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REVIEW

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Systematic review of case reports on COVID-19 associated myocarditis: a discussion on treatments

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Abstract

Although COVID-19 is a disease consisting of mostly upper and lower respiratory symptoms, a subset of patients develop cardiac sequelae including myocarditis and pericarditis. For these patients, a standardized set of diagnostic imaging techniques and treatments has not been established. While there have been numerous case reports on this topic, there are few reviews that evaluate the effectiveness of different treatment modalities with a significant number of cases. We reviewed 146 cases of patients (ages ranging from 2 months old to mid 80 s) obtained from searches on PubMed, Google Scholar, and several case report journals. ECG abnormalities, elevated inflammatory markers, and reduced left ventricular ejection fraction were most associated with COVID-19 myocarditis. While classic symptoms of COVID-19 include upper respiratory symptoms, a subset of patients diagnosed with COVID-19 displayed no signs of respiratory disease at all. In 22% of cases, cardiac sequelae was not present until after the patient recovered from COVID-19. Steroids were given in 57.5% of cases. Cardiac MRI was used in 40.4% of cases for diagnosis of myocarditis. Of all the patients who were treated with ECMO, 82.1% of these patients were able to fully recover. The use of cardiac MRI and transthoracic echocardiogram for diagnosis of COVID-19 myocarditis should be heavily considered in any patient with COVID-19 infection. ECMO, IVIG, steroids, and anticoagulants should also be heavily considered. A randomized controlled trial should be conducted to better associate treatments with outcomes.

Keywords Myocarditis, COVID-19, Clinical presentations of COVID-19 associated myocarditis, Treatments for myocarditis

Introduction

In March 2020, the World Health Organization (WHO) declared a pandemic caused by SARS-CoV-2, the virus that causes COVID-19. COVID-19 initially emerged in December 2019 when individuals in Wuhan, China suffered from pneumonia of unidentified origin. These patients presented with common symptoms such as cough, fever, and shortness of breath. It was initially thought that these were the only symptoms COVID-19 produced, but it was later discovered that COVID-19 has a much broader range of presentations, including gastrointestinal symptoms, headache, myalgia, and even asymptomatic presentations.

Although it is predominantly a respiratory infection, there have been several reports of short and long term consequences of cardiac sequelae caused by COVID-19 induced inflammatory responses. One of the most diagnosed cardiac injuries in hospitalized patients with COVID-19 is myocarditis. According to the CDC, there is on average a 16 × higher risk of myocarditis among patients diagnosed with COVID-19 compared

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to those who do not contract COVID-19 [1]. Current guidelines in diagnosing, managing, and treating patients with COVID-19 are constantly changing, warranting frequent systematic reviews that discuss the most recently published data. While there have been numerous case reports on this topic, there are few reviews that evaluate the effectiveness of different treatment modalities with a significant number of cases. This systematic review aims to discuss current treatments and outcomes of patients diagnosed with COVID-19 induced myocarditis.

Methods

A systematic medical literature review was conducted in the English language. A search of PubMed and several case report journals were completed with key terms "COVID-19 myocarditis." A total of 146 case reports were identified and used for this review. A thorough screening of all case reports was completed to ensure that included reports covered COVID-19 related myocarditis only. Cases that discussed other cardiac injuries, such as takotsubo cardiomyopathy, MISC-A, pericarditis, and cardiac tamponade, were excluded. Cases that hypothesized COVID-19 vaccination as a potential cause of myocarditis were excluded. For each case, patient demographics were collected including gender and age. Additionally, comprehensive information of clinical presenting symptoms, diagnostic results (including imaging and biopsy finding), ECG findings, and laboratory values were obtained. Furthermore, we included the variety of treatments that were administered to patients including steroids, antiviral medications, NSAIDs, surgical interventions, and immune and cardiac medications (Table 1).

Table 1 Demographics

Sex*	Total	% (number of cases/total cases)
Male	100	69
Female	45	31
Age		
0–18 yr	31	21
18–29 yr	24	16
30–49 yr	48	33
50–64 yr	28	19
65 +	15	10

* Total reported for sex is 145. One article did not specify sex

Results

During the period spanning from 2020 to 2022, we identified 146 (145 noted in our figure because one case did not report the sex) individual cases of myocarditis that occurred after or during active COVID-19 infection. We conducted an analysis of the population demographics for each case, encompassing a cohort of 146 patients who were diagnosed with myocarditis secondary to a COVID-19 infection. Our data collection efforts successfully included patients across a wide range of ages, allowing for a comprehensive understanding of the impacts of COVID-19-induced myocarditis across different age groups. Our analysis revealed a notable male predominance among the cases, accounting for 69% of the total patients. One case did not report the sex of the affected individual and therefore could not be categorized into either group. There were no significant differences in age in each sex group. Most of the cases (84%) were able to successfully recover from myocarditis secondary to COVID-19 infection, while a minority of patients (14%) died. The outcomes for 2% of the cases were not reported (Fig. 1).

Clinical presentations exhibited a range of findings, indicating variability in symptoms. The most frequently reported presenting symptoms were shortness of breath (43%) and chest pain (29%). Additional presenting symptoms are summarized in Table 2. There is also a subset of patients with delayed cardiac presentations (22%) and no signs of respiratory disease (25%). We did not see any significant differences in presentation of symptoms based on demographics.

In terms of diagnostic tools, 67.9% of these case studies reported reduced left ventricular ejection fraction (LVEF) on echocardiogram findings. Electrocardiogram (ECG) findings were variable and showed classic findings of

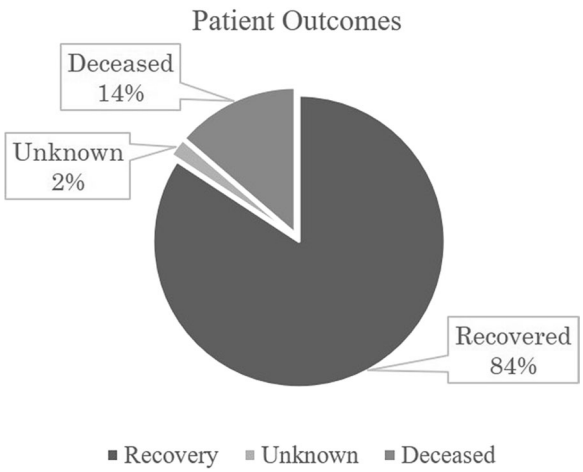

Fig. 1 Percentage of cases that reported a patient recovery or mortality following the illness reported

Table 2 Presenting symptoms

Presenting symptoms	Total	% (number of cases/total cases)
Chest pain	42	29
Palpitations	6	4
Shortness of breath	62	43
Cough	33	23
Sore throat	3	2
Fever	68	47
Upper respiratory tract symptoms (cough mainly)	10	7
Myalgia	14	10
Fatigue	23	16
Syncope	7	5
No Signs of Respiratory Disease	36	25
Delayed cardiac presentations	32	22
Gastrointestinal symptoms	39	27
Other	29	20

Table 3 Diagnostic results

Diagnostic testing	Total	% (number of cases/total cases)
Echocardiogram results		
Reduced left ventricular ejection fraction (LVEF)	95	68
Pericardial effusion	35	25
Ventricular Hypertrophy	17	12
Valve Regurgitation	13	9
Dilated cardiomyopathy	8	6
Hypokinesia	56	40
Thrombus	9	6
Normal	19	14
Use of Cardiac MRI	59	40
Use of Coronary angiography	28	19
Use of Endomyocardial Biopsy	18	12
EKG Findings		
ST elevation	31	24
ST elevation; diffuse	19	15
ST depression	11	9
T-wave inversion	23	18
Sinus tachycardia	37	29
Normal	13	10
Elevated lab values		
Troponin	128	90
D-dimer	57	40
Pro B-type natriuretic peptide	65	46
C-reactive Protein	83	59
Normal	4	3

myocarditis: 24.4% exhibited ST elevation, 15% showed diffuse ST elevation, and 29.1% had sinus tachycardia**.** A large majority of patients had elevated troponin levels (90.1%) and a slight majority had elevated C-reactive protein (58.5%). There was no significant difference in imaging presentation related to sex or age of patients (Tables 3 and 4).

