC time on mortality (available upon request)