

Angiographic Findings in COVID-19 Patients Presenting with ST-elevation Myocardial Infarction

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Abstract:

Background: Even though viral pneumonia is the most common clinical manifestation of COVID-19, myocardial injury is also common and can have a variety of causes, including myocardial infarction. Our goal is to examine the results of invasive coronary angiography (ICA) in COVID-19 patients who present with ST-elevation myocardial infarction (STEMI).

Methods: Twenty-six consecutive patients confirmed to have COVID-19 and STEMI were screened from October 2020 to October 2022. Emergent invasive strategy (primary PCI [PPCI]) was done in 22 cases, whereas the remaining patients treated medically were excluded.

Results: Almost one third of patients (31.8%) who underwent PPCI had non-obstructed coronary arteries on invasive angiography (labelled MINOCA).

Conclusion: Atypical MI-like presentations are common in COVID-19 patients, including the absence of a culprit coronary lesion (referred to as MINOCA). These unusual manifestations suggest that myocyte damage may be caused by causes other than the cessation of coronary artery flow. Additional research, including cardiac MRI, is necessary to clarify those pathways.

Keywords: COVID-19, Myocardial infarction (MI), Myocardial infarction with no obstructive coronary artery (MINOCA), Invasive coronary angiography (ICA).

1. Introduction:

Among patients with COVID-19, there is a high prevalence of cardiovascular disease (CVD), particularly in critically ill patients (1). COVID-19 can worsen underlying CVD and even precipitate de novo cardiac complications by varying mechanisms (2). The current study aimed to identify the type of coronary lesions in COVID-19 patients presenting with STEMI through assessment by invasive coronary angiography (ICA).

2. Methods

This descriptive study prospectively enrolled 22 consecutive COVID-19 patients presenting to Assiut University Hospitals from October 2020 to October 2022 with ST-elevation myocardial infarction (STEMI) who underwent primary PCI (PPCI).

Patients had to satisfy the prespecified inclusion and exclusion criteria.

The study protocol was approved by the local Ethics Board of Assiut University (IRB no: 17101302). Verbal consent was acquired before PPCI per our institution's standard of care for acute STEMI cases.

2.1. Inclusion Criteria

- Patients presenting with symptoms and an ECG indicative of acute STEMI (3), and
- COVID-19 symptoms developed within 48 hours of hospital admission & are confirmed by reverse transcription-polymerase chain reaction (RT-PCR) or COVID-19 IgM antibodies (Abs) to have COVID-19.

2.2.

2.3.Exclusion Criteria

- Initial concomitant COVID-19 symptoms were treated by thrombolysis.
- History of previous diagnosis of MI or myocarditis.
- History of previous PCI in the infarct-related artery.
- Patients who refused the procedure.

2.4.Sample Size Calculation

The study included all comers who satisfied the inclusion criteria within the prespecified enrollment period (October 2020 to October 2022).

2.5.Testing for COVID-19

Testing was done with either COVID-19 antibodies (IgM) or RT-PCR. For RT-PCR, a sample was collected from the patient's nose or throat and treated to extract only the RNA in the sample. The turnaround time to deliver the results was about 24 hours.

2.6.Initial Assessment and ECG Triage

Demographic and clinical data were collected, including age, sex, risk factors for atherosclerotic cardiovascular disease, and symptoms of COVID-19 infection, if any were present. KILLIP class was noted as per the classification (4).

A 12-lead surface ECG was obtained to confirm the diagnosis of STEMI (5).

Laboratory investigations were withdrawn, including myocardial injury biomarkers.

Renal chemistry, liver function tests, CBC, CRP, lipid profile, serum ferritin, ESR, and D-Dimer were also withdrawn.

2.7.Revascularization for STEMI Patients
PPCI was performed as per the standard procedure.

2.8.Echocardiography

Echocardiography was done at baseline. Any Segmental wall motion abnormalities (SWMA) were noted, in addition to assessment of left ventricular (LV) systolic function by M-mode across the mid-LV.