A range of therapeutic interventions were employed, including steroids (47.3%), antivirals (20.5%), NSAIDs (41.7%), immunosuppressive drugs (41.1%), anticoagulants (28.8%), inotropes (25.3%), vasopressors (31.5%), and antibiotics (40.4%). Patients with severe cases of myocarditis required lifesaving measures such as extracorporeal membrane oxygenation (ECMO) (28%).

Discussion

Although classic presentations of COVID-19 typically involve respiratory symptoms, it is important for clinicians to be prepared for cardiac manifestations of the disease. The occurrence of myocarditis after COVID-19 infection does not depend on the initial health or pre-existing cardiovascular problems. Myocarditis secondary to COVID-19 can have a silent progression, as it can develop unexpectedly over the course of disease. The severity and complexity of symptoms often depends on the extent of myocardial involvement. Without treatment, complications may occur such as arrhythmia, cardiomyopathy, intracardiac thrombosis, and even death. Based on the data collected, we see that there are several patients who presented with cardiac symptoms alone with a confirmed infection of COVID-19. The exact pathophysiology is unknown, but it is hypothesized that the virus damages the myocardium by attaching to angiotensin-converting enzymes 2 receptors (ACE2) and increases inflammatory cytokine production [2]. Furthermore, myocarditis may arise because of inflammation associated with cytokine storms, autoimmune damage, and inflammation of coronary endothelial cells [3].

ACE2 receptor is a membrane bound protein found in cardiac epithelium and allows SARS-CoV-2 entry into the cell, where it replicates and antagonizes stress granule formation, further promoting cell damage. Systemic inflammation may also contribute to the development of myocarditis. The cytokine IL-6 has been implicated in the pathophysiology of myocarditis by attracting inflammatory cells to the myocardium. It is a key mediator of cytokine storm, a life threatening condition that involves excessive production of proinflammatory cytokines and an uncontrolled immune response, which can further damage the myocardium [4]. Even though the clear pathogenesis of cardiac involvement is still

Table 4 Treatments

Treatments	Total	% (number of cases/ total cases)
Steroids		
Methylprednisolone	40	27.4
Dexamethasone	15	10.3
Prednisone	14	9.6
Anti-virals		
Remdesivir	11	7.5
Chloroquine/ hydroxychloroquine	19	13
NSAIDS		
Colchicine	21	14.4
Aspirin	31	21.2
Ibuprofen	9	6.1
Surgical		
Use of ECMO	28	19.2
Implantable devices	14	9.6
Catheterization	5	3.4
Pericardiocentesis	6	4.1
Immune drugs		
Intravenous immunoglobulin	38	26
Tocilizumab	12	8.2
Interferon	1	0.7
Anakinra	9	6.2
Cardiac drugs		
Use of anticoagulants	42	28.8
Inotropes	37	25.3
Vasopressors	46	31.5
Angiotensin-II receptor blocker	1	0.7
ACE Inhibitor	13	8.9
Beta-blocker	23	15.8
Anti-Arrhythmic	11	7.5
Other		
Diuretics	22	15.1
Unspecified anti-inflammatory	5	3.4
Antibiotics	59	40.4
Unspecified Steroids	15	10.3
Unspecified anti-virals	13	8.9
Hydrocortisone	3	2.1
Acetaminophen	4	2.7
Mineralocorticoid antagonist	2	1.4

ECMO: Extracorporeal membrane oxygenation

unknown, it is proposed that SARS-CoV-2 has the ability to disseminate through blood or lymphatics of the respiratory tract, leading to inflammation and pericardial effusion [5].

Common presenting symptoms observed in individuals with COVID-19 related myocarditis include chest pain, palpitations, shortness of breath, cough, sore throat, and fever. It is important for clinicians to be aware that cardiac symptoms may present alone, without respiratory symptoms, and may appear delayed to the onset of viral infection. COVID-19 related myocarditis typically occurs after the acute phase of infection [6]. A study conducted on over 150,000 US veterans revealed that individuals who have had COVID-19 faced an elevated risk of developing cardiovascular diseases, including myocarditis, 30 days post infection. They adjusted for cofounding variables including demographics and comorbidities. This increase in risk was also observed even in those who did not require hospitalization during the active phase of the infection [7]. In our review, we found that 22% of patients dealt with delayed cardiac presentations after initial infection of COVID-19. As of today, the exact mechanism behind the delayed onset of symptoms in cases of fulminant myocarditis following the resolution of COVID-19 infection is not fully understood. The delayed onset suggests that there may be complex factors contributing to the development of myocarditis in some individuals, potentially involving post viral immune response or some other pathology. Thus, it is crucial to monitor and follow up on patients, especially those with comorbidities, closely to see if any cardiac manifestations arise.

Current treatments for myocarditis are mainly supportive. The American College of Cardiology published their most updated guidelines in treating COVID-19 induced myocarditis in March 2022 [8]. These guidelines, which were written before this analysis, reflect many of the same trends that are observed here, such as the use of cardiovascular magnetic resonance (CMR), ECG, and echocardiogram for diagnosis and anti-inflammatory agents for treatment. While endomyocardial biopsy is considered the gold standard for diagnosing myocarditis, it is often avoided due to its invasive nature. In our review, we see that there is a high survival rate amongst patients who followed these treatment protocols. CMR is a great diagnostic tool for detecting immune mediated myocarditis and is useful in distinguishing between various potential sources of chest pain in individuals affected by COVID-19 [9]. We see here that echocardiogram and CMR are the most commonly used diagnostic tools because they are cost efficient and minimally invasive.

As per the guidelines published by the American College of Cardiology [8], certain abnormalities observed in an electrocardiogram (ECG) and echocardiogram can indicate potential cardiac issues. These abnormalities include diffuse T-wave inversion, ST-segment elevation without reciprocal ST-segment depression, and prolongation of the QRS complex duration on ECG. In this review, the observed ST changes on ECG display a

wide range of patterns. Majority of patients exhibited elevated ST segments (24%) and sinus tachycardia (29%), however diffuse ST elevation, ST depression and T wave inversion were present as well. While elevated ST segments and sinus tachycardia can raise suspicion for fulminant myocarditis, they should be interpreted in conjunction with other clinical findings for a comprehensive assessment. Furthermore, 68% of patients were reported to have reduced left ventricular ejection fraction on echocardiogram which is consistent with findings of myocarditis [8]. There was not consistent documentation on how much the ejection fraction was reduced and how it improved over time. Early detection of echocardiogram and ECG changes indicative of myocarditis allows for timely noninvasive intervention and implementation of appropriate treatment strategies.

