Original Article

COVID-19 and Acute Myocardial Infarction: Exploring Clinical Factors and Treatment Expenditures

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Abstract

Background: *The concurrence of acute myocardial infarction (AMI) with COVID-19 can complicate the clinical conditions of patients and affect the patterns of hospital resource utilization. This study aimed to investigate and analyze the direct treatment costs of AMI patients with concurrent COVID-19.*

Methods: *This cross-sectional study collected and analyzed clinical data, including symptoms, readmission, and interventions, and treatment cost data for all patients at Tehran Heart Center using SPSS26 software. The mean medical costs of patients from January through May 2022 were also calculated.*

Results: *The COVID-19 group was composed of 72.9% male and 27.1% female patients, whereas the non-COVID-19 group consisted of 67.3% male and 32.7% female patients. Most of the patients in the COVID-19 group (60%) were in the elderly age group (>65 y). The length of stay was 8.70±5.84 days for the COVID-19 group and 6.31±4.42 days for the non-COVID-19 group. The mortality rate in the COVID-19 group was 24%, higher than the 5% rate in the other group. Additionally, the average total treatment costs were $6384.54±$6760.13 in the COVID-19 group and $6362.49±$4343.07 in the non-COVID-19 group (P>0.78 and P>0.050).*

Conclusion: *The study found that the COVID-19 group had a significantly higher in-hospital mortality rate than the non-COVID-19 group. During the follow-up period, the incidence of complications (chest pain and heart failure) was higher in the non-COVID-19 group. It also showed that longer hospital stays resulted in higher treatment costs.*

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Keywords: *Myocardial infarction; COVID-19; Costs and cost analysis; Mortality; COVID-19 epidemiology*

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Introduction

Since the outbreak of the COVID-19 pandemic worldwide, there has been a surge in demand for medical care and greater pressure on health and medical systems.[1] The pandemic has caused many formidable challenges in providing medical services in various dimensions.[2] A meta-analysis study showed that high blood pressure, diabetes, chronic obstructive respiratory disease, cardiovascular disease (CVD), and cerebrovascular disease were among the most significant risk factors in patients with COVID-19.[3] Several primary data analyses have also demonstrated that patients with CVD are among those most affected by COVID-19, a serious concern from a public health perspective. Given the global prevalence of CVD, the effects of global pandemics can have irreversible consequences for these patients.[4,5]

Acute myocardial infarction (AMI) is caused by the complete blockage of a coronary artery, leading to a sudden lack of blood supply and oxygen to the heart muscle. COVID-19 infection is more prevalent in patients with cardiovascular illnesses, such as AMI, with this group of patients being more likely to develop severe symptoms.[6]

Before the spread of COVID-19, CVD, including AMI, was considered one of the most significant epidemics in many countries, particularly in developing nations, with the resultant healthcare costs. Overall, 38 million deaths occur worldwide due to non-communicable diseases, such as CVD, diabetes, chronic respiratory diseases, and cancer. Nonetheless, during crises and epidemics of infectious diseases, cardiovascular patients face increased challenges, and their management becomes more complex.[7]

According to the World Bank report, the COVID-19 pandemic will lead to a reduction of (2.50%–4.57%) in global exports and a decrease of (−2.09% to −3.86%) in the world economy. The International Monetary Fund (IMF) also forecasted that the world economy would shrink by about 3% due to the COVID-19 pandemic, surpassing the impact of the 2008–2009 financial crisis.[8] Additionally, the COVID-19 pandemic has imposed a significant economic burden on patients and the general population.[9] A related study indicated that treatment costs for COVID-19 patients were significantly higher than those for other infectious diseases, likely attributable to the increased likelihood of hospitalization and mortality associated with COVID-19.[10] The coexistence of 2 costly diseases in patients can substantially impact their medical expenses. Therefore, investigating the cost aspects associated with the COVID-19 pandemic in patients with chronic medical conditions, such as AMI, is essential.

