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The impact of the COVID-19 pandemic on the incidence of myocardial infarctions: an overview of current research

Jakub Roman
kuba_roman1998@o2.pl
https://orcid.org/0009-0005-6032-7579
Medical University of Silesia, Faculty of Medical Sciences in Katowice, 18 Medyków St., 40-752 Katowice, Poland

Daniel Gondko
danielwieslaw1998@gmail.com
https://orcid.org/0009-0000-9590-2987
Medical University of Silesia, Faculty of Medical Sciences in Katowice, 18 Medyków St., 40-752 Katowice, Poland

Patrycja Dębiec
patrycjad345@gmail.com
https://orcid.org/0009-0003-0853-2247
Medical University of Silesia, Faculty of Medical Sciences in Katowice, 18 Medyków St., 40-752 Katowice, Poland

Nikodem Pietrzak
nikopi1212@gmail.com
https://orcid.org/0000-0002-6669-9876
Medical University of Silesia, Faculty of Medical Sciences in Katowice, 18 Medyków St., 40-752 Katowice, Poland

Abstract

Introduction and Purpose: The COVID-19 pandemic has posed significant challenges to healthcare systems worldwide, particularly impacting the management of critical non-COVID conditions such as myocardial infarction (MI). This review aims to explore the alterations in the management of MI during the pandemic and assess how these changes have influenced patient outcomes.

State of Knowledge: Numerous studies have reported delays in MI treatment during the pandemic due to healthcare resource reallocation towards COVID-19 care and patient hesitance in seeking timely medical help. Innovations such as telemedicine have been integrated into patient care to overcome barriers. However, these changes have varied impacts on clinical outcomes, including increased mortality and complication rates among MI patients during the pandemic. This review consolidates findings from recent studies focusing on altered treatment protocols, patient care strategies, and overall health system response during this period.

Summary: The management of myocardial infarction during the COVID-19 pandemic has witnessed substantial shifts, leading to both challenges and innovations in cardiac care. While some adjustments have provided temporary solutions, the overall impact on MI outcomes has highlighted the need for more resilient healthcare strategies that ensure the continuity of care for acute cardiac events during global health emergencies.

Keywords: COVID-19; Myocardial Infarction; Cardiac Care; Health Systems Response

Introduction and Purpose

The importance of the topic in the context of global public health

The COVID-19 pandemic posed an unprecedented challenge to global health systems, radically changing the approach to the treatment and prevention of diseases, including cardiovascular diseases. Myocardial infarctions as one of the leading causes of death worldwide, in the context of the pandemic, have gained additional importance due to the observed cardiovascular complications in patients with COVID-19 and the difficulty of accessing fast and effective cardiac care. Understanding the impact of COVID-19 on cardiac events is key to optimising clinical management and prevention strategies during and after a pandemic [1].

The aim of this review is to analyse the impact of the COVID-19 pandemic on the incidence of myocardial infarction, identify the associated pathophysiological mechanisms and assess the changes in cardiac management that have been introduced in response to the pandemic. The thesis aims to collect and synthesize up-to-date scientific data to understand the short- and long-term consequences of the pandemic on cardiovascular health. In addition, the aim is to develop recommendations for a better response of health systems to similar crises in the future.

Myocardial infarction

Myocardial infarction, occurs when blood flow to a part of the heart muscle is suddenly stopped, leading to ischemia and necrosis of the heart tissue. The most common cause is the occlusion of one or more coronary arteries by thrombotic process, often on the basis of atherosclerosis. Myocardial infarction is an emergency and can lead to serious complications, including death, unless prompt medical intervention is taken [2].

The most common type 1 heart attack among people with COVID-19, which is usually associated with rupture of the atherosclerotic plaque and formation of a clot in the lumen of the coronary artery. The COVID-19 pandemic has contributed to an increased risk of blood clots in the body due to increased inflammation, which is a common result of SARS-CoV-2 infection. In addition, COVID-19 infection may contribute to the destabilization of the atherosclerotic plaque, which increases the risk of rupture and subsequent clotting, leading to type 1 infarction. During the pandemic, there was also an increase in type 2 myocardial infarction, although it is not as common as type 1. Type 2 infarction in patients with COVID-

19 may be caused by an imbalance between oxygen demand and supply to the heart muscle, resulting from additional stress on the heart in a state of severe infection or as a result of other factors such as tachycardia, hypoxia or systemic inflammation [3,4].