COVID-19 myocarditis can often lead to sudden severe complications such as heart failure, hypotension, cardiac shock, and severe arrhythmias. Extracorporeal membrane oxygenation (ECMO) serves as a simplified cardiopulmonary bypass that can be utilized for extended duration of time. ECMO provides temporary respiratory and circulatory support when the heart and lungs are unable to function adequately. In recent years, ECMO has been effectively employed as an emergency adjuvant therapy for acute circulatory and respiratory failures that arise from diverse causes [10]. Our review revealed that patients with severe cases of myocarditis arising from COVID-19 infection did require ECMO (28%). Because our sample size was relatively limited, we were unable to find any specific correlations between the severity of clinical presentation with patient demographics. While ECMO does not directly treat myocarditis, it plays a crucial role in stabilizing hemodynamics, enhancing systemic tissue perfusion, reducing the need for high-dose vasoactive medications, and effectively supporting patients during the acute phase of myocarditis [10]. Available data on the outcomes of patients on veno-arterial ECMO for COVID-19 related complications is limited, but the existing literature suggests that the survival rate for patients on ECMO until hospital discharge falls within 40–45% [11]. The role of ECMO support in managing cardiopulmonary failure resulting from COVID-19 infection is continuously evolving, and a multidisciplinary approach should be used in the decision of ECMO implementation in patients with fulminant myocarditis secondary to COVID-19.

While the current approach to medication management for COVID-19 related myocarditis is primarily focused on providing supportive care, certain patterns have been observed in the treatment. Majority of patients among the cases cited were treated with steroids and NSAIDs, as well as other treatments such as immunosuppressive drugs, anticoagulants, inotropes, vasopressors, and antibiotics. In our review, we observed a trend associated with positive outcomes when treated with these agents. Because glucocorticoids have strong antiinflammatory effects, they can be clinically used in management of myocarditis by potentially preventing excessive inflammation from damaging cardiac tissue. It is important to note that the efficacy of corticosteroids in treating myocarditis is controversial in the literature, with some studies suggesting it has a beneficial effect only in severe COVID-19 [12]. In our review, methylprednisolone, dexamethasone, and prednisone were the most frequently utilized drugs from the glucocorticoid family. The case study from 2022 highlights the use of glucocorticoids in the management of cytokine storm and viral myocyte damage [13]. Intravenous immunoglobulin (IVIG) infusion was the most common choice of immune drug administered to a patient. It has been suggested to potentially improve viral clearance and aid the removal of cytokines contributing to myocardial damage [14]. In viral myocarditis, IL-6 is considered the central mediator of cytokine storm, playing a crucial role in proinflammatory responses from immune cells, including T lymphocytes. Tocilizumab is an immune drug administered, which functions by preventing IL-6 from binding to IL-6 receptor and cell membrane receptor, thereby partially inhibiting the inflammatory cascade in the body [15]. Based on positive outcomes found through this systematic review of cases, administration of corticosteroid treatment and immunosuppressant medications can play a vital part in reducing the severity of inflammatory state associated with COVID-19 myocarditis. Although the use of steroids and NSAIDs were predominant in treatment of COVID-19 related myocarditis, our review also includes cases of patients who were successfully treated with other combinations of drugs such as inotropes, renin–angiotensin–aldosterone system inhibitors, and diuretics.

Limitations

The review's limitations primarily revolve around its reliance on case reports, which introduces selection bias. Due to the nature of case reports, each case's unique clinical presentation created challenges to draw broader conclusions. Additionally, another potential limitation is the risk of missed data since the case reports were not written in a standardized manner. The lack of standardized reporting protocols may have led to variations in the amount and quality of information

provided. Despite the limitations, it is important to highlight that the use of case reports in our review holds value in identifying trends and generating hypotheses. A randomized control trial is recommended to better associate treatments with outcomes.

Conclusion

COVID-19-related myocarditis is a significant cardiac manifestation that clinicians should be prepared to encounter. As of today, there are no definitive treatments available for myocarditis. Because there was a variety of treatments, it was difficult to draw associations between specific treatments to outcomes, warranting further study in this area. Diagnosis of COVID-19 myocarditis relies on various tools such as ECG, echocardiogram, and CMR. Detecting abnormalities in these tests allows for timely intervention and treatment. Based on our review, supportive care appears to serve as the primary approach to treatment of COVID-19 myocarditis, with glucocorticoids and immunosuppressive drugs showing positive outcomes in potentially reducing inflammation. The approach of using extracorporeal membrane oxygenation (ECMO) in severe cases can stabilize hemodynamics and provide critical care during the acute phase of myocarditis. Monitoring and following up on patients, especially those with comorbidities, is crucial to detect any delayed cardiac manifestations. Due to the lack of comprehensive studies on a larger scale, treatment approaches must be personalized on an individual level until further research is conducted.

Appendix

- Gorecka MM, Thirunavukarasu S, Levelt E, Greenwood JP. Progressive myocardial dysfunction following COVID-19. *BMJ Case Rep*. 2021;14(11):e246291. https://doi.org/10.1136/bcr-2021-246291
- Gaine S, Devitt P, Coughlan JJ, Pearson I. COVID-19-associated myocarditis presenting as new-onset heart failure and atrial fibrillation. *BMJ Case Rep*. 2021;14(7):e244027. https://doi.org/10.1136/bcr-2021-244027
- Dalen H, Holte E, Guldal AU, et al. Acute perimyocarditis with cardiac tamponade in COVID-19 infection without respiratory disease. *BMJ Case Rep*. 2020;13(8):e236218. https://doi.org/10.1136/bcr-2020-236218
- Anton-Vazquez V, Byrne L, Anderson L, Hamzah L. COVID-19 cardiac injury and the use of colchicine. *BMJ Case Rep*. 2021;14(2):e241047. https://doi.org/10.1136/bcr-2020-241047
- Houshmand G, Ghorashi SM, Mirrazeghi F, Omidi N. Concomitant active inflammation of myocardium and thyroid, incidental finding in COVID-19 pandemic: A case report. *Clin Case Rep*. 2021;9(10):e04998. https://doi.org/10.1002/ccr3.4998
- Abdulraheem E, Shaikhoun M, Kung D. Severe peripartum cardiomyopathy complicated by COVID-19 infection and small intestinal obstruction. *Clin Case Rep*. 2021;9(7):e04505. https://doi.org/10.1002/ccr3.4505
- Moghimi M, Khodadadi K, Sarvandi M. Clinical patterns of endothelial damage and thrombotic events in two patients with COVID-19: A case report. *Clin Case Rep*. 2021;9(7):e04406. https://doi.org/10.1002/ccr3.4406
- Mansoor A, Chang D, Mitra R. Rhythm, conduction, and ST elevation with COVID-19: Myocarditis or myocardial infarction? *HeartRhythm Case Rep*. 2020;6(10):671–675. https://doi.org/10.1016/j.hrcr.2020.08.001
- Al-Assaf O, Mirza M, Musa A. Atypical presentation of COVID-19 as subclinical myocarditis with persistent high-degree atrioventricular block treated with pacemaker implant. *HeartRhythm Case Rep*. 2020;6(11):884–887. https://doi.org/10.1016/j.hrcr.2020.09.003
- Khalid Y, Dasu N, Dasu K. A case of novel coronavirus (COVID-19)-induced viral myocarditis mimicking a Takotsubo cardiomyopathy. *HeartRhythm Case Rep*. 2020;6(8):473–476. https://doi.org/10.1016/j.hrcr.2020.05.020
- Meel R, Ramsamy TD, Narsing R, Wong M. Focal myocarditis in a young male with SARS-CoV-2 infectionRu. Academic.oup.com. February 15, 2021. Accessed July 2023. https://academic.oup.com/omcr/article/2021/2/omaa142/6136164?searchresult=1.
- Zayour M, Al Ashkar R, Karaki M, Chammas E, Shatila W. Focal myocarditis as the first sign in the presentation of a COVID-19 infection: A case report. *Cureus*. 2022;14(6):e26358. https://doi.org/10.7759/cureus.26358
- Jeon SB. pages 1–77. E-jnc.org. Published 2022. Accessed June 15, 2023. https://e-jnc.org/upload/pdf/JNC_v15n1_full.pdf#page=69
- Pasha MA, Isaac S, Khan Z. Recurrent myocarditis following COVID-19 infection and the mRNA vaccine. *Cureus*. 2022;14(7):e26650. https://doi.org/10.7759/cureus.26650