2.9.Statistical Analysis

All statistical calculations were done using SPSS (Statistical Package for the Social Sciences; SPSS Inc., Chicago, IL, USA) version 22. Data were statistically described in terms of mean $\pm$ standard deviation ($\pm$ SD), or median and IQR when not normally distributed, frequencies (number of cases), and relative frequencies (percentages) when appropriate. Comparison of quantitative variables was done using the Student-t test for normally distributed data and the Mann-Whitney U test for non-normally distributed data. For comparing categorical data, Chi square (χ^2) test was performed. The exact test was used when the expected frequency was less than 5. The P-value is always two-tailed and set significantly at the 0.05 level.

3. Results

The baseline characteristics of the enrolled patients are summarized in **Table 1**.

	MINOCA (N=7)	STEMI (N=15)	P- value
Age (years)	29 (27.5 – 46.5)	45.2 (32.5 - 52)	0.1091
Gender			0.9522
Female	1.0 (14.3%)	2.0 (13.3%)	
Male	6.0 (85.7%)	13.0 (86.7%)	
HTN	1.0 (14.3%)	3.0 (20.0%)	0.7462
DM	1.0 (14.3%)	1.0 (6.7%)	0.5632
Smoking	3.0 (42.9%)	7.0 (46.7%)	0.1412
FH of CAD	1.0 (14.3%)	0.0 (0.0%)	0.1342
Previous Vascular event	0.0 (0.0%)	2.0 (13.3%)	0.3112

The baseline characteristics of the enrolled patients are summarized in **Table 1**.

	MINOCA (N=7)	STEMI (N=15)	P- value
Hospital stay (days)	3 (2.5 – 6)	3 (3 – 5.5)	
GI symptoms	0.0 (0.0%)	1.0 (6.7%)	0.4842
Loss of smell	1.0 (14.3%)	1.0 (6.7%)	0.5632
Loss of taste	1.0 (14.3%)	1.0 (6.7%)	0.5632
Killip Class			0.2032
Killip I	7.0 (100.0%)	12.0 (80.0%)	
Killip IV	0.0 (0.0%)	3.0 (20.0%)	
MACE	0.0 (0.0%)	4.0 (26.7%)	0.1312

HTN: Hypertension; **DM:** Diabetes mellitus; **FH:** family history; **CAD:** coronary artery disease; **GIT:** gastrointestinal; **MACE:** major adverse cardiac events; **MINOCA:** myocardial infarction with no obstructive coronary artery lesion; **STEMI:** ST-elevation myocardial infarction. Quantitative data are presented in the form of median (IQR), and qualitative data in the form of numbers (%).

3.1.ECG and angiographic findings in patients presenting with STEMI

During PPCI, obstructive lesions were identified in 15 patients, whereas in 7 patients, no obstructive lesions were identified and were therefore labelled

"MINOCA". The most common ECG pattern was anterior STEMI, and the most frequently identified culprit was the LAD. Detailed ECG and angiographic findings are described in **Table 2**.

Table 2. ECG and angiographic findings.

ECG findings	MINOCA (n=7)	STEMI (n=15)	Total (n=22)	P value
ST deviation on admission				0.104
Anterior MI	1.0 (14.3%)	9.0 (52.6%)	10.0 (45.4%)	
Inferior MI	4.0 (57.1%)	5.0 (33.3%)	9.0 (40.9%)	
Lateral MI	2.0 (28.6%)	1.0 (16.7%)	3.0 (13.6%)	
Culprit lesion				0.0031*
No culprit	7.0 (100.0%)	0.0 (0.0%)		
LAD	0.0 (0.0%)	9.0 (60.0%)		
RCA	0.0 (0.0%)	5.0 (33.3%)		
LCx	0.0 (0.0%)	1.0 (6.7%)		

ECG: Electrocardiography, **STEMI:** ST elevation myocardial infarction, **LAD:** left anterior descending, **RCA:** right coronary artery, **LCx:** left circumflex, **MINOCA:** myocardial infarction with no obstructive coronary artery. Data are presented as a number (%), *P < 0.05%.