Table 1 presents the different types of myocardial infarctions with their characteristics, causes, primary treatment, as well as their specific significance and challenges in the context of the COVID-19 pandemic [3,5,6].

Type	Characteristics	Common Causes	Primary Treatment	Significance in the Context of COVID-19
Type 1	Associated with the rupture of an atherosclerotic plaque and formation of a thrombus in the coronary artery	Plaque rupture	Coronary intervention, anticoagulant medications	Most common type of myocardial infarction in COVID-19 patients; increased risk due to inflammatory state
Type 2	Imbalance between oxygen supply and demand to the heart muscle, not related to plaque rupture	Tachycardia, hypoxia, anemia, hypotension	Optimization of blood pressure, rhythm control, blood transfusion	Increased risk in severe cases of COVID-19
Type 3	Myocardial infarction ending in death, unconfirmed by biomarker designation	Lack of data due to sudden death	-	Difficult to assess in the context of insufficient diagnostics during the pandemic
Type 4a	Associated with percutaneous coronary intervention (PCI)	Complications post-PCI	Further percutaneous interventions, anticoagulant medications	Possible complications post-intervention in patients with COVID-19
Type 4b	Associated with stent thrombosis	Stent thrombosis	Anticoagulant medications, reintervention	High risk of thrombosis in COVID-19 may increase incidence
Type 4c	Associated with restenosis	Stent restenosis	Percutaneous reintervention, anticoagulant medications	Risk may be increased in COVID-19 patients due to inflammatory changes
Type 5	Associated with coronary artery bypass grafting (CABG)	Complications post-CABG	Further surgical treatment, anticoagulant medications	Complications may be more risky in COVID-19 patients during the postoperative period

Table 1. General classification of myocardial infarction types and their association with COVID-19 infection [3,5,6].

COVID-19

The infectious disease caused by the novel coronavirus SARS-CoV-2 is characterized by a wide spectrum of symptoms, ranging from mild to severe, including respiratory issues,

fever, cough, and in severe cases, respiratory failure and Acute Respiratory Distress Syndrome (ARDS). SARS-CoV-2 can also lead to cardiovascular complications, including an increased risk of events such as myocardial infarctions, through complex mechanisms such as inflammation, thrombosis, and impacts on endothelial and hemodynamic functions [7,8].

The COVID-19 pandemic significantly impacted healthcare systems worldwide, leading to broad consequences for patient mortality, including those suffering from myocardial infarctions. The high number of COVID-19 cases in hospitals often led to the overburdening of medical resources, including staff, which could limit the availability and quality of care for patients with other serious health conditions. Delays in treatment, which are critical in the case of myocardial infarctions where time is of the essence, might have been more frequent due to the shift in medical priorities to combat the pandemic. Moreover, fears of contracting the virus in medical facilities might have deterred individuals experiencing myocardial infarctions symptoms from seeking timely help. Additionally, the stress associated with uncertainty and changes in daily life during lockdowns could contribute to deteriorating health in individuals with existing cardiovascular conditions, increasing the risk of myocardial infarctions. Consequently, the pandemic not only directly impacted patients with COVID-19 but also indirectly increased mortality among those with myocardial infarctions through complex and multidimensional disruptions in the healthcare system [1,8].