- Camastra G, Ciolina F, Arcari L, Cacciotti L, Pucci M. Heart and lung fibrosis in a patient with COVID-19-related myocarditis. *J Cardiovasc Echogr*. 2022;32(1):52–53. https://doi.org/10.4103/jcecho.jcecho_43_21
- Malakan Rad E, Momtazmanesh S. COVID-19-induced silent myocarditis and newly developed hypertension in a 3-year-old boy. *Egypt Heart J*. 2022;74(1):44. https://doi.org/10.1186/s43044-022-00282-w
- Thomson A, Totaro R, Cooper W, Dennis M. Fulminant Delta COVID-19 myocarditis: a case report of fatal primary cardiac dysfunction. *Eur Heart J Case Rep*. 2022;6(4):ytac142. https://doi.org/10.1093/ehjcr/ytac142
- Desai C, Aggarwal S, Khan AA. Acute myocarditis secondary to paediatric inflammatory multisystem syndrome temporally associated with COVID-19 infection. *Cureus*. 2022;14(2):e22420. https://doi.org/10.7759/cureus.22420
- Campoamor D, Seixas R, Gama L, Duarte J, Araújo T. Arrhythmogenic cardiomyopathy as a late complication of COVID-19-induced myocarditis. *Cureus*. 2022;14(2):e21941. https://doi.org/10.7759/cureus.21941
- Aldeghaither S, Qutob R, Assanangkornchai N, et al. Clinical and histopathologic features of myocarditis in multisystem inflammatory syndrome (adult)-associated COVID-19. *Crit Care Explor*. 2022;10(2):e0630. https://doi.org/10.1097/CCE.0000000000000630
- Carrasco-Molina S, Ramos-Ruperto L, Ibáñez-Mendoza P, et al. Cardiac involvement in Adult Multisystemic Inflammatory Syndrome related to COVID-19. Two case reports. *J Cardiol Cases*. 2022;26(1):24–27. https://doi.org/10.1016/j.jccase.2022.01.017
- Casavecchia G, Corbo MD, Gravina M, et al. Arrhythmic myocarditis in an adolescent male: A unique presentation of multi-organ inflammatory syndrome (MIS-C). *Am J Emerg Med*. 2022;54:122–126. https://doi.org/10.1016/j.ajem.2022.01.061
- Woods GM, Kim DW, Paden ML, Viamonte HK. Thrombolysis in children: A case report and review of the literature. *Front Pediatr*. 2021;9:814,033. https://doi.org/10.3389/fped.2021.814033
- Salavati E, Hajirezaee H, Niazkar HR, Ramezani MS, Sargazi A. COVID-19 patients may present with myocarditis: A case report emphasizing the cardiac involvement of SARS-CoV-2. *Med J Islam Repub Iran*. 2021;35:104. https://doi.org/10.47176/mjiri.35.104
- Vannella KM, Oguz C, Stein SR, et al. Evidence of SARS-CoV-2-specific T-cell-mediated myocarditis in a MIS-A case. *Front Immunol*. 2021;12:779,026. https://doi.org/10.3389/fimmu.2021.779026
- Edwards JJ, Harris MA, Toib A, Burstein DS, Rossano JW. Asymmetric septal edema masking as hypertrophy in an infant with COVID-19 myocarditis. *Prog Pediatr Cardiol*. 2022;64(101,464):101,464. https://doi.org/10.1016/j.ppedcard.2021.101464
- de la Guía-Galipienso F, García-González P, Fabregat-Andrés O, et al. Cardiac magnetic resonance in the diagnosis of the unusually detected acute myocarditis in the young people: a case report. *AME Case Rep*. 2021;5:35. https://doi.org/10.21037/acr-21-24
- Aggarwal A, Cohen E, Figueira M, et al. Multisystem inflammatory syndrome in an adult with COVID-19-A trial of anakinra: A case report: A case report. *Infect Dis Clin Pract (Baltim Md)*. 2021;29(6):e420-e423. https://doi.org/10.1097/IPC.0000000000001028
- Kwon S, Alter E, Bangalore S, Nolan A. COVID-19 myocarditis: A case report, overview of diagnosis and treatment. *Infect Dis Clin Pract (Baltim Md)*. 2021;29(6):e414-e417. https://doi.org/10.1097/IPC.0000000000001016
- Fiore G, Sanvito F, Fragasso G, Spoladore R. Case report of cardiogenic shock in COVID-19 myocarditis: peculiarities on diagnosis, histology, and treatment. *Eur Heart J Case Rep*. 2021;5(10):ytab357. https://doi.org/10.1093/ehjcr/ytab357
- Bemtgen X, Klingel K, Hufnagel M, et al. Case report: Lymphohistiocytic myocarditis with severe cardiogenic shock requiring mechanical cardiocirculatory support in multisystem Inflammatory Syndrome following SARS-CoV-2 infection. *Front Cardiovasc Med*. 2021;8:716,198. https://doi.org/10.3389/fcvm.2021.716198
- Le CK, Nguyen MB, Vo AT. ST-elevation in an adolescent with COVID-19: Myopericarditis or myocardial infarction? *Am J Emerg Med*. 2022;52:271.e1-271.e3. https://doi.org/10.1016/j.ajem.2021.08.068
- Shah HP, Frye R, Chang S, Faherty E, Steele J, Karnik R. Challenges of diagnosing viral myocarditis in adolescents in the era of COVID-19 and MIS-C. *Case Rep Pediatr*. 2021;2021:4,797,498. https://doi.org/10.1155/2021/4797498
- Singh M, Mehta N, Hayat F, et al. Recurrent chest pain after COVID-19: Diagnostic utility of cardiac magnetic resonance imaging. *CJC Open*. 2022;4(1):100–104. https://doi.org/10.1016/j.cjco.2021.08.003