3.2.Laboratory findings

The laboratory results of the studied patients are summarized in Table 3. All patients had significantly elevated

inflammatory markers, particularly serum ferritin and ESR. None of the other laboratory parameters was significantly different among the studied groups.

Table 3. Laboratory data among the studied participants.

Lab parameters	MINOCA (n=7)	STEMI (n=15)	P value
Total CHO	148 (127 - 155)	159 (140.5 – 170.5)	0.4561
LDL	77 (62 – 91.5)	101 (95 – 121.8)	0.0981
HDL	36 (32 – 39.5)	32.8 (29 – 36.5)	0.7421
TGs	113 (90.5 – 121.5)	119 (110 - 176)	0.2291
Cr	0.8 (0.6 – 0.9)	0.8 (0.7 – 0.9)	0.3221
Urea	4 (3.8 – 5.2)	4.0 (3.07 – 5.2)	0.3111
ALT	24 (23 - 34)	57 (36.5 – 72)	0.4341
AST	38 (25 – 70.5)	77.7 (27.5 - 206)	0.2191
ALP	73 (69 - 87)	73 (69 – 87)	0.7801
INR	1 (0.94 – 1.1)	1 (1.0 – 1.2)	0.0981
PC	92 (85 – 114.5)	78 (57.5 – 90.5)	0.055
PT	12 (11.2 - 12)	13 (12.7 – 16.5)	0.0571

Table 3. Laboratory data among the studied participants. (Cont.)

Lab parameters	MINOCA (n=7)	STEMI (n=15)	P value
D-dimer	1.5 (0.9 – 1.8)	1.7 (1.1 – 2.3)	0.7931
Ferritin	310 (225 - 385)	400 (293.5 - 585)	0.1791
CRP	18 (9.4 – 29.2)	28 (18.5 – 124.3)	0.0721
ESR	18 (17 – 36.5)	25 (20 – 37)	0.0871
WBCs	7 (6 - 9)	13.5 (10 – 17.5)	0.0521
Hgb	13.5 (12.5 – 14.3)	13.5 (12.5 – 14.8)	0.9651
PLTs	264 (220.5 - 344)	222 (174 - 331)	0.3681
Lymph	1.6 (1.2 – 1.85)	0.7 (0.45 – 1.6)	0.1051
Troponin	11.5 (10.2 - 17)	25 (19 – 40.5)	0.1761

STEMI: ST elevation myocardial infarction, **MINOCA:** myocardial infarction with no obstructive coronary artery. **ALT:** alanine transaminase, **AST:** aspartate transaminase, **ALP:** alkaline phosphatase, **CHO:** cholesterol, **Cr:** creatinine, **CRP:** C-reactive protein, **ESR:** Erythrocyte sedimentation rate, **Hgb:** hemoglobin, **LDL:** low density lipoprotein, **HDL:** high density lipoprotein, **INR:** international normalized ratio, **PC:** prothrombin concentration, **PT:** prothrombin time, **PLTs:** platelets, **TGs:** triglycerides, **WBCs:** white blood cells. Quantitative data are presented in the form of median (IQR).

3.3.Echocardiographic findings

In patients with MINOCA, the baseline echocardiography showed no segmental wall motion abnormalities or global hypokinesia in the majority of patients, whereas in

patients with obstructive STEMI, the majority had regional wall motion abnormalities that could be assigned to a specific coronary territory (**Table 4**).

Table 4. Echocardiographic findings of the enrolled patients.

	MINOCA (n=7)	STEMI (n=15)	P value
SWMA distribution			0.0121*
No SWMA	4.0 (57.1%)	2.0 (13.3%)	
LAD	0.0 (0.0%)	8.0 (53.3%)	
RCA	0.0 (0.0%)	4.0 (26.7%)	
LCx	2.0 (28.6%)	1.0 (6.7%)	
Global hypokinesia	1.0 (14.3%)	0.0 (0.0%)	
EF (%)	59.86 ± 10.02	50.0 ± 10.0	0.0782
Mean ± SD			

STEMI: ST elevation myocardial infarction, MINOCA: myocardial infarction with no obstructive coronary artery, SWMA: segmental wall motion abnormalities, EF: ejection fraction, LAD: left anterior descending, RCA: right coronary artery, LCx: left circumflex. Quantitative data are presented as mean±SD, and qualitative data are presented as number (%). *P < 0.05%.