Understanding and synthesizing relevant data can provide policymakers with valuable insights into the overall treatment costs of COVID-19. Consequently, the primary objective of this study was to examine and analyze the direct treatment costs of AMI patients with COVID-19.

Methods

The present study was based on data collected from AMI patients with COVID-19 treated between January and May 2022 at Tehran Heart Center (THC), affiliated with Tehran University of Medical Sciences. The research was conducted ethically and under the supervision of the Ethics Committee of Iran University of Medical Sciences (ID: IR.IUMS.REC.1399.860).

The consecutive sampling method was employed for this study. Consecutive sampling is a non-probability sampling technique where participants are selected based on their availability or specific criteria sequentially. This method sequentially recruits individuals who fulfill the researcher's requirements. Research suggests that consecutive sampling exhibits less bias than convenience sampling, making it a suitable choice for certain research contexts.[11,12]

Our research population consisted of all 100 AMI patients with COVID-19, designated as the COVID-19 group, who were consecutively admitted between January and May 2022. Four patients were excluded from the study based on the exclusion criteria, including early discharge or transfer to another hospital. To enhance the study's validity, the non-COVID-19 group included twice the number of AMI patients as the COVID-19 group. The non-COVID-19 group was matched with the COVID-19 group based on age, sex, and clinical conditions to minimize confounding factors in the study. Demographic and clinical information, such as age, sex, risk factors, and diagnostic and therapeutic measures, were extracted from the Hospital Information System (HIS) for analysis. For the evaluation of the impact of COVID-19 on the treatment costs of AMI patients, the study population was assigned to 2 groups: patients with AMI alone (the non-COVID-19 group) and patients with both AMI and COVID-19 (the COVID-19 group). Medical costs were extracted for both groups, considering all short- and medium-term complications. Descriptive statistics methods were employed to analyze and report the cost-related aspects of medical services and care. The average total treatment costs for each patient were determined by summing up the average inpatient costs (including hospitalization and follow-up) within each category.

Categorical variables were presented as absolute (numbers) and relative (percentages) figures, while continuous variables were presented as mean and standard deviation (mean±SD). Moreover, the direct treatment costs were calculated based on purchasing power parity (PPP) in 2020, adjusted to an equivalent of 42,000 Rials per 1 dollar ($).[13]

Total treatment cost per patient = (the mean cost of visit) + (the mean cost of nursing services) + (the mean cost of diagnostic services) + (the mean cost of laboratory) + (the mean cost of interventions) + (the mean cost of drug and tools) + (the mean cost of ICU beds)

For the comparison of the 2 study groups and evaluation of the impact of COVID-19 on the costs of AMI patients, the data were collected and entered into SPSS 26 statistical software. The Kolmogorov-Smirnov test was utilized to determine the normality of the data distribution. Depending on the data distribution, either a *t*-test for normal distribution or its non-parametric equivalent, the Mann-Whitney *U* test, was used for analysis.

Results

Data collection was conducted from January through May 2022. A total of 295 patients referred to THC were included in the study, with 96 patients having both AMI and COVID-19 registered as the case group, and the remaining 199 patients with AMI alone regarded as the control group.

The COVID-19 group consisted of 72.9% male and 27.1% female patients, while the non-COVID-19 group had 67.3% male and 32.7% female patients. In the COVID-19 group, 60.4% of patients were over 65 years old, compared with 42.2% in the non-COVID-19 group. The mean age was 67.52±1.32 years in the COVID-19 group and 62.82±1.42 years in the non-COVID-19 group (Table 1). The majority of AMI patients in the study had ST-elevation myocardial infarction (STEMI), accounting for 60.4% in the COVID-19 group and 62.8% in the non-COVID-19 group. The most common symptoms associated with COVID-19 in patients were dyspnea (68.8%), cough (10.4%), and fever (15.6%). Both study groups experienced chest pain, with a prevalence of 97.9% in the COVID-19 group and 97% in the non-COVID-19 group. The medical history of CVD, diabetes, and high blood pressure was among the most significant chronic conditions observed in the studied patients (Figure 1). In both groups, the highest prevalence was found in the medical history of diabetes, accounting for 37.5% in the COVID-19 group and 43.2% in the non-COVID-19 group.