- Ishikura H, Maruyama J, Hoshino K, et al. Coronavirus disease (COVID-19) associated delayed-onset fulminant myocarditis in patient with a history of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. *J Infect Chemother*. 2021;27(12):1760–1764. https://doi.org/10.1016/j.jiac.2021.08.007
- Nedeljkovic IP, Giga V, Ostojic M, et al. Focal myocarditis after mild COVID-19 infection in athletes. *Diagnostics (Basel)*. 2021;11(8):1519. https://doi.org/10.3390/diagnostics11081519
- Fatmi SS, Basso R, Liaqat A, Tariq F, Swamiappan R. COVID-19 myocarditis: Rationale for early diagnosis and intervention. *Cureus*. 2021;13(7):e16494. https://doi.org/10.7759/cureus.16494
- De Stefano D, Parillo M, Garipoli A, Beomonte Zobel B. Imaging findings in a case of myo-pericarditis associated with SARS CoV-2 disease. *J Cardiol Cases*. 2021;24(5):210–214. https://doi.org/10.1016/j.jccase.2021.07.006
- Meyer M, Vogel T, Meyer A, et al. Presence of active myocarditis at the 6 month follow-up appointment for a severe form of COVID-19: a case report. *ESC Heart Fail*. 2021;8(5):4307–4312. https://doi.org/10.1002/ehf2.13461
- Al-Falahi Z, Al-Harthi S, Farhan H, Al Busaidi I, Al Alawi AM. Late-onset COVID-19-related multisystem inflammatory syndrome in a middle-aged man. *Cureus*. 2021;13(6):e15855. https://doi.org/10.7759/cureus.15855
- Ghafoor K, Ahmed A, Abbas M. Fulminant myocarditis with ST elevation and cardiogenic shock in a SARS-CoV-2 patient. *Cureus*. 2021;13(7):e16149. https://doi.org/10.7759/cureus.16149
- Okor I, Sleem A, Zhang A, Kadakia R, Bob-Manuel T, Krim SR. Suspected COVID-19-induced myopericarditis. *Ochsner J*. 2021;21(2):181–186. https://doi.org/10.31486/toj.20.0090
- Farooqi A, Tahir N, Parkash O, Ying GW, Zahra F. SARS-CoV-2 myocarditis due to severe obesity. *Cureus*. 2021;13(5):e15074. https://doi.org/10.7759/cureus.15074
- Osorio Martínez A, González-Razo VT, Navarro-Sánchez V, Souto Meiriño CA, Ahumada-Ayala M. SARS-CoV-2-related subacute thyroiditis, myocarditis, and hepatitis after full resolution of COVID-19 serum markers. *Am J Case Rep*. 2021;22:e932321. https://doi.org/10.12659/AJCR.932321
- Egas D, Guadalupe JJ, Prado-Vivar B, et al. SARS-CoV-2 detection and sequencing in heart tissue associated with myocarditis and persistent arrhythmia: A case report. *IDCases*. 2021;25(e01187):e01187. https://doi.org/10.1016/j.idcr.2021.e01187
- Sivalokanathan S, Foley M, Cole G, Youngstein T. Gastroenteritis and cardiogenic shock in a healthcare worker: a case report of COVID-19 myocarditis confirmed with serology. *Eur Heart J Case Rep*. 2021;5(2):ytab013. https://doi.org/10.1093/ehjcr/ytab013
- Kallel O, Bourouis I, Bougrine R, Housni B, El Ouafi N, Ismaili N. Acute myocarditis related to Covid-19 infection: 2 cases report. *Ann Med Surg (Lond)*. 2021;66(102,431):102,431. https://doi.org/10.1016/j.amsu.2021.102431
- Das BB. SARS-CoV-2 myocarditis in a high school athlete after COVID-19 and its implications for clearance for sports. *Children (Basel)*. 2021;8(6):427. https://doi.org/10.3390/children8060427
- Ghugre NR, Orbach A, Biswas L, et al. Suspected subclinical myocarditis detected by cardiac magnetic resonance imaging late post COVID-19 recovery. *J Cardiol Cases*. 2021;24(5):203–205. https://doi.org/10.1016/j.jccase.2021.04.014
- Pérez-Acosta G, Santana-Cabrera L, Blanco-López J, Martín-González JC. COVID-19 myopericarditis: A case report. *Rev Clin Esp (Barc)*. 2021;221(5):312–313. https://doi.org/10.1016/j.rceng.2020.11.004
- Rasras H, Boudihi A, Hbali A, Ismaili N, Ouafi NE. Multiple cardiovascular complications of COVID-19 infection in a young patient: a case report. *Pan Afr Med J*. 2021;38:192. https://doi.org/10.11604/pamj.2021.38.192.27471
- Pascariello G, Cimino G, Calvi E, et al. Cardiogenic shock due to COVID-19-related myocarditis in a 19-year-old autistic patient. *J Med Cases*. 2020;11(7):207–210. https://doi.org/10.14740/jmc3
- Menter T, Cueni N, Gebhard EC, Tzankov A. Case report: Co-occurrence of myocarditis and thrombotic microangiopathy limited to the heart in a COVID-19 patient. *Front Cardiovasc Med*. 2021;8:695,010. https://doi.org/10.3389/fcvm.2021.695010
- Hu H, Ma F, Wei X, Fang Y. Coronavirus fulminant myocarditis treated with glucocorticoid and human immunoglobulin. *Eur Heart J*. 2021;42(2):206. https://doi.org/10.1093/eurheartj/ehaa190
- Uchida M, Kashima Y, Mochizuki K, et al. Multisystem inflammatory syndrome in children—A new syndrome complicated with acute heart failure following severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) infection. *Circ J*. 2021;85(6):948–952. https://doi.org/10.1253/circj.CJ-21-0243