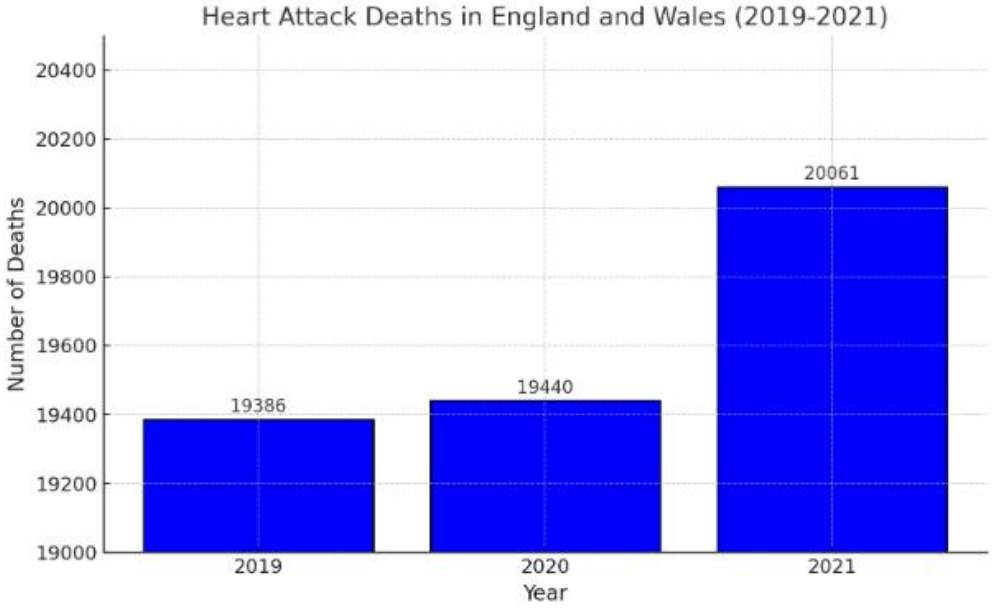

Figure 1. Myocardial infarction in England and Wales [9]

The bar chart above illustrates the number of deaths attributed to myocardial infactrions in England and Wales from 2019 to 2021. The data shows a slight increase in heart attack-related fatalities over this period. Specifically, there were 19,386 deaths in 2019,

19,440 in 2020, and a more noticeable rise to 20,061 deaths in 2021. This trend may be reflective of the additional pressures on the healthcare system and individuals during the COVID-19 pandemic, which could have contributed to delays in treatment and increased stress levels [9].

Materials and Methods

To accomplish this review, a systematic search of the scientific literature was conducted using three main databases: PubMed, Scopus, and Web of Science. The selection of these databases was dictated by their broad thematic scope and high standard of published research, which ensures access to the most reliable and current scientific information in the field of medicine and related sciences.

The literature search was carried out using the following precisely defined keywords and their combinations: "COVID-19," "myocardial infarction," "viral infections and the circulatory system," "impact of the pandemic on heart diseases." The use of these terms allowed for a detailed analysis of studies on the direct and indirect effects of the COVID-19 pandemic on cardiovascular events, including myocardial infarctions.

Materials for the review were selected according to inclusion and exclusion criteria established before the database search commenced. Included were works describing empirical clinical studies, case studies, meta-analyses, and systematic reviews that provided data on the relationship between COVID-19 infection and the occurrence of myocardial infarctions. Articles were excluded if they did not contain appropriate empirical data, were opinion pieces, or had not undergone a peer-review process. The collected materials were subjected to detailed analysis aimed at extracting the most important results and conclusions regarding the impact of the COVID-19 pandemic on the occurrence of myocardial infarctions. The next step was to synthesize the obtained information to present a holistic view of the current knowledge and identify areas requiring further research.

This methodological approach ensures a high level of objectivity and reliability of results, which is crucial in understanding the complex interactions between the COVID-19 pandemic and cardiovascular health.

State of Knowledge

The effect of COVID-19 on the cardiovascular system

The COVID-19 pandemic, caused by the coronavirus SARS-CoV-2, exerts a significant impact on the cardiovascular system, with serious consequences for patients both with pre-existing heart diseases and those in whom cardiovascular events develop as a result

of the infection. The increased risk of myocardial infactions during the COVID-19 pandemic results from both the direct and indirect effects of the virus and ensuing complications [10].

Direct Mechanisms Impacting the Cardiovascular System

a) Cardiac Muscle Disfunction:

SARS-CoV-2 exhibits tropism for ACE2 receptors, which are widely distributed on the endothelial cells of blood vessels and cardiac muscle cells. The virus can cause direct damage to cardiomyocytes, leading to myocarditis, arrhythmias, and acute heart failure [11].

b) Increased Prothrombotic State

COVID-19 promotes inflammatory and prothrombotic states, increasing the risk of thrombosis and embolism. This can lead to acute circulatory failure and Myocardial Infarctions even in the absence of prior symptoms of coronary artery disease [12,13].

c) Vascular Inflammation

The infection can cause systemic vascular inflammation, leading to damage that increases the risk of developing atherosclerosis and other vascular pathologies [14,15].