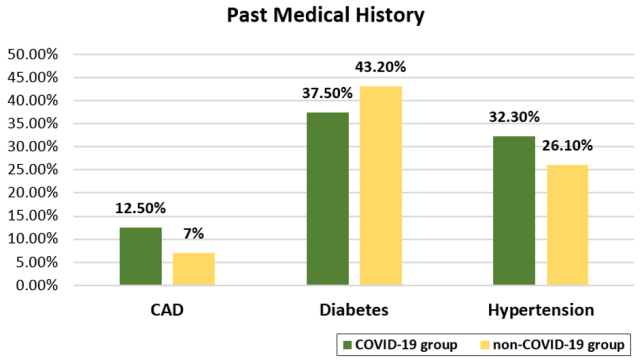

Figure 1. The image presents the past medical history of the study groups (COVID-19 and non-COVID-19).

The length of hospital stay (LOS) was 8.70±5.84 days in the COVID-19 group and 6.31±4.42 days in the non-COVID-19 group. The study also evaluated readmission within 31 days after the initial discharge. In the COVID-19 group, 10.4% of patients experienced readmission, compared with 5% in the non-COVID-19 group. Among COVID-19 patients, 11.5% required intubation during their hospitalization due to the severity of the disease. Regarding mortality, the rates were 24% and 5% for the COVID-19 and non-COVID-19 groups, respectively (Table 2).

Patients were followed up for 1 year. In the COVID-19 group, 53.4% of patients required hospital referral again, with 25.6% admitted as inpatients and 74.4% treated as outpatients, whereas in the non-COVID-19 group, 32.8% of patients were readmitted (P=0.004 and P<0.050, respectively). The most significant complications observed

Table 1. Demographic characteristics of the studied patients (N=295)*

Variable	COVID-19 Group	Non-COVID-19 Group
Sex		
Male	70 (72.9)	134 (67.3)
Female	26 (27.1)	65 (32.7)
Age (y)		
20-39	2 (2.1)	6 (3)
40-65	36 (37.5)	109 (54.)
> 65	58 (60.4)	84 (42.2)
Mean±SD	67.52±1.32	62.82±1.42
Type of Basic Insurance		
Iranian Health Insurance	53 (55.2)	92 (46.2)
Social Security Insurance	36 (37.5)	87 (43.7)
No insurance	1 (1.1)	7 (3.5)
Other kinds of insurance	6 (6.2)	13 (6.5)

*Data are presented as mean±SD or n (%).

Table 2. Clinical characteristics of the studied patients (N=295)*

Characteristic	COVID-19 Group	Non-COVID-19 Group
Types of AMI		
STEMI	58 (60.4)	125 (62.8)
NSTEMI	38 (39.6)	74 (37.2)
Symptoms		
Chest pain	94 (97.9)	193 (97.0)
Fever	15 (15.6)	0
Cough	10 (10.4)	0
Dyspnea	66 (68.8)	36 (18.1)
Past Medical History		
CAD	12 (12.5)	14 (7.0)
Diabetes	36 (37.5)	86 (43.2)
Hypertension	31 (32.3)	52 (26.1)
Angiography Result		
SVD	17 (17.7)	62 (31.2)
2VD	22 (22.9)	48 (24.1)
3VD	39 (40.6)	83 (41.7)
No angiography	18 (18.8)	6 (3.0)
Types of Intervention		
CABG	18 (18.8)	50 (31/6)
PCI	29 (30.2)	98 (49.3)
MT	39 (40.6)	38 (19.1)
No intervention	5 (5.2)	0
Average LOS	8.70±5.84, d	6.31±4.42, d
Readmission	10.40	5.0
Intubation	11 (11.5)	0
In-hospital mortality	23 (24.0)	10 (5.0)