- Abdelazeem B, Borcheni M, Alnaimat S, Mallikethi-Reddy S, Sulaiman A. Persistent cardiac magnetic resonance imaging features of myocarditis detected months after COVID-19 infection. *Cureus*. 2021;13(4):e14250. https://doi.org/10.7759/cureus.14250
- Gaudriot B, Mansour A, Thibault V, et al. Successful heart transplantation for COVID-19-associated post-infectious fulminant myocarditis. *ESC Heart Fail*. 2021;8(4):2625–2630. https://doi.org/10.1002/ehf2.13326
- Taouihar S, Bouabdallaoui A, Aabdi M, et al. ST elevation revealing acute myocarditis with SARS cov 2 infection: Case report. *Ann Med Surg (Lond)*. 2021;65(102,313):102,313. https://doi.org/10.1016/j.amsu.2021.102313
- Nikoo MH, Mozaffari R, Hatamnejad MR, Bazrafshan M, Kasaei M, Bazrafshan H. Systolic dysfunction and complete heart block as complications of fulminant myocarditis in a recovered COVID-19 patient. *J Cardiol Cases*. 2021;24(4):177–181. https://doi.org/10.1016/j.jccase.2021.03.009
- Tung-Chen Y, Algora-Martín A, Rodríguez-Roca S, Díaz de Santiago A. COVID-19 multisystemic inflammatory syndrome in adults: a not to be missed diagnosis. *BMJ Case Rep*. 2021;14(4):e241696. https://doi.org/10.1136/bcr-2021-241696
- Valitutti F, Verde A, Pepe A, et al. Multisystem inflammatory syndrome in children. An emerging clinical challenge for pediatric surgeons in the COVID 19 era. *J Pediatr Surg Case Rep*. 2021;69(101,838):101,838. https://doi.org/10.1016/j.epsc.2021.101838
- Servato ML, Valente FX, García-Moreno LG, et al. Intraventricular conundrum in a SARS-CoV-2-positive patient with elevated biomarkers of myocardial injury. *JACC Case Rep*. 2021;3(4):566–572. https://doi.org/10.1016/j.jaccas.2021.01.030
- Sollie ZW, Vallepu SR, Tharumia Jagadeesan C, White LC, Nagalapuram V. Challenges in managing pericardial disease related to post viral syndrome after COVID-19 infection. *Cureus*. 2021;13(2):e13461. https://doi.org/10.7759/cureus.13461
- Meizinger C, Klugherz B. Focal ST-segment elevation without coronary occlusion: myocardial infarction with no obstructive coronary atherosclerosis associated with COVID-19-a case report. *Eur Heart J Case Rep*. 2021;5(2):ytaa532. https://doi.org/10.1093/ehjcr/ytaa532
- Tomlinson LG, Cohen MI, Levorson RE, Tzeng MB. COVID-19-associated multisystem inflammatory syndrome in children presenting uniquely with sinus node dysfunction in the setting of shock. *Cardiol Young*. 2021;31(7):1202–1204. https://doi.org/10.1017/S1047951121000035
- Purdy A, Ido F, Sterner S, Tesoriero E, Matthews T, Singh A. Myocarditis in COVID-19 presenting with cardiogenic shock: a case series. *Eur Heart J Case Rep*. 2021;5(2):ytab028. https://doi.org/10.1093/ehjcr/ytab028
- Ruiz JG, Kandah F, Dhruva P, Ganji M, Goswami R. Case of Coronavirus disease 2019 myocarditis managed with biventricular Impella support. *Cureus*. 2021;13(2):e13197. https://doi.org/10.7759/cureus.13197
- Della Paolera S, Valencic E, Piscianz E, et al. Case report: Use of anakinra in Multisystem Inflammatory Syndrome during COVID-19 pandemic. *Front Pediatr*. 2020;8:624,248. https://doi.org/10.3389/fped.2020.624248
- Shah JZ, Kumar SA, Patel AA. Myocarditis and pericarditis in patients with COVID-19. *Heart Views*. 2020;21(3):209–214. https://doi.org/10.4103/HEARTVIEWS.HEARTVIEWS_154_20
- Sheikh AB, Javed N, Sheikh AAE, Upadhyay S, Shekhar R. Diabetes insipidus and concomitant myocarditis: A late sequelae of COVID-19 infection. *J Investig Med High Impact Case Rep*. 2021;9:2,324,709,621,999,954. https://doi.org/10.1177/2324709621999954
- Tseng YS, Herron C, Garcia R, Cashen K. Sustained ventricular tachycardia in a paediatric patient with acute COVID-19 myocarditis. *Cardiol Young*. 2021;31(9):1510–1512. https://doi.org/10.1017/S1047951121000792
- Gioia MA, Okunade A, Friedman A, Ahmed MF, Syed RA. A case of myopericarditis and cardiac tamponade as the initial presentation of COVID-19 infection. *Cureus*. 2021;13(1):e12967. https://doi.org/10.7759/cureus.12967
- Yeleti R, Guglin M, Saleem K, et al. Fulminant myocarditis: COVID or not COVID? Reinfection or co-infection? *Future Cardiol*. 2021;17(8):1307–1311. https://doi.org/10.2217/fca-2020-0237
- Milla-Godoy GC, Park R, Jiang W, Hartkopf MW, Treadwell T. Fulminant COVID-19-associated myocarditis in an otherwise healthy female. *Cureus*. 2021;13(1):e12736. https://doi.org/10.7759/cureus.12736
- Papageorgiou JM, Almroth H, Törnudd M, van der Wal H, Varelogianni G, Lawesson SS. Fulminant myocarditis in a COVID-19 positive patient treated with mechanical circulatory support—a case report. *Eur Heart J Case Rep*. 2021;5(2):ytaa523. https://doi.org/10.1093/ehjcr/ytaa523

- Thrupthi K, Ganti A, Acherjee T, Mehmood MA, Vakde T. A rare case of acute pericarditis due to SARS-CoV-2 managed with aspirin and colchicine. *Cureus*. 2021;13(1):e12534. https://doi.org/10.7759/cureus.12534
- Fadiran O. An atypical case of COVID-19 induced pancytopenia, rhabdomyolysis and myocarditis. *Cureus*. 2021;13(1):e12455. https://doi.org/10.7759/cureus.12455
- Volis I, Livneh I, Hussein K, Raz-Pasteur A. COVID-19-associated suspected myocarditis as the etiology for recurrent and protracted fever in an otherwise healthy adult. *Am J Med Sci*. 2021;361(4):522–525. https://doi.org/10.1016/j.amjms.2020.11.001
- Cirks BT, Rowe SJ, Jiang SY, et al. Sixteen weeks later: Expanding the risk period for multisystem inflammatory syndrome in children. *J Pediatric Infect Dis Soc*. 2021;10(5):686–690. https://doi.org/10.1093/jpids/piab007
- Özturan İU, Köse B, Özkan B, Köse A. Myopericarditis caused by severe acute respiratory syndrome coronavirus 2. *Clin Exp Emerg Med*. 2020;7(4):326–329. https://doi.org/10.15441/ceem.20.109
- Hudowenz O, Klemm P, Lange U, et al. Case report of severe PCR-confirmed COVID-19 myocarditis in a European patient manifesting in mid January 2020. *Eur Heart J Case Rep*. 2020;4(6):1–6. https://doi.org/10.1093/ehjcr/ytaa286
- Henwood M, Lake D, Allen F, Sange M. Myocarditis in SARS-CoV-2 negative patients with suspected preceding infection. *BMJ Case Rep*. 2021;14(1):e239513. https://doi.org/10.1136/bcr-2020-239513
- Sauer F, Dagrenat C, Couppie P, Jochum G, Leddet P. Pericardial effusion in patients with COVID-19: case series. *Eur Heart J Case Rep*. 2020;4(FI1):1–7. https://doi.org/10.1093/ehjcr/ytaa287
- Iqbal QZ, Haider MA, Sattar SBA, Hanif M, Javid I. COVID-19 induced myocarditis: A rare cause of heart failure. *Cureus*. 2020;12(11):e11690. https://doi.org/10.7759/cureus.11690
- Ciuca C, Fabi M, Di Luca D, et al. Myocarditis and coronary aneurysms in a child with acute respiratory syndrome coronavirus 2. *ESC Heart Fail*. 2021;8(1):761–765. https://doi.org/10.1002/ehf2.13048
- Ali A, Khattak MF, Khan MW. COVID-19 pneumonia: ST-segment elevation myocardial infarction (STEMI) and myocarditis. *Cureus*. 2020;12(12):e11901. https://doi.org/10.7759/cureus.11901
- Niño-Taravilla C, Espinosa-Vielma YP, Otaola-Arca H, Poli-Harlowe C, Tapia LI, Ortiz-Fritz P. Pediatric Inflammatory Multisystem Syndrome temporally associated with SARS-CoV-2 treated with Tocilizumab. *Pediatr Rep*. 2020;12(3):142–148. https://doi.org/10.3390/pediatric12030029
- Gulersen M, Staszewski C, Grayver E, et al. Coronavirus disease 2019 (COVID-19)-related multisystem inflammatory syndrome in a pregnant woman. *Obstet Gynecol*. 2021;137(3):418–422. https://doi.org/10.1097/AOG.0000000000004256
- Tiwary T, Baiswar S, Jinnur P. A rare case of COVID-19 myocarditis with cardiac tamponade in a young diabetic adult with renal failure. *Cureus*. 2020;12(11):e11632. https://doi.org/10.7759/cureus.11632
- Caraffa R, Marcolongo R, Bottio T, et al. Recurrent autoimmune myocarditis in a young woman during the coronavirus disease 2019 pandemic. *ESC Heart Fail*. 2021;8(1):756–760. https://doi.org/10.1002/ehf2.13028
- Othenin-Girard A, Regamey J, Lamoth F, et al. Multisystem inflammatory syndrome with refractory cardiogenic shock due to acute myocarditis and mononeuritis multiplex after SARS-CoV-2 infection in an adult. *Swiss Med Wkly*. 2020;150(4546):w20387. https://doi.org/10.4414/smw.2020.20387
- Beaudry JT, Dietrick B, Lammert DB, et al. Fatal SARS-CoV-2 inflammatory syndrome and myocarditis in an adolescent: A case report: A case report. *Pediatr Infect Dis J*. 2021;40(2):e72-e76. https://doi.org/10.1097/INF.0000000000002978
- Singhavi R, Sharma K, Desai HD, Patel R, Jadeja D. A case of hemolytic anemia with acute myocarditis and cardiogenic shock: A rare presentation of COVID-19. *Cureus*. 2020;12(9):e10657. https://doi.org/10.7759/cureus.10657
- Fischer Q, Brillat-Savarin N, Ducrocq G, Ou P. Case report of an isolated myocarditis due to COVID-19 infection in a paediatric patient. *Eur Heart J Case Rep*. 2020;4(FI1):1–5. https://doi.org/10.1093/ehjcr/ytaa180
- Li A, Garcia-Bengochea Y, Stechel R, Azari BM. Management of COVID-19 myopericarditis with reversal of cardiac dysfunction after blunting of cytokine storm: a case report. *Eur Heart J Case Rep*. 2020;4(FI1):1–6. https://doi.org/10.1093/ehjcr/ytaa224
- Bernal-Torres W, Herrera-Escandón Á, Hurtado-Rivera M, Plata-Mosquera CA. COVID-19 fulminant myocarditis: a case report. *Eur Heart J Case Rep*.