4. Discussion

In the current study, we aimed to identify the type of coronary lesion in COVID-19 patients presenting with myocardial infarction (MI) through assessment by ICA. We categorized patients into STEMI with obstructive lesions and MINOCA based on ECG and angiographic findings. Only 22 patients were enrolled over the course of two years, which could be partly due to the declining presentation of STEMI patients to PPCI centers during the COVID-19 pandemic, which was observed both locally and internationally (6).

By reviewing the baseline data of the cases, we observed that MINOCA cases had a younger age (median 29 years, IQR: (27 – 46 years) compared to obstructive STEMI cases. This suggests that COVID-19 may be an independent risk factor in younger patients. Lee et al. found that younger patients had a higher risk of cardiovascular outcomes (7).

Overall, we found a distinct pattern of coronary lesions in COVID-19-infected patients compared to classic MI patients. For instance, in 7 patients (31.8%), no obstructive disease was found, which

indicates the potential for developing other forms of myocardial injury other than type 1 MI among COVID-19 patients (3).

The left anterior descending (LAD) had the highest frequency of coronary involvement in patients with obstructive lesions on coronary angiography. This aligns with Ahmed et al.'s finding that the LAD was the most frequently involved vessel in patients with myocardial infarction (8).

. Other groups have described the high prevalence of non-obstructive coronary artery disease accompanying STEMI during the COVID-19 pandemic at a rate quite similar to our study (9)(10).

For example, in a series of 18 STEMI patients in New York City, only 67% of the patients who underwent angiography had obstructive coronary artery disease (11). Similarly, a study of 28 COVID-19 patients from northern Italy with STEMI who underwent coronary angiography showed that culprit lesions were not identified in approximately 40.0% of patients (9). This suggests that myocardial injury could be attributed to mechanisms other than inadequate epicardial coronary arterial flow,

such as exacerbated inflammatory response and/or direct viral effects (12).

Notably, rather than being a result of organ-specific myocarditis, the rise in cardiac troponin (cTn) may frequently represent the heart's "share" of the overall inflammation.

As previously proposed, C-reactive protein may directly and actively contribute to atherogenesis and the disruption of atherosclerotic plaque and serve as a marker of widespread inflammation. Thus, by increased inflammation, platelet activation, endothelial dysfunction, and stasis, COVID-19 may predispose patients to thrombotic diseases (13)(14).

4.1. Limitations

This is a single-center experience and represents a small number of patients. In addition, the current study only described

the pattern of coronary lesions in MI patients with active COVID-19 infection, and did not follow up on patients' clinical outcomes. This warrants examination in further studies. Also, we recommend assessing myocardial injury patterns using cardiac magnetic resonance (CMR), particularly in patients with MINOCA.

5. Conclusion

Atypical MI-like presentations are common in COVID-19 patients, including the absence of a culprit coronary lesion (referred to as MINOCA). These unusual manifestations suggest that myocyte damage may be caused by causes other than the cessation of coronary artery flow. Additional research, including cardiac MRI, is necessary to clarify those pathways.

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7. **Disclosures:** The authors have no financial interest to declare in relation to the content of this article.

8. **Data availability:** The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

9. **Conflict of interest:** The authors declare no competing interests.