*Data are presented as mean±SD or n (%).
AMI, Acute myocardial infarction; STEMI, ST-elevation myocardial infarction; NSTEMI, Non-ST-elevation myocardial infarction; CAD, Coronary artery disease; SVD, Single-vessel disease; 2VD, Two-vessel disease; 3VD, Three-vessel disease; CABG, Coronary artery bypass graft surgery; PCI, Percutaneous coronary intervention; MT, Medical treatment; LOS, Length of hospital stay

Table 3. Health outcomes of the studied patients during follow-up

Characteristic	COVID-19 Group	Non-COVID-19 Group	(Sig Level=0.05)
Readmission	39 (53.4)	62 (32.8)	0.004
Inpatient	10 (25.6)	19 (30.6)	
Outpatient	29 (74.4)	43 (69.4)	
Complication			
Chest pain	39 (53.4)	52 (83.9)	0.023
Heart failure	6 (8.2)	9 (14.5)	0.002
Angina	4 (5.5)	7 (11.3)	0.059
Cardiogenic shock	3 (4.1)	2 (3.2)	0.621
LOS, d (mean±SD)	7.80±4.48	2.74±3.67	0.002
Mortality rate (1 y)	3 (4.1)	2 (3.2)	0.006

LOS, Length of stay

Table 4. Total medical costs for the case and non-COVID-19 groups (hospitalization and follow-up costs)

Medical Costs	Mean±SD ($)		Median ($)		(Sig Level=0.05)
	COVID-19 Group	Non-COVID-19 Group	COVID-19 Group	Non-COVID-19 Group	
Visit	354.31±332.89	101.36±154.72	202.1	46.9	0.001
Nursing	144.06±92.17	76.07±112.56	112.5	48.3	0.020
Diagnostic	428.82±219.21	464.57±438.95	438.9	399.9	0.001
Laboratory	510.41±456.61	257.38±327.24	327.2	144.6	0.004
Interventions	475.24±749.13	802.81±59.29	59.2	474.4	0.001
Drugs and devices	2366.67±2618.94	3558.41±1694.44	1694.4	1602.1	0.534
ICU beds	2105.08±2291.18	1101.9±1556.82	1556.8	600.6	0.002
Total treatment cost	6384.54±6760.13	6362.49±4343.07	4391.4	3317.1	0.787

Table 5. Total cost, patient share, basic insurance share, and complementary insurance share (first admission)

	COVID-19 Group ($)			Non-COVID-19 Group ($)		
	Patient	Basic	Complementary	Patient	Basic	Complementary
Mean±SD	560.12±837.86	3503.59±3118.9	400.35±797.84	893.89±5333.16	3163.8±3481.97	426.56±751.22
Total cost		4630.01±4130.22			4620.67±6668.97	

Table 6. Total cost, patient share, basic insurance share, and complementary insurance share (follow-up period)

	COVID-19 Group ($)			Non-COVID-19 Group ($)		
	Patient	Basic	Complementary	Patient	Basic	Complementary
Mean±SD	175.99±154.09	1913.5±1544.78	387.51±484.85	514.43±920.96	1448.63±1163.47	112.13±311.88
Total cost		2490.4±2127.47			2124.18±1985.87	

were chest pain, heart failure, angina, and cardiogenic shock. The average LOS during follow-up was 7.80±4.48 days in the COVID-19 group and 2.74±3.67 days in the non-COVID-19 group (P=0.002 and *P*<0.050, respectively). The 1-year mortality rate was 4.1% in the COVID-19 group and 3.2% in the non-COVID-19 group (Table 3).