2020;4(FI1):1–6. https://doi.org/10.1093/ehjcr/ytaa212

- Trpkov C, MacMullan P, Feuchter P, et al. Rapid response to cytokine storm inhibition using anakinra in a patient with COVID-19 myocarditis. *CJC Open*. 2021;3(2):210–213. https://doi.org/10.1016/j.cjco.2020.10.003
- Gay HC, Sinha A, Michel E, et al. Fulminant myocarditis in a patient with coronavirus disease 2019 and rapid myocardial recovery following treatment. *ESC Heart Fail*. 2020;7(6):4367–4370. https://doi.org/10.1002/ehf2.13041
- Jain S, Nolan SM, Singh AR, et al. Myocarditis in multisystem inflammatory syndrome in children associated with Coronavirus disease 2019. *Cardiol Rev*. 2020;28(6):308–311. https://doi.org/10.1097/CRD.0000000000000341
- Mansoor A, Chang D, Mitra R. Rhythm, conduction, and ST elevation with COVID-19: Myocarditis or myocardial infarction? *HeartRhythm Case Rep*. 2020;6(10):671–675. https://doi.org/10.1016/j.hrcr.2020.08.001
- Garot J, Amour J, Pezel T, et al. SARS-CoV-2 fulminant myocarditis. *JACC Case Rep*. 2020;2(9):1342–1346. https://doi.org/10.1016/j.jaccas.2020.05.060
- Richard I, Robinson B, Dawson A, Aya A, Ali R. An atypical presentation of fulminant myocarditis secondary to COVID-19 infection. *Cureus*. 2020;12(7):e9179. https://doi.org/10.7759/cureus.9179
- Cogan E, Foulon P, Cappeliez O, Dolle N, Vanfraechem G, De Backer D. Multisystem inflammatory syndrome with complete Kawasaki disease features associated with SARS-CoV-2 infection in a young adult. A case report. *Front Med (Lausanne)*. 2020;7:428. https://doi.org/10.3389/fmed.2020.00428
- Salamanca J, Díez-Villanueva P, Martínez P, et al. COVID-19 "fulminant myocarditis" successfully treated with temporary mechanical circulatory support. *JACC Cardiovasc Imaging*. 2020;13(11):2457–2459. https://doi.org/10.1016/j.jcmg.2020.05.003
- Khatri A, Wallach F. Coronavirus disease 2019 (Covid-19) presenting as purulent fulminant myopericarditis and cardiac tamponade: A case report and literature review. *Heart Lung*. 2020;49(6):858–863. https://doi.org/10.1016/j.hrtlng.2020.06.003
- Gnecchi M, Moretti F, Bassi EM, et al. Myocarditis in a 16-year-old boy positive for SARS-CoV-2. *Lancet*. 2020;395(10,242):e116. https://doi.org/10.1016/S0140-6736(20)31,307-6
- Kesici S, Aykan HH, Orhan D, Bayrakci B. Fulminant COVID-19-related myocarditis in an infant. *Eur Heart J*. 2020;41(31):3021. https://doi.org/10.1093/eurheartj/ehaa515
- Beşler MS, Arslan H. Acute myocarditis associated with COVID-19 infection. *Am J Emerg Med*. 2020;38(11):2489.e1-2489.e2. https://doi.org/10.1016/j.ajem.2020.05.100
- Trogen B, Gonzalez FJ, Shust GF. COVID-19-associated myocarditis in an adolescent. *Pediatr Infect Dis J*. 2020;39(8):e204-e205. https://doi.org/10.1097/INF.0000000000002788
- Giacomet V, Manfredini VA, Meraviglia G, et al. Acute inflammation and elevated cardiac markers in a two-month-old infant with severe acute respiratory syndrome Coronavirus 2 infection presenting with cardiac symptoms. *Pediatr Infect Dis J*. 2020;39(7):e149-e151. https://doi.org/10.1097/INF.0000000000002750
- Oberweis ML, Codreanu A, Boehm W, et al. Pediatric life-threatening Coronavirus disease 2019 with myocarditis. *Pediatr Infect Dis J*. 2020;39(7):e147-e149. https://doi.org/10.1097/INF.0000000000002744
- Doyen D, Moceri P, Ducreux D, Dellamonica J. Myocarditis in a patient with COVID-19: a cause of raised troponin and ECG changes. *Lancet*. 2020;395(10,235):1516. https://doi.org/10.1016/S0140-6736(20)30,912-0
- Tavazzi G, Pellegrini C, Maurelli M, et al. Myocardial localization of coronavirus in COVID-19 cardiogenic shock: COVID-19 does not spare the heart. *Eur J Heart Fail*. 2020;22(5):911–915. https://doi.org/10.1002/ejhf.1828
- Shahrami B, Davoudi-Monfared E, Rezaie Z, et al. Management of a critically ill patient with COVID-19-related fulminant myocarditis: A case report. Respir Med Case Rep. 2022;36(101,611):101,611. https://doi.org/10.1016/j.rmcr.2022.101611davi
- Grueva Nastevska E, Kotlar I, Kandic E, et al. Fulminant Myocarditis in Covid 19 -Case report. https://doi.org/10.33320/maced.pharm.bull.2021.67.01.009
- Rajpal S, Kahwash R, Tong MS, et al. Fulminant myocarditis following SARS-CoV-2 infection: JACC patient care pathways. J Am Coll Cardiol. 2022;79(21):2144–2152. https://doi.org/10.1016/j.jacc.2022.03.346
- Devi S, Kar N, Bhuniya S, Behera A, Kapardar B. Severe COVID-19 pneumonia associated with transient complete heart block and myocarditis: A