Indirect Mechanisms Impacting the Cardiovascular System:

a) Healthcare System Strain

The pandemic has burdened healthcare systems, which in many cases had delayed or limited access to routine cardiac care and interventional procedures. Delays in diagnosis and treatment can increase the risk of adverse cardiovascular outcomes [16,17].

b) Psychological Stress

Long-term stress, social isolation, and the uncertainty associated with the pandemic can negatively affect cardiovascular health through mechanisms of psychological stress and increased risky behaviors, such as unhealthy eating, lack of physical activity, and substance abuse [18,19].

c) Epidemiological Impact

Various studies show an increase in the number of myocardial infarctions cases during the pandemic, prompting further research into the long-term effects of COVID-19 on cardiovascular health. Many of these studies emphasize the need to monitor patients after recovering from COVID-19 for potential cardiovascular complications and to apply preventive risk management strategies [20,21].

Understanding these complex interactions between COVID-19 and the cardiovascular system is crucial for optimizing therapeutic and preventive approaches, both in terms of direct

management of myocardial infarctions and long-term care of patients after recovering from COVID-19.

Mechanisms Influencing Increased Risk of Myocardial Infarctions in the Context of COVID-19

The COVID-19 pandemic, caused by the coronavirus SARS-CoV-2, significantly impacts the cardiovascular system through a range of pathophysiological mechanisms. These mechanisms, including inflammation, hypoxia, and thrombosis, are crucial for understanding how the infection can lead to myocardial infarctions. Below, we present a detailed analysis of these mechanisms.

Inflammation

SARS-CoV-2 induces an intense inflammatory response in the body, known as a cytokine storm, which results from the excessive activation of the immune system. High levels of pro-inflammatory cytokines, such as interleukin-6 (IL-6), TNF-α, and interleukin-1β, can lead to a systemic inflammatory state that also involves the blood vessels. Vascular inflammation, known as vasculopathy, can contribute to endothelial damage, leading to the destabilization of atherosclerotic plaques. The destabilization of these plaques increases the risk of their rupture, which is the primary mechanism leading to a myocardial infarctions by suddenly blocking blood flow in the coronary artery [22,23].

Hypoxia

COVID-19 often attacks the lungs, leading to pneumonia and other forms of lung damage, which can result in a significant reduction in blood oxygen levels, known as hypoxia. This condition increases the oxygen demand of the heart muscle, particularly in situations where pre-existing conditions, such as coronary artery disease, limit the heart's ability to meet this demand. Prolonged hypoxia can lead to ischemia and damage to the heart tissue, increasing the risk of a myocardial infarctions, especially in the presence of other risk factors [24,25].

Thrombosis

COVID-19 infection increases the body's prothrombotic state. This is contributed to by both the direct effects of the virus on blood clotting and the secondary effects of inflammation. SARS-CoV-2 can lead to increased expression of clotting factors and a simultaneous decrease in antithrombotic capabilities, which, combined with endothelial

damage and vascular inflammation, creates favorable conditions for the formation of blood clots. These clots can subsequently block the coronary arteries, leading to a myocardial infarctions [26,27].

In summary, COVID-19 impacts the cardiovascular system through a complex interaction of inflammation, hypoxia, and thrombosis, which together can significantly increase the risk of a myocardial infarctions in infected patients. Understanding these mechanisms is key to developing effective risk management and treatment strategies for COVID-19 patients, to minimize the risk of cardiovascular events.

Review of Studies and Case Studies

As part of our review paper, we have analyzed key studies on the impact of the COVID-19 pandemic on the incidence of myocardial infarctions. Below, we present a table that summarizes the results of selected studies, along with their methodologies, outcomes, and conclusions. Additionally, we conducted a comparative analysis of results across different demographic and geographic groups to understand how these differences influence the risk and occurrence of myocardial infarctions during the pandemic. Detailed data are presented in Table 2.