The COVID-19 group had an average of 7.6 doctor's visits, with an average cost of $354.3 (14,880,790 Rials). In contrast, the non-COVID-19 group had an average of 3.5 visits per patient, with an average cost of $101.36 (4,256,960 Rials) per visit. Due to the long average LOS in the COVID-19 group (8.70 d) compared with the non-COVID-19 group (6.31 d), the average cost of ICU beds was higher in the COVID-19 group ($1207.7 or 50,723,440 Rials) than in the non-COVID-19 group ($880.98 or 37,001,350 Rials) (Figure 2). During the follow-up period, the average cost of ICU beds remained higher in the COVID-19 group ($897.38 or 37,689,800 Rials) than in the non-COVID-19 group ($220.92 or 9,278,470 Rials). The average cost of vascular and surgical interventions, such as angioplasty and coronary artery bypass graft surgery (CABG), was higher in the non-COVID-19 group ($802.81 or 33,717,840 Rials) than in the COVID-19 group ($6475.2 or 19,958,600 Rials). The average total treatment costs were $6384.54 (299,057,650 Rials) in the COVID-19 group and $6362.49 (283,283,630 Rials) in the non-COVID-19 group (Table 4).

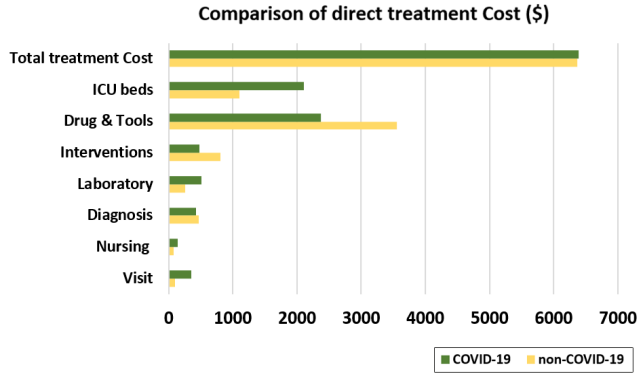

Figure 2. The image depicts a comparison of direct treatment costs ($).

The average total treatment cost during the initial hospitalization in the COVID-19 group was $4630.01 (194,460,556 Rials), with an average out-of-pocket (OOP) payment of approximately 12%. In the non-COVID-19 group, the average total cost was $4620.67 (194,068,256 Rials), with an average OOP payment of approximately 19% (Table 5). Furthermore, besides basic insurance, 41.7% of patients in the COVID-19 group and 42.2% of patients in the non-COVID-19 group had complementary insurance.

The average total treatment cost during the follow-up period was $2490.4 (104,597,108 Rials) in the COVID-19 group, as opposed to $2124.18 (89,215,376 Rials) in the non-COVID-19 group (Table 6).

The significance test indicated that the difference between the total medical costs of the 2 groups was not significant (P>0.78 and P>0.05). Nevertheless, upon examining specific costs, such as the cost of vascular interventions (P<0.001 and P<0.05) and the cost of ICU beds (P<0.002 and P<0.05), a significant difference in costs was observed.

Discussion

This study aimed to assess the clinical and economic aspects of AMI patients admitted to THC with COVID-19. The results indicated that the majority of patients in both groups were male, and the prevalence of AMI was higher in men. This finding aligns with multiple epidemiological studies on MI, which reported higher AMI prevalence in men due to risk factors such as smoking being more common among males.[14, 15]

A study revealed that diabetic patients experienced more fever and dyspnea symptoms upon COVID-19 infection. Moreover, respiratory complications and ICU hospitalization rates were higher in this patient group, leading to more severe clinical complications and potentially increased mortality rates.[16] Most patients with COVID-19 (37.5%) had diabetes and experienced a more severe form of the disease, resulting in their admission to ICU beds. The

average LOS for patients with AMI and COVID-19 was 8.7 days, while patients with AMI alone stayed in the hospital for 6.3 days. In other studies, such as a study on LOS for COVID-19 patients in China, it was found that COVID-19 significantly increased the average LOS.[17] This increase in LOS has resulted in a significant rise in the costs of ICU beds and medical services. Overall, the burden caused by COVID-19 has been significant in terms of hospital costs, availability of intensive care beds, and LOS.[18]