case report. Authorea Preprints. Published online 2022. https://doi.org/10.22541/au.164864634.49885855/v1
- Hasan MN, Afzal A, Sami CA, Chowdhury FR, Faruque DEMM. A young lady with myopericarditis: An unusual presentation of COVID-19 infection. Cureus. 2022;14(7):e26673. https://doi.org/10.7759/cureus.26673
- Shabbir A, Camm CF, Elkington A, et al. Myopericarditis and myositis in a patient with COVID-19: a case report. Eur Heart J Case Rep. 2020;4(6):1–6. https://doi.org/10.1093/ehjcr/ytaa370
- Mirabella S, Bansode O, Mashaal H, Akella J. COVID-19 Suspected myopericarditis without pulmonary involvement. *Heart Lung*. 2022;51:14–16. https://doi.org/10.1016/j.hrtlng.2021.10.00
- Mejia EJ, O'Connor MJ, Mavroudis CD, et al. Successful treatment of fulminant myocarditis with intracardiac thrombus in COVID-19. *J Heart Lung Transplant*. 2022;41(4):S521. https://doi.org/10.1016/j.healun.2022.01.1320
- Paul JF, Charles P, Richaud C, Caussin C, Diakov C. Myocarditis revealing COVID-19 infection in a young patient. *Eur Heart J Cardiovasc Imaging*. 2020;21(7):776. https://doi.org/10.1093/ehjci/jeaa107
- Menter T, Cueni N, Gebhard EC, Tzankov A. Case report: Co-occurrence of myocarditis and thrombotic microangiopathy limited to the heart in a COVID-19 patient. *Front Cardiovasc Med*. 2021;8:695,010. https://doi.org/10.3389/fcvm.2021.695010
- Hu H, Ma F, Wei X, Fang Y. Coronavirus fulminant myocarditis treated with glucocorticoid and human immunoglobulin. *Eur Heart J*. 2021;42(2):206. https://doi.org/10.1093/eurheartj/ehaa190
- Yan L, Mir M, Sanchez P, et al. COVID-19 in a Hispanic woman. Arch Pathol Lab Med. 2020;144(9):1041–1047. https://doi.org/10.5858/arpa.2020-0217-sa
- Kamarullah W, Nurcahyani, Mary Josephine C, Bill Multazam R, Ghaezany Nawing A, Dharma S. Corticosteroid therapy in management of myocarditis associated with COVID-19; A systematic review of current evidence. Arch Acad Emerg Med. 2021;9(1):e32. https://doi.org/10.22037/aaem.v9i1.1153
- Haussner, William, et al. "COVID-19 associated myocarditis: A systematic review." *American Journal of Emergency Medicine*, vol. 51, 2 Oct. 2021, pp. 150–155.
- Naneishvili T, Khalil A, O'Leary R, Prasad N. Fulminant myocarditis as an early presentation of SARS-CoV-2. *BMJ Case Rep*. 2020;13(9):e237553. https://doi.org/10.1136/bcr-2020-237553
- Henwood M, Lake D, Allen F, Sange M. Myocarditis in SARS-CoV-2 negative patients with suspected preceding infection. *BMJ Case Rep*. 2021;14(1):e239513. https://doi.org/10.1136/bcr-2020-239513

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Author contributions
VL and GT performed the initial identification and review of literature. VL, GT, and EA interpreted the case reports, were major contributors to writing the manuscript, and prepared figures. MD contributed significantly to the conception, design, and revision of this work. All authors have read and approved the final manuscript.

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References
1. "Association between COVID-19 and Myocarditis Using Hospital-Based Administrative Data - United States, March 2020–January 2021." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 2 Sept. 2021, www.cdc.gov/mmwr/volumes/70/wr/mm7035e5.htm.
2. Sawalha K, Abozenah M, Kadado AJ, Battisha A, Al-Akchar M, Salerno C, Hernandez-Montfort J, Islam AM. Systematic review of COVID-19 related myocarditis: insights on management and outcome. Cardiovasc Revasc Med. 2021;23:107–13. https://doi.org/10.1016/j.carrev.2020.08.028.
3. Ismayl M, Abusnina W, Thandra A, et al. Delayed acute myocarditis with COVID-19 infection. Proc (Bayl Univ Med Cent). 2022;35(3):366–8. https://doi.org/10.1080/08998280.2022.2030189.
4. Siripanthong B, Nazarian S, Muser D, et al. Recognizing COVID-19-related myocarditis: the possible pathophysiology and proposed guideline for diagnosis and management. Heart Rhythm. 2020;17(9):1463–71. https://doi.org/10.1016/j.hrthm.2020.05.001.
5. Cairns L, Abed El Khaleq Y, Storrar W, Scheuermann-Freestone M. COVID-19 myopericarditis with cardiac tamponade in the absence of respiratory symptoms: a case report. J Med Case Rep. 2021;15(1):31. https://doi.org/10.1186/s13256-020-02618-z.
6. Sayegh MN, Goins AE, Hall MAK, Shin YM. Presentations, diagnosis, and treatment of post-COVID viral myocarditis in the inpatient setting: a

narrative review. Cureus. 2023;15(5): e39338. https://doi.org/10.7759/cureus.39338.
7. Xie Y, Xu E, Bowe B, Al-Aly Z. Long-term cardiovascular outcomes of COVID-19. Nat Med. 2022;28:583–90. https://doi.org/10.1038/s41591-022-01689-3.
8. Gluckman T, Bhave N, et al. 2022 ACC expert consensus decision pathway on cardiovascular sequelae of COVID-19 in adults: myocarditis and other myocardial involvement, post-acute sequelae of SARS-CoV-2 infection, and return to play. J Am Coll Cardiol. 2022;79(17):1717–56.
9. Hatipoglu S, Lyon AR, Pennell DJ. CMR unveiling the cause of post CoVid-19 infection chest pain. Int J Cardiovasc Imaging. 2021;37(6):2025–6. https://doi.org/10.1007/s10554-021-02161-y.
10. Zhao F, Shi G, Wu Z, Guo Z. A successful rescue of juvenile fulminant myocarditis by extracorporeal membrane oxygenation combined with intra-aortic balloon pump: a case report. Ann Transl Med. 2021;9(16):1355. https://doi.org/10.21037/atm-21-3959
11. Buitrago DH, Munoz J, Finkelstein ER, Mulinari L. A case of fulminant myocarditis due to COVID-19 in an adolescent patient successfully treated with venous arterial ECMO as a bridge to recovery. J Card Surg. 2022;37(5):1439–43. https://doi.org/10.1111/jocs.16313.
12. Haussner W et al. COVID-19 associated myocarditis: a systematic review. Am J Emergency Med, 2021, 51: 150–155.
13. Vu VH, Nguyen MTT, Nguyen KD, Pham TTH, Truong BQ. A case of COVID-19-induced delayed-onset myocarditis. Am J Case Rep. 2022;23:e935577. https://doi.org/10.12659/AJCR.935577
14. Shahrami B, Davoudi-Monfared E, Rezaie Z, et al. Management of a critically ill patient with COVID-19-related fulminant myocarditis: a case report. Respir Med Case Rep. 2022;36(101611): 101611. https://doi.org/10.1016/j.rmcr.2022.101611davi.
15. Sadremomtaz A, Hashemi J, Sahebnasagh A, et al. A possible guide as a tool to complementary effects of new Coronavirus. Arch Anesthesia Critic Care. 2021. https://doi.org/10.18502/aacc.v7i4.7633

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