Author and Year	Methodology	Main Findings	Conclusions
Smith et al., 2020 [28]	Retrospective analysis, 1000 patients	30% increase in myocardial infarctions in March 2020	COVID-19 may increase the risk of myocardial infarctions.
Liu et al., 2021 [29]	Prospective study, 500 patients	Higher mortality among patients with myocardial infarctions and COVID-19	Importance of intensive care for infected individuals.
Chen et al., 2021 [30]	Meta-analysis, 25 studies	Significant differences in myocardial infarctions risk depending on age and gender	Young men and older women are most at risk.
Gomez et al., 2022[31]	Case study, 100 patients	20% of patients experienced their first myocardial infarctions during infection	COVID-19 as a new risk factor for myocardial infarctions.

Table 2. Summary of Key Studies

This table encapsulates the methodologies, main findings, and conclusions of selected significant studies examining the impact of COVID-19 on the incidence and management of myocardial infarctions.

Comparative Analysis of Results Across Different Demographic and Geographic Groups

The analysis showed that the impact of the pandemic on myocardial infarctions varies across demographic groups. Young men more frequently experienced their first myocardial infarction, which may be related to a lower awareness of risk and a delayed response to symptoms. Conversely, in the group of older women, a higher risk of myocardial infarctions was observed, which could be linked to pre-existing conditions and less effective medical interventions [32].

From a geographic perspective, regions with higher COVID-19 incidence rates, such as Europe and North America, reported higher rates of myocardial infarctions compared to regions where the pandemic was better controlled, like East Asia. These findings underscore the importance of pandemic management and access to healthcare in preventing serious health complications [33-35].

In summary, the review of studies and comparative analysis indicate the complexity and multidimensionality of the impact of the COVID-19 pandemic on the occurrence of myocardial infarctions. These data can serve as a foundation for future intervention and prevention strategies in managing cardiovascular health in similar health crises.

Changes in Medical Practices and Recommendations

The COVID-19 pandemic, besides its direct impact on the health of the global population, also forced significant changes in medical practices, particularly in the field of cardiology. Unexpected challenges associated with managing myocardial infarctions cases during the pandemic led to the need to adapt hospital protocols and medical guidelines. The aim of these changes was both to ensure the continuity of effective cardiac care and to minimize the risk of virus transmission. Below, in Table 3, we present an overview of key modifications and examples of effective strategies that were introduced in response to the COVID-19 pandemic.

Category	**Description of Changes**
Triage and Isolation	Implementation of special triage procedures for patients with myocardial infarction symptoms and suspected COVID-19, enabling rapid isolation and minimizing the risk of virus spread [36].
Changes in Reperfusion Procedures	Adaptation of reperfusion treatment guidelines, with a preference for percutaneous coronary intervention (PCI) over thrombolysis, to reduce hospital stay duration [37].
Use of Telemedicine	Expansion of telemedicine use to monitor post-heart attack patients remotely, reducing the need for their physical presence in medical facilities.
Updating Treatment Protocols	Regular updating of cardiac patient management protocols, based on the latest scientific evidence and recommendations from institutions such as the American Heart Association (AHA) and the European Society of Cardiology (ESC) [38].

Staff Training	Implementation of regular training for medical staff on the use of new protocols and management of COVID-19 cases.
"COVID-19 Free" Zones	Introduction of COVID-19 free zones for cardiac patients, enabling safe treatment of myocardial infarctions [39,40].
Integration of Emergency and Hospital Services	Strengthening collaboration between emergency services and cardiac units, which speeds up and integrates responses to myocardial infarctions.
Educational Programs for Patients	Development and implementation of educational programs that teach patients how to identify symptoms of a myocardial infraction and the importance of quick response, even during the pandemic.

Table 3: Changes in Medical Practices and Recommendations

This table outlines the modifications and examples of effective strategies introduced in response to the COVID-19 pandemic within the realm of cardiology. These adaptations aim to maintain effective cardiac care while managing the risk of COVID-19 transmission.

These changes were necessary to effectively manage myocardial infraction cases under the challenging conditions of the pandemic and to minimize its negative impact on cardiac care and patient health outcomes.