The high average LOS in the COVID-19 group (8.7 d) compared with the non-COVID-19 group (6.3 d) led to increased average costs for ICU stays. Another study found that with advancing age and the presence of risk factors like CVD, hypertension, and diabetes, ICU bed occupancy rates and LOS increased, with the highest reported LOS being 15 days. Additionally, the highest COVID-19-related mortality rates were observed among patients hospitalized in ICU beds.[19]

Two studies concentrating on cardiovascular patients and invasive vascular interventions recommended reducing invasive interventions and exploring alternative treatment options for cardiovascular patients.[20, 21] The average cost of vascular and surgical interventions, such as angioplasty and CABG, was higher in the non-COVID-19 group than in the COVID-19 group. In the COVID-19 group, most patients received medical treatment (45.83%) due to specific clinical conditions and the presence of COVID-19 with AMI, while vascular interventions and invasive surgery were minimized. In contrast, only 19.1% of patients in the non-COVID-19 group received medical treatment, with the majority undergoing percutaneous coronary intervention (PCI) and CABG, resulting in higher vascular and surgical intervention costs. It can be inferred that the coexistence of COVID-19 with AMI led to a decrease in standard treatment approaches (interventional cardiology) and an increase in alternative options like medical treatment. Data analysis revealed that the mortality rate in the COVID-19 group was approximately 5-fold higher than that in the non-COVID-19 group. The increased in-hospital mortality is likely associated with the reduced use of standard vascular intervention and the heightened reliance on medical treatment in COVID-19 patients. A similar study found that STEMI patients with concurrent COVID-19 infection had significantly higher in-hospital mortality (≈2-fold) and were less likely to receive same-day PCI, overall PCI (any day), and CABG during hospitalization than those without COVID-19.[22]

A study examining the effects of COVID-19 on AMI patients in Turkey demonstrated higher ejection fraction, mortality rates, and cardiogenic shock incidence in AMI patients with COVID-19 than in those without.[21] COVID-19 can exacerbate heart damage in AMI patients and contribute to increased mortality.[23] The results of this study align with these findings, as both studies underscore the detrimental impact of COVID-19 on AMI patients, resulting in elevated mortality rates and poorer outcomes. Numerous studies focusing on examining the direct costs of COVID-19 treatment have identified the high costs of hospitalization for these patients as a substantial challenge within the healthcare system. These studies stress the importance of efficient resource allocation to tackle this issue.[24]

With increasing patient age and the presence of underlying medical conditions, treatment costs have risen significantly. Consequently, COVID-19 has imposed a considerable financial burden on patients, the healthcare system, and insurance organizations.[25] Although the cost of standard vascular interventions was higher in the non-COVID-19 group than in the COVID-19 group, the concurrent presence of COVID-19 with AMI and the extended disease duration led to increased costs related to ICU bed stays in the COVID-19 group. The concurrence of COVID-19 with AMI has resulted in an increased burden on service provider systems, patients, and insurance institutions due to elevated resource consumption, reduced bed turnover rates, and prolonged hospital stays. The findings of this study, highlighting the economic burden of COVID-19 on direct treatment costs for patients, the healthcare system, and insurance organizations, chime with the results of other studies.[9]

The present study gathered data from 295 AMI patients in a single hospital in Tehran; therefore, the findings might not be generalizable to the entire population of Iran. The primary limitation of this research is the inability to investigate long-term patient outcomes, necessitating further evaluation to study these outcomes in the future.

Conclusion

The results of the present study revealed a significantly higher in-hospital mortality rate in the COVID-19 group than in the non-COVID-19 group. Additionally, extended LOS contributed to increased direct treatment costs. The COVID-19 group also exhibited a higher readmission rate than the non-COVID-19 group. During follow-up, complications such as chest pain and heart failure occurred more frequently in the non-COVID-19 group. Studying COVID-19 alongside costly diseases like CVD is crucial for efficient resource management within the healthcare system. Furthermore, managing patients with underlying conditions during pandemics necessitates the development of more effective treatment protocols. Future studies should examine total costs (direct and indirect treatment) and indirect costs to determine the economic burden imposed by the coexistence of communicable and non-communicable diseases.

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