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10. List of abbreviations

Abs	Antibodies
ALP	Alkaline phosphatase
ALT	Alanine trans-aminase
AMI	Acute myocardial injury
AST	Aspartate trans-aminase
CBC	Complete blood count
CMR	Cardiac magnetic resonance.
COVID-19	Coronavirus disease 2019.
CRP	C-reactive protein
CTn	Cardiac troponin
CVD	Cardiovascular diseases
DM	Diabetes mellitus
ECG	Electrocardiogram
EF	Ejection fraction
ESR	Erythrocyte sedimentation ratio
GIT	Gastrointestinal tract
HDL	High-density lipoproteins

HTN	Hypertension
ICA	Invasive coronary angiography
IgM	Immunoglobulin M
INR	International normalized ratio
IQR	Interquartile range
LAD	Left anterior descending coronary artery
LCx	Left circumflex coronary artery
LDL	Low-density lipoproteins
LV	Left ventricle
MACE	Major adverse cardiovascular events
MI	Myocardial infarction
MINOCA	Myocardial infarction with non-obstructive coronary arteries
PC	Prothrombin concentration
PCI	percutaneous coronary intervention
PT	Prothrombin time
RT- PCR	Reverse transcription polymerase chain reaction.
STEMI	ST elevation myocardial infarction
SWMA	Segmental wall motion abnormality
TLC	Total leucocytic count.
WBCs	White blood cells

11. References:

1. Clerkin KJ, Fried JA, Raikhelkar J, et al. COVID-19 and Cardiovascular Disease. *Circulation*. 2020 May;141(20):1648–55.
2. Bernardes JP, Mishra N, Tran F, et al. Longitudinal Multi-omics Analyses Identify Responses of Megakaryocytes, Erythroid Cells, and Plasmablasts as Hallmarks of Severe COVID-19. *Immunity*. 2020 Dec;53(6):1296–1314.e9.
3. Thygesen K, Alpert JS, Jaffe AS, et al. Fourth universal definition of myocardial infarction (2018). *Eur Heart J*. 2019;40(3):237–69.
4. Mello BHG de, Oliveira GBF, Ramos RF, et al. Validation of the Killip-Kimball classification and late mortality after acute myocardial infarction. *Arq Bras Cardiol*. 2014 Aug;103(2):107–17.
5. Ibanez B, James S, Agewall S, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. *Eur Heart J*. 2018 Jan;39(2):119–77.
6. De Luca G, Verdoia M, Cercek M, et al. Impact of COVID-19 Pandemic on Mechanical Reperfusion for Patients With STEMI. *J Am Coll Cardiol* [Internet]. 2020 Nov;76(20):2321–30. Available from: <https://linkinghub.elsevier.com/retrieve/pii/S0735109720372399>
7. Lee MT, Baek MS, Kim TW, et al. Cardiovascular outcomes between COVID-19 and non-COVID-19 pneumonia: a nationwide cohort study. *BMC Med*. 2023 Oct;21(1):394.
8. Ahmed IAM, Khalid NHM, Abd-Elmagid AEM, et al. Common coronary artery occlusions in patients with myocardial infarction. *Pan Afr Med J*. 2022;42.
9. Stefanini GG, Montorfano M, Trabattini D, et al. ST-Elevation Myocardial Infarction in Patients With COVID-19: Clinical and Angiographic Outcomes. Vol. 141, *Circulation*. 2020. p. 2113–6.
10. Tam CF, Cheung K, Lam S, et al. Impact of coronavirus disease 2019 (<scp>COVID</scp> -19) outbreak on outcome of myocardial infarction in

- Hong Kong, China. Catheter Cardiovasc Interv. 2021 Feb;97(2).
11. Bangalore S, Sharma A, Slotwiner A, et al. ST-Segment Elevation in Patients with Covid-19 — A Case Series. *N Engl J Med*. 2020 Jun;382(25):2478–80.
 12. Clerkin KJ, Fried JA, Raikhelkar J, et al. COVID-19 and Cardiovascular Disease. *Circulation*. 2020;2019:1648–55.
 13. Solano-López J, Zamorano JL, Pardo Sanz A, et al. Risk factors for in-hospital mortality in patients with acute myocardial infarction during the COVID-19 outbreak. *Rev Española Cardiol (English Ed)*. 2020 Dec;73(12):985–93.
 14. Bikdeli B, Madhavan M V., Jimenez D, et al. COVID-19 and Thrombotic or Thromboembolic Disease: Implications for Prevention, Antithrombotic Therapy, and Follow-Up. *J Am Coll Cardiol*. 2020 Jun;75(23):2950–73.