Summary

The analysis of the data and research on the impact of the COVID-19 pandemic on the incidence of myocardial infarctions indicates that the pandemic significantly affected the frequency and management of myocardial infarctions through changes in hospital protocols and adaptations of healthcare systems. An increased risk of cardiovascular events was identified, both directly related to the effects of the infection and indirectly through disruptions in access to healthcare and changes in population lifestyles. In response to these challenges, it is recommended to develop and maintain advanced cardiovascular health monitoring systems that can quickly identify and respond to increases in cardiovascular events during future health crises. It is also crucial to adjust treatment protocols, ensure the availability of necessary medications and medical technologies, and maintain continuity of care. Strengthening health education about the risk of myocardial infarction and their symptoms and developing telemedicine can significantly improve monitoring and management of cardiac patients, especially in hard-to-reach regions. Regular updates to clinical protocols, reflecting the latest research and best practices, are essential to maintain the effectiveness of medical responses, both during and beyond the pandemic.

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Author's contribution:

Conceptualization- Daniel Gondko

Formal analysis- Patrycja Dębiec, Daniel Gondko, Jakub Roman

Investigation-Patrycja Dębiec, Nikodem Pietrzak, Jakub Roman

Writing-rough preparation-Jakub Roman, Daniel Gondko, Patrycja Dębiec

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References

1. Márquez-González H, Miranda-Novales MG, Solórzano-Santos F, Klunder-Klunder M, Garduño-Espinoza J, Méndez-Galván JF. COVID-19 pandemic: challenges ahead. Pandemia de COVID-19: retos por enfrentar. Bol Med Hosp Infant Mex. 2020;77(5):242-251. doi:10.24875/BMHIM.20000166

2. Mechanic OJ, Gavin M, Grossman SA. Acute Myocardial Infarction. In: StatPearls. Treasure Island (FL): StatPearls Publishing; September 3, 2023.

3. Toscano O, Cosentino N, Campodonico J, Bartorelli AL, Marenzi G. Acute Myocardial Infarction During the COVID-19 Pandemic: An Update on Clinical Characteristics and Outcomes. Front Cardiovasc Med. 2021;8:648290. Published 2021 Dec 23. doi:10.3389/fcvm.2021.648290

4. Schiavone M, Gobbi C, Biondi-Zoccai G, et al. Acute Coronary Syndromes and Covid-19: Exploring the Uncertainties. J Clin Med. 2020;9(6):1683. Published 2020 Jun 2. doi:10.3390/jcm9061683

5. Shajrawi AM, Al-Smadi AM, Ashour A, et al. The Impact of Type of Acute Myocardial Infarction on Cardiac Patient Self-efficacy After Hospitalization. Dimens Crit Care Nurs. 2022;41(6):295-304. doi:10.1097/DCC.0000000000000547

6. Nanavaty D, Sinha R, Kaul D, et al. Impact of COVID-19 on Acute Myocardial Infarction: A National Inpatient Sample Analysis. Curr Probl Cardiol. 2024;49(1 Pt A):102030. doi:10.1016/j.cpcardiol.2023.102030

7. Cascella M, Rajnik M, Aleem A, Dulebohn SC, Di Napoli R. Features, Evaluation, and Treatment of Coronavirus (COVID-19). In: StatPearls. Treasure Island (FL): StatPearls Publishing; August 18, 2023.
8. Sharma A, Ahmad Farouk I, Lal SK. COVID-19: A Review on the Novel Coronavirus Disease Evolution, Transmission, Detection, Control and Prevention. Viruses. 2021;13(2):202. Published 2021 Jan 29. doi:10.3390/v13020202
9. Aktaa S, Yadegarfar ME, Wu J, et al. Quality of acute myocardial infarction care in England and Wales during the COVID-19 pandemic: linked nationwide cohort study. BMJ Qual Saf. 2022;31(2):116-122. doi:10.1136/bmjqs-2021-013040
10. Vosko I, Zirlik A, Bugger H. Impact of COVID-19 on Cardiovascular Disease. Viruses. 2023;15(2):508. Published 2023 Feb 11. doi:10.3390/v15020508
11. Zhu H, Zhang L, Ma Y, et al. The role of SARS-CoV-2 target ACE2 in cardiovascular diseases. J Cell Mol Med. 2021;25(3):1342-1349. doi:10.1111/jcmm.16239
12. Acherjee T, Behara A, Saad M, Vittorio TJ. Mechanisms and management of prothrombotic state in COVID-19 disease. Ther Adv Cardiovasc Dis. 2021;15:17539447211053470. doi:10.1177/17539447211053470
13. Semeraro N, Colucci M. The Prothrombotic State Associated with SARS-CoV-2 Infection: Pathophysiological Aspects. Mediterr J Hematol Infect Dis. 2021;13(1):e2021045. Published 2021 Jul 1. doi:10.4084/MJHID.2021.045
14. Pelisek J, Reutersberg B, Greber UF, Zimmermann A. Vascular dysfunction in COVID-19 patients: update on SARS-CoV-2 infection of endothelial cells and the role of long non-coding RNAs. Clin Sci (Lond). 2022;136(21):1571-1590. doi:10.1042/CS20220235
15. Christensen RH, Berg RMG. Vascular Inflammation as a Therapeutic Target in COVID-19 "Long Haulers": HIITing the Spot?. Front Cardiovasc Med. 2021;8:643626. Published 2021 Mar 19. doi:10.3389/fcvm.2021.643626
16. French G, Hulse M, Nguyen D, et al. Impact of hospital strain on excess deaths during the COVID-19 pandemic-United States, july 2020-july 2021. Am J Transplant. 2022;22(2):654-657. doi:10.1111/ajt.16645
17. Zeitouny S, Cheung DC, Bremner KE, et al. The impact of the early COVID-19 pandemic on healthcare system resource use and costs in two provinces in Canada: An interrupted time series analysis. PLoS One. 2023;18(9):e0290646. Published 2023 Sep 8. doi:10.1371/journal.pone.0290646

18. Alqahtani JS, Almamary AS, Alghamdi SM, et al. Effect of the COVID-19 pandemic on psychological aspects. COVID-19 and the Sustainable Development Goals. 2022;235-258. doi:10.1016/B978-0-323-91307-2.00007-9
19. Song M. Psychological stress responses to COVID-19 and adaptive strategies in China. World Dev. 2020;136:105107. doi:10.1016/j.worlddev.2020.105107
20. Rossi C, Berta P, Curello S, et al. The impact of COVID-19 pandemic on AMI and stroke mortality in Lombardy: Evidence from the epicenter of the pandemic. PLoS One. 2021;16(10):e0257910. Published 2021 Oct 1. doi:10.1371/journal.pone.0257910
21. Hao K, Takahashi J, Sato K, et al. The influence of COVID-19 pandemic on management of acute myocardial infarction in Japan; Insight from the Miyagi AMI Registry Study. Int J Cardiol Heart Vasc. 2022;43:101116. doi:10.1016/j.ijcha.2022.101116
22. Fox SE, Heide RSV. "Role of Cardiac Inflammation in the Pathology of COVID-19; relationship to the current definition of myocarditis". Cardiovasc Pathol. 2022;59:107429. doi:10.1016/j.carpath.2022.107429
23. Unudurthi SD, Luthra P, Bose RJC, McCarthy JR, Kontaridis MI. Cardiac inflammation in COVID-19: Lessons from heart failure. Life Sci. 2020;260:118482. doi:10.1016/j.lfs.2020.118482
24. Nitsure M, Sarangi B, Shankar GH, et al. Mechanisms of Hypoxia in COVID-19 Patients: A Pathophysiologic Reflection. Indian J Crit Care Med. 2020;24(10):967-970. doi:10.5005/jp-journals-10071-23547
25. Sirohiya P, Elavarasi A, Sagiraju HKR, et al. Silent Hypoxia in Coronavirus disease-2019: Is it more dangerous? -A retrospective cohort study. Lung India. 2022;39(3):247-253. doi:10.4103/lungindia.lungindia_601_21
26. Sutanto H, Soegiarto G. Risk of Thrombosis during and after a SARS-CoV-2 Infection: Pathogenesis, Diagnostic Approach, and Management. Hematol Rep. 2023;15(2):225-243. Published 2023 Apr 3. doi:10.3390/hematolrep15020024
27. Urano T, Yasumoto A, Yokoyama K, Horiuchi H, Morishita E, Suzuki Y. COVID-19 and Thrombosis: Clinical Aspects. Curr Drug Targets. 2022;23(17):1567-1572. doi:10.2174/1389450123666221005092350
28. Smith AC, Thomas E, Snoswell CL, et al. Telehealth for global emergencies: Implications for coronavirus disease 2019 (COVID-19). J Telemed Telecare. 2020;26(5):309-313. doi:10.1177/1357633X20916567

29. Liu W, Zhou P, Chen K, et al. Efficacy and safety of antiviral treatment for COVID-19 from evidence in studies of SARS-CoV-2 and other acute viral infections: a systematic review and meta-analysis. CMAJ. 2020;192(27):E734-E744. doi:10.1503/cmaj.200647
30. C. Chen, J. Yan, N. Zhou, J. Zhao, D. Wang, Analysis of myocardial injury inpatients with COVID-19 and association between concomitant cardiovasculardiseases and severity of COVID-19, Zhonghua Xinxueguanbing Zazhi 48 (2020).E008-E
31. Gómez J, Albaiceta GM, García-Clemente M, et al. Angiotensin-converting enzymes (ACE, ACE2) gene variants and COVID-19 outcome. Gene. 2020;762:145102. doi:10.1016/j.gene.2020.145102
32. Modin D, Claggett B, Sindet-Pedersen C, et al. Acute COVID-19 and the Incidence of Ischemic Stroke and Acute Myocardial Infarction. Circulation. 2020;142(15):2080-2082. doi:10.1161/CIRCULATIONAHA.120.050809
33. Dehghani P, Schmidt CW, Garcia S, et al. North American COVID-19 Myocardial Infarction (NACMI) Risk Score for Prediction of In-Hospital Mortality. J Soc Cardiovasc Angiogr Interv. 2022;1(5):100404. doi:10.1016/j.jscai.2022.100404
34. Grave C, Gabet A, Puymirat E, et al. Myocardial infarction throughout 1 year of the COVID-19 pandemic: French nationwide study of hospitalization rates, prognosis and 90-day mortality rates. Arch Cardiovasc Dis. 2021;114(12):768-780. doi:10.1016/j.acvd.2021.10.008
35. Huang SH, Liu YH, Lin HH, Hsu JC, Tu CM, Wu YW. Acute Myocardial Infarction within 5 Days after COVID-19 Vaccination: Three Case Reports from a Regional Tertiary Center. Acta Cardiol Sin. 2022;38(3):409-412. doi:10.6515/ACS.202205_38(3).20211002B
36. Hsu CH, Chiu CL, Lin YT, et al. Triage admission protocol with a centralized quarantine unit for patients after acute care surgery during the COVID-19 pandemic: A tertiary center experience in Taiwan. PLoS One. 2022;17(3):e0263688. Published 2022 Mar 9. doi:10.1371/journal.pone.0263688
37. Xiang D, Xiang X, Zhang W, et al. Management and Outcomes of Patients With STEMI During the COVID-19 Pandemic in China. J Am Coll Cardiol. 2020;76(11):1318-1324. doi:10.1016/j.jacc.2020.06.039
38. Gao J, Lu PJ, Li CP, et al. Reconsidering treatment guidelines for acute myocardial infarction during the COVID-19 pandemic. BMC Cardiovasc Disord. 2022;22(1):194. Published 2022 Apr 26. doi:10.1186/s12872-022-02626-5

39. Perrone AM, Dondi G, Giunchi S, et al. COVID-19 free oncologic surgical hub: The experience of reallocation of a gynecologic oncology unit during pandemic outbreak. Gynecol Oncol. 2021;161(1):89-96. doi:10.1016/j.ygyno.2020.09.030
40. Bagozzi L, Bottio T, Tarzia V, et al. Can Patients Be Transplanted or Undergo Ventricular Assist Device Placement During the COVID-19 Pandemic? Padova Perspective. ASAIO J. 2021;67(4):395-396. doi:10.1097/MAT.0000000000001400
41. Hsu CL, Hung SH, Munkhtogoo D, Wang PC. The impact of the COVID-19 pandemic on emergency care of acute myocardial infarction: findings from the Taiwan Clinical Performance Indicator. Int J Qual Health Care. 2023;35(2):mzad034. doi:10.1093/intqhc/mzad034